SOIL CHARACTERIZATION AT THE LINDE FUSRAP SITE AND THE IMPACT ON SOIL VOLUME ESTIMATES

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ABSTRACT

The former Linde site in Tonawanda, New York is currently undergoing active remediation of Manhattan Engineering District's radiological contamination. This remediation is authorized under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The focus of this paper will be to describe the impact of soil characterization efforts as they relate to soil volume estimates and project cost estimates. An additional objective is to stimulate discussion about other characterization and modeling technologies, and to provide a "Lessons Learned" scenario to assist in future volume estimating at other FUSRAP sites.

Initial soil characterization efforts at the Linde FUSRAP site in areas known to be contaminated or suspected to be contaminated were presented in the Remedial Investigation Report for the Tonawanda Site, dated February 1993. Results of those initial characterization efforts were the basis for soil volume estimates that were used to estimate and negotiate the current remediation contract.

During the course of remediation, previously unidentified areas of contamination were discovered, and additional characterization was initiated. Additional test pit and geoprobe samples were obtained at over 500 locations, bringing the total to over 800 sample locations at the 135-acre site. New data continues to be collected on a routine basis during ongoing remedial actions.

Test pit and geoprobe sampling identifies contaminant characteristics at their exact location. Contamination just a few feet from the sample location might not have been detected, which sometimes led to a false assumption that an area had been fully characterized. Radiological scanning during excavation often revealed additional contamination, and consequently, increased excavation quantities and project costs.

A number of different field screening techniques have been used, such as gamma walkover surveys, Large Area Plastic Scintillator (LAPS), and others. Field experiences indicate that buildings, concrete, asphalt, or slag that covers much of the site produce interference that impacts the effectiveness of the walkover surveys in these areas.
After FUSRAP was transferred to the Corps of Engineers, volume estimating began in February 1999 based on the 1993 Remedial Investigation/Feasibility Study. Volume estimates have varied significantly for a number of reasons, which will be detailed.

INTRODUCTION

The Linde site is located in the Town of Tonawanda, a suburb north of Buffalo, New York. The site is currently occupied by Praxair, Inc., and is an industrial complex that serves as their worldwide research and development facility. There are over 1,500 people working at the facility. The property is comprised of approximately 135 acres, and is surrounded by a residential neighborhood, a public park and golf course, railroad tracks and other commercial properties. Commercial and industrial activities have been conducted at the Linde site since the 1930's.

During much of the 1940's, the former Linde Air Products Division of Union Carbide Industrial Gas processed uranium ores under a contract with the Manhattan Engineering District (MED). Linde was selected to support the MED program because of their experience in processing uranium to produce salts used to color ceramic glazes. The related activities under the MED contract used a three-phase process for the separation of uranium dioxide from uranium ores and tailings, and for conversion of uranium dioxide to uranium tetrafluoride. This resulted in elevated levels of radionuclides in portions of the property and several buildings. The principle radionuclides of concern are uranium, thorium, and radium.

FUSRAP was initiated in 1974 to identify, investigate, and clean up or control sites throughout the United States that were part of the early atomic energy program. Under its authority to conduct the Formerly Utilized Sites Remedial Action Program, US Department of Energy (DOE) conducted several characterization studies at the Tonawanda Sites between 1978 and 1992 which formed the basis for future actions at the Linde property.

In 1997, the Energy and Water Development Appropriation Act, PL 105-62 was signed into law, transferring responsibility for the administration and execution of FUSRAP from DOE to the U.S. Army Corps of Engineers (USACE).

PREVIOUS STUDIES

Among the studies conducted by DOE were a Remedial Investigation, Baseline Risk Assessment, and a Feasibility Study of the collective Tonawanda Sites. During the Remedial Investigation study in 1993, previous radiological surveys were researched and noted. A brief summary of those surveys is noted below:

Oak Ridge National Laboratory (ORNL) 1978

ORNL conducted a radiological survey during October and November 1976, entitled "Radiological Survey of the Former Linde Uranium Refinery, Tonawanda, New York". It included residual alpha and beta-gamma contamination levels in Buildings 30, 31, 37, 38, and 14 as well as external gamma radiation levels at those buildings, and throughout the Linde property. Soil samples were taken at both onsite and adjacent offsite properties to determine concentrations of uranium-238, radium-226, actinium-227, and thorium-232. Forty-two boreholes were drilled throughout the Linde site and buildings, and five offsite samples were obtained and analyzed.

Ford, Bacon & Davis Utah, Inc (FBDU) 1981

FDBU conducted a survey in December 1981 entitled "Preliminary Engineering and Environmental Evaluation of the Remedial Action Alternatives for the Linde Air Products Site, Tonawanda, New York". Residual alpha and beta-gamma contamination levels in Buildings 30, 31, 37, 38, and 14 were measured along with external gamma radiation levels at those buildings, and throughout the Linde property. Soil, surface water, and groundwater samples were taken onsite to determine concentrations of uranium-238, radium-226, and thorium-232. FBDU used the same locations as ORNL to verify results and drilled 20 boreholes on the site.

Oak Ridge Associated Universities (ORAU) 1981

In 1981 ORAU conducted a survey to measure Uranium-238, uranium-235, radium-226. potassium-40, cesium-137, thorium-230, and thorium-232 concentrations in onsite and offsite soils. Soils samples were collected during the development of two new wells near the locations of site injection wells. The injection wells were used for the discharge of liquid effluent resulting from MED operations.

Based upon the ORNL, FBDU, and ORAU studies, the following areas of contamination were identified:

1. Northwest corner of the main parking lot
2. Northeast corner of the Linde property and the rail spur
3. Soil beneath Building 30

Those three locations formed the basis for the "Remedial Investigation for the Tonawanda Site" which was completed for DOE by Bechtel National Incorporated (BNI) in 1993.

Subsurface Explorations

To confirm previous survey results, and to investigate other potential contaminant sources, general site characterization activities were conducted between October 1988 and March 1989 by BNI. A more precise definition of the extent of radioactive contamination was needed in order to develop a remedial action plan.

The initial step involved using a gamma scintillation detector with a 2 x 2 sodium iodide crystal to detect radioactive materials, and to identify areas with a high probability of subsurface contamination. The next step was a systematic sampling program using borehole drilling and hand augers to collect soils for analysis. Borehole samples were collected in undisturbed soils using a 2-inch diameter, 18-inch long stainless steel split-spoon sampler. Hand-auger samples were collected with a 1-inch diameter, 36-inch long stainless steel auger.

A total of 328 investigation sample points throughout the site were gathered and analyzed. General results are summarized and presented below.

Subsurface Exploration Results

Natural soils at the Linde site appear to have been covered by layers of fill that range in thickness from 0 – 17 feet. The fill material contains substantial quantities of slag and flyash, both of which are known to contain naturally occurring radioactive materials (NORM). Primary radioactive contaminants are uranium-238, radium-226, and thorium-230, and were noted as being located in four areas throughout the site. Figure 1 represents the location of the four areas on the Linde site as shown in the Remedial Investigation Study completed in 1993.

> Area 1 – Northwest corner of the main parking lot. Anecdotal evidence suggested that soil was brought to this area as fill, and the parking lot is several feet higher than the adjacent property immediately to the north. The depth of radioactive contamination was estimated at 4-feet in this area due to the presence of a natural clay layer.
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> Area 2 – Along the northern boundary of the property at the northeast corner of the parking area. Contaminated soils were removed during the construction of Building 90 and placed between the building and the north property line. Radioactive contamination was estimated to a depth of 4-feet in this area due to the presence of a natural clay layer.
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> Area 3 – Along the northeast corner of the site, including the railroad spur into the property. Since the contamination extended beyond the property line, additional samples were collected which confirmed the presence of uranium-238 and thorium-230. Uranium ores were transported onto the Linde facility via the railroad spur, and processing residues were stockpiled in the areas around Buildings 30, 38, 39, and 58. As in Areas 1 and 2, the extent of radioactive contamination was estimated at a depth of 4-feet because of the natural clay that was encountered.
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> Area 4 – This area is around Buildings 38, Building 58 and the adjacent blast wall, and also around the interior and exterior of Building 30. Extensive MED related activities were conducted within Building 30, which was specifically

constructed for the purpose of processing and refining uranium ore materials. The extent of contamination was estimated to be as deep as 9-feet in some locations beneath Building 30 due to the depth of its foundation walls.

It should be noted that the Remedial Investigation Report recommended that additional delineation of contamination would be needed during cleanup efforts because of the conservative methods used to identify potential excavation areas.

Quantity Estimates

Using the data generated from DOE's Remedial Investigation, USACE contracted with Argonne National Laboratory (ANL) in 1998 to develop a soil excavation volume estimate for the Linde site.

Data was analyzed by ANL for a variety of lift thicknesses where the radioactive contaminants were detected. Statistical/geostatistical software was used to calculate the probability and extent of soil contamination in a particular area. Estimates were developed which considered the variability of radionuclide activity throughout the site. ANL noted that there were large areas where no data or sample locations were available to characterize the site, and recommended that additional sampling and gamma walkover screening be performed.

The analysis performed by ANL resulted in an estimated in situ disposal volume of approximately 18,000 cubic yards of radiologically contaminated soils. This volume was used for Government estimating and contract negotiations.

RECORD OF DECISION

By April 1998, USACE issued a Record of Decision (ROD) for the Tonawanda Sites except Linde, and remediation was initiated in June 1998 at Ashland 2. The ROD for the Linde Site was issued in March 2000, and the selected plan called for residual radioactive material removal and building and slab removal actions to comply with standards found in 40 CFR Part 192. Those standards refer to cleanup of the uranium mill sites designated under the Uranium Mill Tailings Radiation Control Act (UMTRCA) and the Nuclear Regulatory Commission (NRC) standards for decommissioning of licensed uranium and thorium mills. Primary elements of the selected plan involve the excavation of soils with contaminants of concern (radium, thorium, and uranium) above the soil cleanup levels, placement of clean backfill materials, and cleanup of contaminated surfaces in buildings with contaminants of concern above the surface cleanup levels.
It should be noted that two other operable units at the Linde site are not included within the March 2000 ROD. Building 14 and Linde Site groundwater are being addressed and evaluated for potential future actions.

Compliance with standards identified within the March 2000 ROD will require the following:

1. Remove MED-related soil so that the concentrations of radium do not exceed background by more than 5 picocurries per gram (pCi/g) in the top 15 centimeters (cm) of soil or 15 pCi/g in any 15 cm layer below the top layer, averaged over an area of 100 square meters
2. Remediate occupied or habitable buildings so that an annual average radon decay product concentration (including background) does not exceed 0.002 Working Level (WL) and the level of gamma radiation does not exceed the background level by more than 20 microroentgens per hour
3. Control the releases of radon into the atmosphere resulting from the management of uranium byproduct materials do not exceed an average release rate of 20pCi/meter squared second
4. Removal of MED-related soils with residual radionuclide concentrations averaged over a 100 square meter area that exceeds unity for the sum of the ratios of these radionuclide concentrations to the associated concentration limits, above background, of 554 pCi/g for total uranium (U_{total}), 5 pCi/g for Radium-226 (Ra-226), and 14 pCi/g for Thorium-230 (Th-230) for surface cleanups and 3,021 pCi/g of U_{total}, 15 pCi/g of Ra-226, and 44 pCi/g of Th-230 for subsurface cleanups
5. Remediate the Linde Site to insure that no concentration of total uranium exceeding 600 pCi/g above background will remain in site soils
6. Removal of MED-related residual radioactive materials from surfaces to meet the benchmark dose of 8.8 mrem/year based on the specific location of the surfaces and exposure scenarios

Verification of compliance with soil cleanup standards is demonstrated using surveys developed in accordance with the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) and as required by applicable or relevant and appropriate requirements (ARARs).

Remedial action at the Linde site began in June 2000, and the current scheduled completion is April 2004.

Subsurface Explorations

The Linde site is approximately 135 acres in size and is heavily industrialized. Much of the site is impervious because approximately 66 acres of the property consists of buildings, sidewalks, and pavement. As done with the RI, the Linde property was subdivided into Areas during preparation of the contract Scope of Work to delineate suspected locations of contamination, and of potential excavation sites. Figure 2 shows those locations as they were depicted in the ROD.

Area 8 - This area is similar to the RI Area 4 because it includes the entire footprint of Building 30. It also includes Buildings 38 and 67, and a potential contamination source at the southeast corner of Building 70. As noted earlier, Building 30 was built for the purpose of processing and refining uranium ore materials for the MED contract.

Area 9 - This includes Building 31, Building 57, and Building 58. Much of it would correspond to parts of the RI Area 4.

Area 9A - Consists of the contaminated areas east of the Linde site property line, including the railroad spur, the main railroad line, and properties east of the railroad along Military Road. This would partially correspond to the RI Area 3.

Area 10 - This is located at the northeast corner of the Linde property, and includes Buildings 73, 73B, 75, and 76. Area 10 similarly would correspond to the RI Area 4.

Area 11 - The section of Linde parking lots, as well as the north property line are included in Area 11. This generally corresponds to the RI Areas 1 and 2.

Gamma walkover surveys were performed using a 2 x 2 NaI (TI) gamma scintillator to determine the presence of gamma-emitting residual radioactivity at or near the surface in areas previously identified within the Remedial Investigations. The surveys were also used to investigate other suspected locations of contamination.

In areas where contamination had been consistently documented, excavation was initiated. As soils were removed, site Health Physics (HP) Technicians scanned the exposed soils to confirm the presence of radionuclides until the ROD standards are met. Samples are taken for laboratory analysis to confirm the field results, and eventually the excavation is complete.

Other areas of contamination were not detected in previous studies, but the gamma walkover surveys showed levels that warranted further exploration. This additional exploration consisted of excavated test pits or geoprobes. The test pits were excavated, and samples were scanned in the bucket. Samples were also taken for laboratory analysis. Test pits were used in open grassy areas where they would not pose a hazard to pedestrians, and were backfilled as soon as all sampling was completed. Geoprobes were performed in paved areas, or in other locations where test pits were not practical. The geoprobes consisted of a truck mounted hydraulic push rig, which advanced a steel sampling tube and casing shoe via steel rods in approximately four-foot increments. Soils samples are contained in a 3-inch diameter tube equipped with a disposable acetate liner within the casing shoe. Samples are scanned with a 2 x 2 NaI (TI) detector to determine potential layers of elevated contamination. Boring logs noting the description of soils, color, moisture content, consistency, gradation, and other pertinent data are also maintained.

A total of over 500 additional investigation sample points have been gathered at various locations at the Linde site through October 2001, and continue to be obtained wherever necessary during the course of project cleanup by USACE.

Subsurface Exploration Results

During remediation, excavation areas were again subdivided into areas that were designated by letter. Contaminants of concern were the MED-related U-238, Ra-226, and Th-230. The general locations are shown in Figure 3, and the results are summarized below:

Area A – Area A contains Buildings 38, 39, 67, 75, and 76, all of which have been demolished or relocated. It is generally bounded by Building 30 to the south, a roadway between Area A and Building 90 to the west, a roadway between Area A and Building 58 to the east, and another roadway to the north bordering an open storage area. Contamination was generally identified throughout this area, and gamma walkover surveys and scanning during excavation confirmed this. Building 67 was not originally slated for demolition, however geoprobes through the concrete floor showed contamination under the southeast corner. Demolition was performed, and during subsoil excavation, additional contamination was uncovered. The quantity estimate prior to excavation was approximately 3,200 CY. Final quantities were over 5,600 CY.

Area B - This area started out, as noted in the RI Study, as having contamination near the northwest corner of Building 90. Early stages of the remediation project showed that was not the case. An area at the northeast corner of Building 90 was investigated as a potential location for construction office trailers, and a test pit was excavated there. Previously undetected levels of contamination precluded use of the area, and offices were then located inside unoccupied space in Building 31. With the discovery of contamination north of Building 90, the area to the west became suspect for several reasons. First, that grassy field had historically been used as a dumpsite for many years. Little is known about what was dumped there; however; it was important information, which warranted further study. Another reason for suspicion was the fact that drainage ditches originating at the east end of the property had formerly passed through the area during the 1940's when MED related activities were at their peak. Most of the MED related ore processing activities took place at the east end of the property. In addition, when Building 90 was constructed in 1980 subsoils within the building footprint had been scraped and placed onto the grassy field. This was done in an attempt to help insure that Building 90 would not be built upon contaminated soils.

Numerous test pits and geoprobes were performed in the grassy areas and parking lots west of Building 90 between July and October 2000 to determine the extent of contamination. Prior to the additional subsurface investigations, it was estimated that approximately 3,000 CY of material would be excavated for disposal from an area that at that time included both Area B and Area I. It was concluded that Area B would require excavation of some quantity less than 3,000 CY. Excavation began in December 2000, and numerous pockets of previously undetected contamination were encountered. The excavation had extended south and encroached into Parking Lots 3 and 5. The result of this encroachment was that a temporary parking lot had to be constructed on Praxair property to accommodate their employees. Ten additional geoprobes were drilled through the parking lot surface to help delineate the south limit of contamination in April 2001. One additional test pit was dug to help determine the westerly limit of contamination, and sampling and scanning were routinely performed throughout the course of excavation activities.

One interesting aspect that was discovered during excavation was that contamination was often widespread, but in small individual locations. Scanning during excavation often led to the belief that the contaminated soil had all been removed, however, when one last bucket was excavated, the count rates would sometimes rise dramatically, and the dig continued. Relatively small pockets of contaminated soil were difficult to detect with geoprobes.

Excavation within Area B did not end until October 2001. The final quantity of soil excavated at this area was 14,700 CY. This constitutes at least a five-fold increase in quantities.

Area C - Building 31 was constructed for MED purposes during the 1940's. Subsequent expansion of the building covered over some of the contaminated soils, and a portion of the northeast corner of the interior required excavation to remove those soils. The contamination was thought to be limited to six distinct small areas, which were identified through the use of geoprobes drilled through the concrete floor. During excavation, the contamination detected was much more widespread, and nearly all of the floor and subsoils in the northeast corner of the building had to be removed. Quantifying the amount of excavation increase is difficult because Building 31 was originally included in Area 9 (see Figure 2) where contamination was more widespread.

Area D - This area generally follows the footprint of Building 30, which was used extensively during MED related operations at the Linde site. Uranium ores were processed and refined here, and widespread and relatively deep contamination was expected. Pre-excavation walkover surveys confirmed earlier studies, and excavation activities began in March 2001. The excavation is scheduled for completion in August 2002, and quantity estimates have increased from approximately 5,000 CY to approximately 15,500 CY.

Area E - This area includes Buildings 57, 58, 73, and 73B and is located at the northeast corner of the Linde property. All buildings have been demolished, except Building 73B which is being used as a decontamination and maintenance building. It will be removed toward the end of the project. The proximity to the easterly fence line and the railroad spur, where uranium ores entered the site, bring this area into suspicion for contamination. In addition, processing residues were stockpiled in this area. The RI Study did not include Building 58 and the adjacent blast wall as potentially contaminated locations, however, geoprobes were drilled through the floor of the building, and through the blast wall soils, and contamination was present. Original plans did not call for the demolition of Building 58, or for removal of the blast wall, and this situation caused another increase in excavation quantities. Area E has not been completed, as it is bounded by roadways to the west and north, an active parking lot to the south. The east boundary is the boundary of the Praxair property and a Niagara Mohawk Power Company right-of-way. The Niagara Mohawk property also borders with the CSX Railroad property. The original Area 10 and about 1/3 of original Area 9 comprise the current Area E, and the original quantity estimate would equate to about 2,000 CY. The current estimate to complete Area A is 15,000 CY.

Area F - This area is located at the northeast corner of Building 8, and was discovered during investigations surrounding an area known as Pad 19. Building 8 is immediately south of Pad 19. This area was open space where Praxair planned to construct a new building. Area F was not included in the original estimates for the project, and excavation has not been started yet. Geoprobes and test pits were used to delineate this area, and the current quantity estimate is 850 CY.

Area G - Area G comprises the Niagara Mohawk Power Company right-of-way, the CSX Railroad line, and the west end of several properties on Military Road. Geoprobes were drilled on the Niagara Mohawk property, and on the Military road properties, however, CSX Railroad has only allowed access to within 25-feet of the rail line for characterization purposes. Contamination is readily evident both east and west of the railroad tracks, and it can be interpolated that contamination is likely present beneath the tracks. No remediation activities have taken place within Area G to date. Original quantity estimates were approximately 3,020 CY. The additional subsurface data obtained here has reduced the current estimate to 2,700 CY.

Area H - This area was identified as a potential excavation site through anecdotal evidence provided by long-term site workers. It is located on roadways and parking lots in the middle of the property near the northwest corner of Building 70. The Large Area Plastic Scintillator (LAPS) was used initially, and contamination was detected. Geoprobes were drilled in this location in September 2000 which confirmed the need to perform excavation in this area. The original quantity estimate was 7,300 CY. Additional geoprobing was done in March 2001 and the estimate was revised based on the additional data and was reduced to an estimated quantity of 600 CY.

Area I - The entrance to the Praxair facility and the southwest corner of Parking Lot 2 are the general location of this area. It was noted in the RI and was originally estimated that 1,400 CY would need to be excavated, however, additional sampling and geoprobes have further refined the data, and the estimate has dropped to 730 CY. This area has not been excavated to date.

Area J - this area was discovered during relocation of utilities performed by Praxair in October 2000. It appears to be a relatively small area at the northwest corner of Building 43 that is just south of Building 14. It is not clear how the area became contaminated, and the utility installation was interrupted to perform the removal of contaminated soils. The quantity was never estimated prior to the project, and less than 5 CY of soil were removed.

Area K - Similar to Area J, this too was discovered during utility installation work by Praxair. The area is at the northeast corner of Building 14, and it corresponds to an Ore Roasting Oven building and an Ore Storage Area building that had formerly been attached to Building 14. This area had not been previously identified, so there was no estimate of quantities. Approximately 20 CY of contaminated soils were removed in May 2001 to allow for completion of the utilities. Additional excavation to the Building 14 foundation will be performed at a future date.

Area L - This area is located between Buildings 30 and 31. Its original location followed the border between Areas 8 and 9. It has been identified within the RI, and additional geoprobes, primarily around the Utility Tunnel that lies within Area L, have confirmed the presence of contamination. There are no precise original estimates to delineate this area, and the current excavation estimate is 5,600 CY. This figure probably does not represent an increase in quantities.

CONCLUSIONS

1. There are numerous uncertainties involved with excavation at FUSRAP sites. In order to characterize site conditions, an appropriate amount of subsurface exploration is required. Defining what is appropriate is a difficult proposition. The cost of obtaining additional subsurface data must be compared with the value it will provide in terms of estimate accuracy.
2. Historical and anecdotal evidence is extremely important in characterization of a site. It gives insight into property usage, possible pathways of contamination, and potential areas of concern. If available, historical topographic representations of the site or the surrounding properties should be obtained and carefully studied.
3. Site geology should be determined as an early component of a subsurface characterization. At the Linde site, areas of fill were identified and were the primary location of contamination. Throughout the site, the native clay was located at about 4 to 5-feet below the surface, and except at building foundations, the contamination was not detected below this clay layer. This situation may not apply at other sites, and may be dependent on the type of contamination, however, it has been an important factor in estimating quantities at the Linde site.

4. Additional methods of site characterization need to be investigated which will hopefully provide a more accurate picture of site conditions prior to remediation. It was noted earlier that relatively small pockets of contaminated soil were difficult to detect with geoprobes, and could be missed by only short distances of one foot or less.
5. Experience at the Linde site, as well as at several other FUSRAP sites, has shown that quantities tend to increase, and as a result, budgets and spending projections are impacted. Because of the uncertainties with estimating quantities, some level of contingency must be applied to budget projections, especially in the out years.
6. Programmatic budget constraints limited funding to cover additional soil remediation. This lack of funding to cover the increased cost of quantity growth has seriously diminished the efficiency of project operations at the Linde site, and will ultimately prolong the length of the project and drive final costs up.
7. Uncertainties in quantity estimation have a direct impact on current use of FUSRAP sites. The expectations of the property owner at Linde were that excavation would conclude in July 2001. Due to the additional quantities, and coupled with the current funding restrictions, excavation is not scheduled to be completed until October 2003. Final status surveys and backfilling will push project completion out to April 2004. The intrusive remedial actions at an operating industrial facility have impacted capital improvements, daily operations and jeopardized the long-term success of industrial operations at this location.
8. During the course of remediation quantities increased from the original estimate of 24,500 CY to the current total estimate of 61,600 CY. This represents a nearly three-fold increase in excavation.
9. The original estimate to complete soils remediation at the Linde Site was $33.4-mil. With the additional quantities, the current estimate to complete the soils remediation is $55.7-mil.

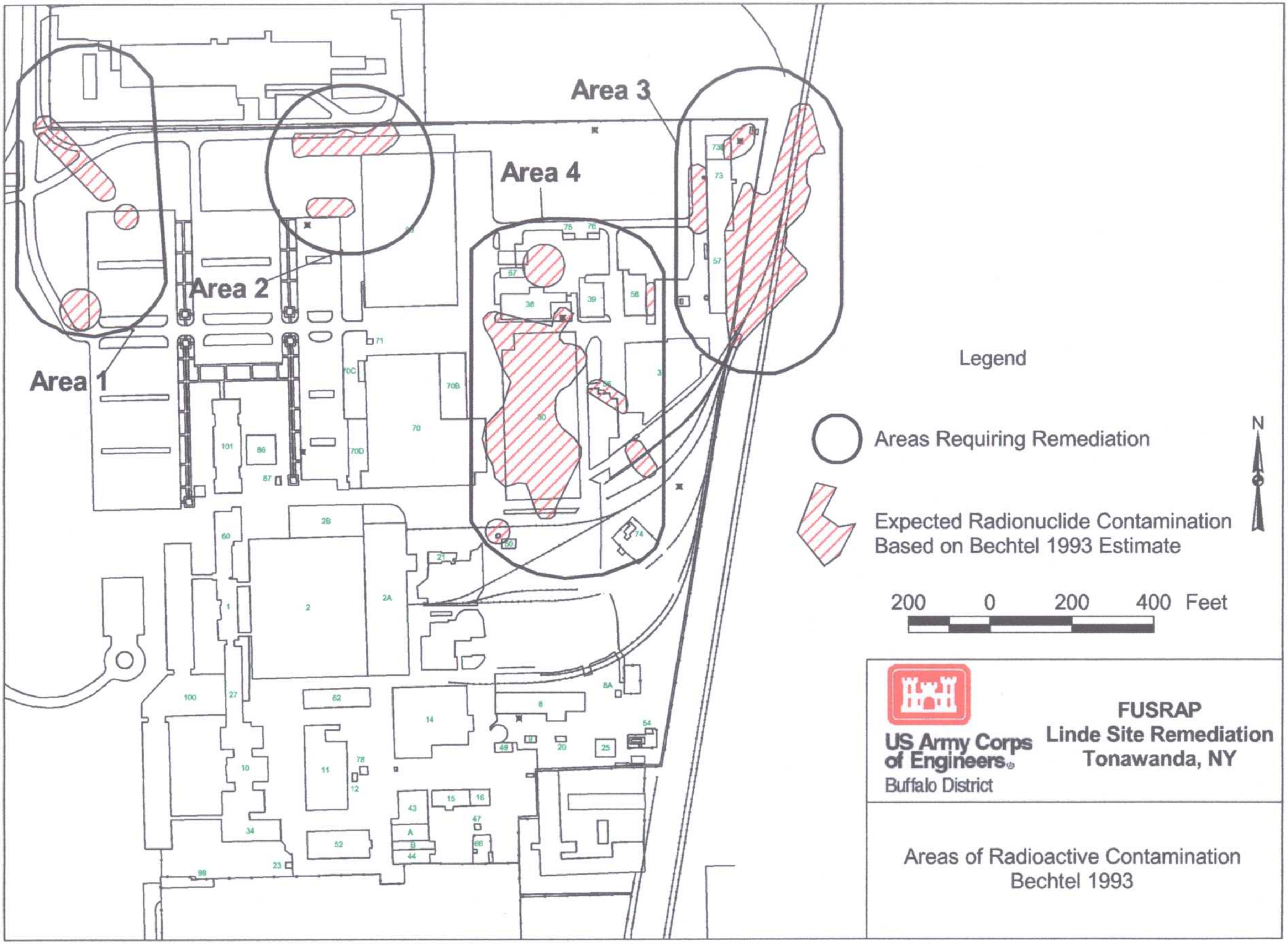

Area 1
Area 2
Area 3
Area 4
Legend
Areas Requiring Remediation
Expected Radionuclide Contamination
Based on Bechtel 1993 Estimate
N
200 0 200 400 Feet
US Army Corps
of Engineers
Buffalo District
FUSRAP
Linde Site Remediation
Tonawanda, NY
Areas of Radioactive Contamination
Bechtel 1993

Figure 1

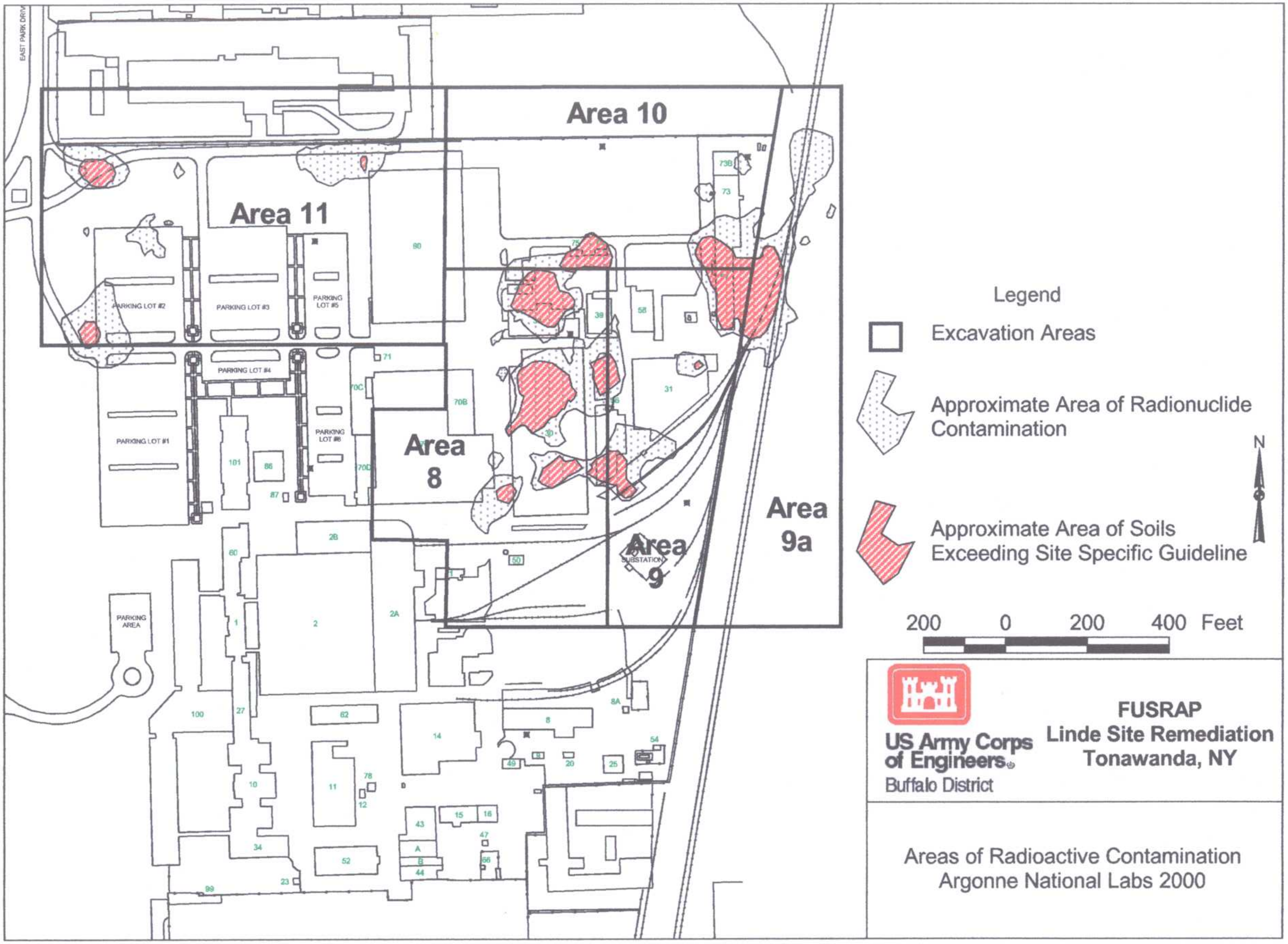
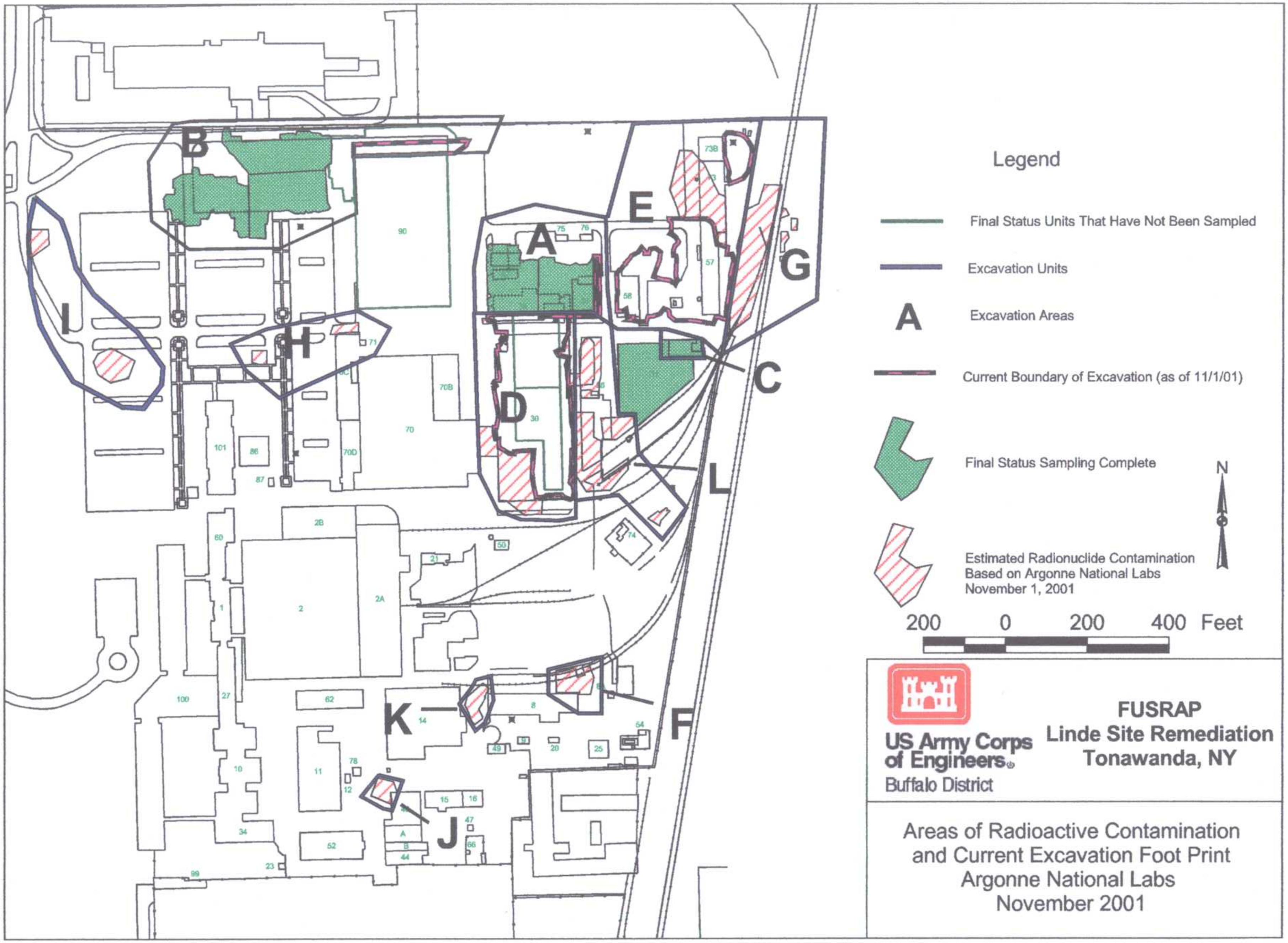

Area 10
Area 11
Area 8
Area 9
Area 9a
PARKING LOT #1
PARKING LOT #2
PARKING LOT #3
PARKING LOT #4
PARKING LOT #5
PARKING LOT #6
PARKING AREA
SUBSTATION
Legend
Excavation Areas
Approximate Area of Radionuclide Contamination
Approximate Area of Soils Exceeding Site Specific Guideline
N
200 0 200 400 Feet
US Army Corps of Engineers
Buffalo District
FUSRAP
Linde Site Remediation
Tonawanda, NY
Areas of Radioactive Contamination
Argonne National Labs 2000

Figure 2



Legend
Final Status Units That Have Not Been Sampled
Excavation Units
A
Excavation Areas
Current Boundary of Excavation (as of 11/1/01)
Final Status Sampling Complete
Estimated Radionuclide Contamination Based on Argonne National Labs November 1, 2001
200 0 200 400 Feet
N
A
B
C
D
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G
H
I
J
K
L
US Army Corps of Engineers
Buffalo District
FUSRAP
Linde Site Remediation
Tonawanda, NY
Areas of Radioactive Contamination and Current Excavation Foot Print Argonne National Labs November 2001

Figure 3