4. NATURE AND EXTENT OF CONTAMINATION

This chapter presents results of the Phase II RI data screening process to identify constituents indicative of impacts from AOC operations. The constituents that are deemed to be related to AOC operations are classified as site-related contaminants (SRCs). These SRCs are then evaluated to determine their occurrence and distribution in environmental media at LL 1. The data incorporated in the SRC evaluation for soils, surface water, and sediment include only those from the Phase II RI investigation. The data obtained during previous investigations (see Section 1.3.3) were not used quantitatively during the evaluation because recent building demolition has moved soils and sediments, making previous measurements no longer applicable. Data from monitoring wells sampled during the Phase I RI for 11 High Priority AOCs at RVAAP (USACE 1998), as well as the Phase II RI, were used to evaluate the nature and extent of contamination.

Section 4.1 of this chapter presents the statistical methods and facility-wide background screening criteria used to distinguish naturally occurring constituents from SRCs indicative of impacts from historical site operations. Sections 4.2 through 4.6 present occurrence and distribution of identified SRCs within each of the data aggregates (surface soil, subsurface soil, sediment, surface water, and groundwater) established for the purposes of this Phase II RI report. Section 4.7 addresses analytical results from the storm sewer system characterization. A summary of the results of the ordnance and explosives avoidance survey is presented in Section 4.8. Field measurements of metals and explosives are compared with their respective laboratory measurements in Section 4.9

Summary analytical results are presented in graphical format in the sections addressing each environmental medium. Table 4-1 provides the facility-wide background criteria. Summary statistics (including determination of SRCs) are provided for each aggregate in each medium in Tables 4-2 through 4-24. Complete listings of laboratory analytical results for each medium are presented in Tables 4-31 through 4-53 at the end of this section.

4.1 DATA EVALUATION METHODS

The processes used to evaluate LL 1 Phase II RI analytical data for each environmental media involve four general steps (1) defining background concentrations, (2) defining data aggregates, (3) data reduction and screening, and (4) data presentation.

4.1.1 Site Chemical Background

Chemicals occur naturally in soils, sediments, surface water, and groundwater. The natural levels of chemicals—called background levels—must be known in order to determine whether the concentrations measured at LL 1 are higher than would be expected if the load line operations had not occurred. The facility-wide background concentrations for soil, sediment, surface water, and groundwater were determined in conjunction with the WBG Phase II RI Study (USACE 2001). Background concentrations were determined by sampling each media in an area that was not impacted by RVAAP activities, as rigorously assessed by examination of historical records and aerial photographs over time and by visits to each background sampling site. The statistical distribution of chemical concentrations for each analyte in each media was tested for outlier points. Four surface soil samples were considered outliers for the background determination because of elevated metals and PAH concentrations and were not included in the background criteria calculations.

The 95% upper tolerance limit of the 95th percentile (95% UTL) was chosen as the statistic for representing the background screening criteria. When using the 95% UTL as a screening criteria, fewer than 5% of the samples from a study site such as LL 1 should exceed the criteria if the distribution of concentrations at the study site is similar to the background distribution. If the concentrations at the study site are above the background criteria, the analyte was considered a potential SRC. To make the background criteria more conservative, the facility-wide background criteria was set to the smaller of the maximum detected concentration or the 95% UTL. For most analytes, the maximum detected value in the background data set was the most conservative criteria and was selected as the background value.

Facility-wide background criteria were not developed for organic compounds. Although some organic compounds occur under natural conditions (i.e., some PAHs) and were detected in the RVAAP background samples, the organic compounds of primary concern, such as explosives, are man-made. The background criteria for all organic compounds were set to zero so that any organic compounds detected would be considered above background.

The background screening criteria for analytes that were not detected in any background sample for a given medium were set to zero. This means that these analytes would be considered as greater than background if any samples had detected concentrations.

All chemicals, except explosives and propellants, with a frequency of detection = or > 5% were screened against the background criteria appropriate for the media sampled. For those constituents with a detection frequency less than 5%, weight-of-evidence was used to determine if it should be screened against background (e.g., clusters of detects, etc.). The criteria for each media are listed in Table 4-1. Surface soil sample results (from 0 to 1 ft depth) were screened against the surface soil background criteria. Subsurface soil results (>1ft depth) were screened against the subsurface background criteria. Sediment and surface water were screened against the sediment and surface water background criteria. Groundwater results were screened against the bedrock zone filtered criteria for filtered samples and the unfiltered criteria for unfiltered samples. The background screening was conducted on aggregates of samples grouped by media and spatial proximity. These aggregates are defined in the following section. Any detected explosive or propellant compound was considered as an SRC regardless of its frequency of detection.

4.1.2 Definition of Aggregates

The LL 1 data were grouped by area into aggregates for statistical summary and comparison with background criteria. For this report, the initial separation of data for discussion of the nature and extent of contamination is by media: surface soils and subsurface soils, groundwater, surface water, and sediment. The Phase II RI surface and subsurface soil sample locations were chosen to investigate specific buildings and surrounding areas; therefore, it is possible to aggregate the resulting data on this basis. The grouping of the data into aggregates is intended to facilitate the discussion of the nature and extent of contamination for the LL 1 area by addressing areas in close proximity (e.g., a group of buildings) and areas with similar operational histories. For surface soils and subsurface soils, the geographic area of LL 1 was separated into eight aggregates consisting of buildings, the perimeter area, and the railroad track bed. The soil aggregate areas depicted on Figure 4-1 include

- Buildings CB-3/CB-801;
- Buildings CB-4/4A and CA-6/6A;
- Buildings CB-13/CB-10;
- Buildings CB-14, CB-17, and CA-15;
- Area around the base of the former Water Tower;
- Former Change Houses (CB-12, -23, -8, -22);

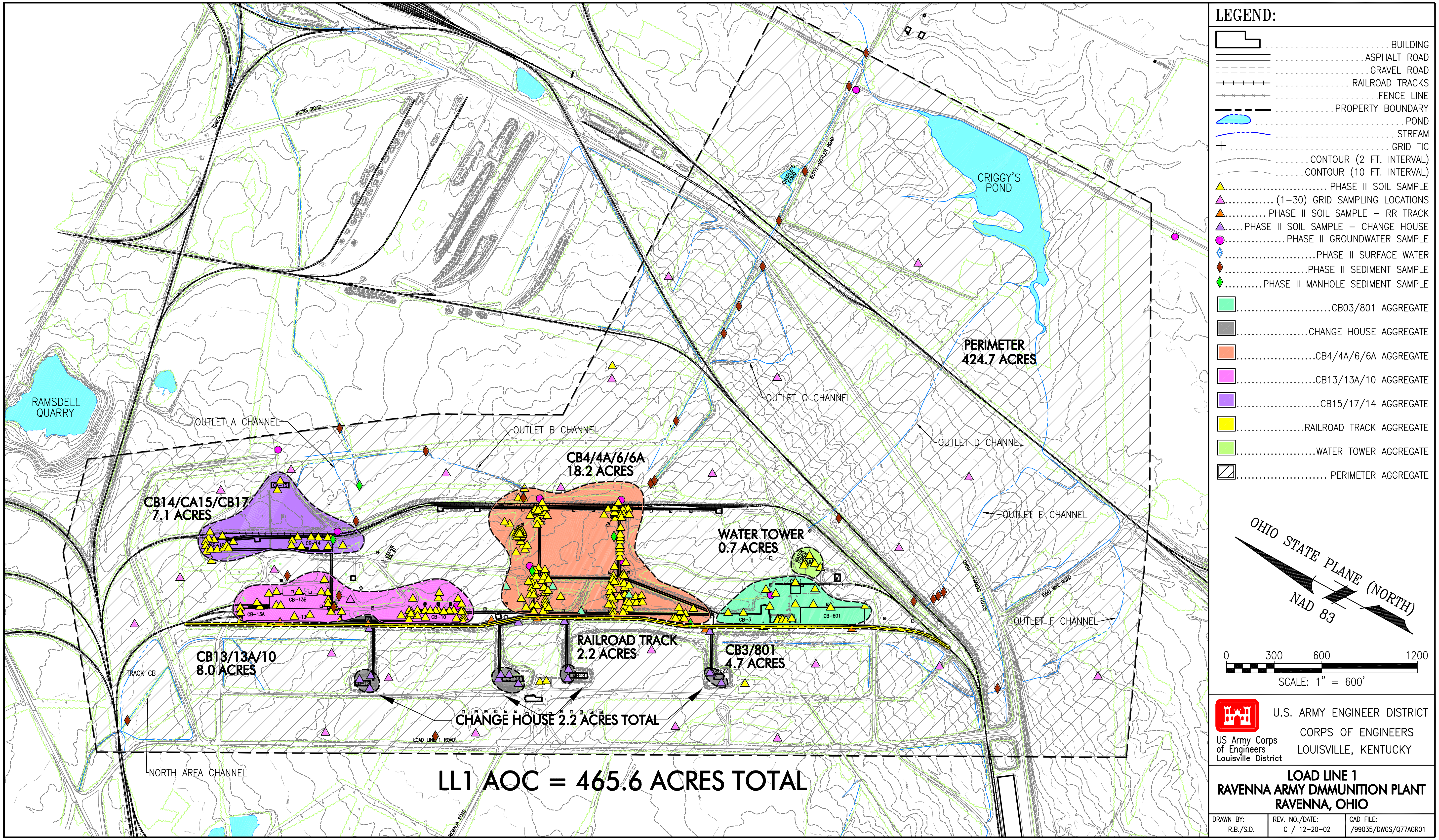


Figure 4-1. Soil Aggregates for Load Line 1 Phase II R1

- Railroad track bed; and
- Perimeter area.

All surface and subsurface soil sample locations that are within an aggregate boundary are included in that aggregate. Any of the random sample locations that fell within the aggregate boundary were also included in the data set for that aggregate. It should be noted that the sample locations and corresponding data for samples collected along the railroad track bed bordering the LL 1 area are one aggregate and are not included in any of the building aggregates. The perimeter area includes that area within the AOC but exterior to the building and Water Tower aggregate boundaries.

For this RI, groundwater is considered as one aggregate and includes data from the existing monitoring wells: those within the LL 1 production area and the two monitoring wells to the north and south of Criggy's Pond (LL1mw-064 and LL1mw-065). Data from groundwater monitoring wells LL2mw-059 and -60 to the south of LL 1 are also included in the discussion of nature and extent; however, these data are not included in the risk assessments, as these monitoring wells are also downgradient of LL 2.

Sediment and surface water sample locations were grouped according to drainage features and the areas drained. For some of these aggregates, a sediment sample was collected, but the corresponding surface water sample was not collected, typically due to dry conditions. The five surface water/sediment aggregates are indicated on Figure 4-2 and include

- Outlets D, E, and F and Criggy's Pond,
- Outlet C and Charlie's Pond,
- Outlets A and B,
- North area channel, and
- Off-AOC.

Samples of sediment and water collected within the storm drain system are discussed separately, as these samples are not considered specific to a particular source area.

4.1.3 Data Reduction and Screening

4.1.3.1 Data reduction

More than 458 environmental soil, sediment, surface water, and field QC samples were collected with approximately 24,500 discrete analyses (i.e., analytes) being obtained, reviewed, and integrated into this RI. These totals do not include field measurements and field descriptions. Analytical results were reported by the laboratory in electronic format and loaded into a database.

Verification of data was performed to ensure all requested data were received and complete. A data review process was performed to document data quality.

Data qualifiers were assigned to each result based on the technical assessment of the data review criteria. Results were qualified as follows:

"U" Not detected
"UJ" Not detected, detection limit estimated
"J" Analyte present but concentration estimated
"R" Result not usable
"=" Analyte present and concentration accurate

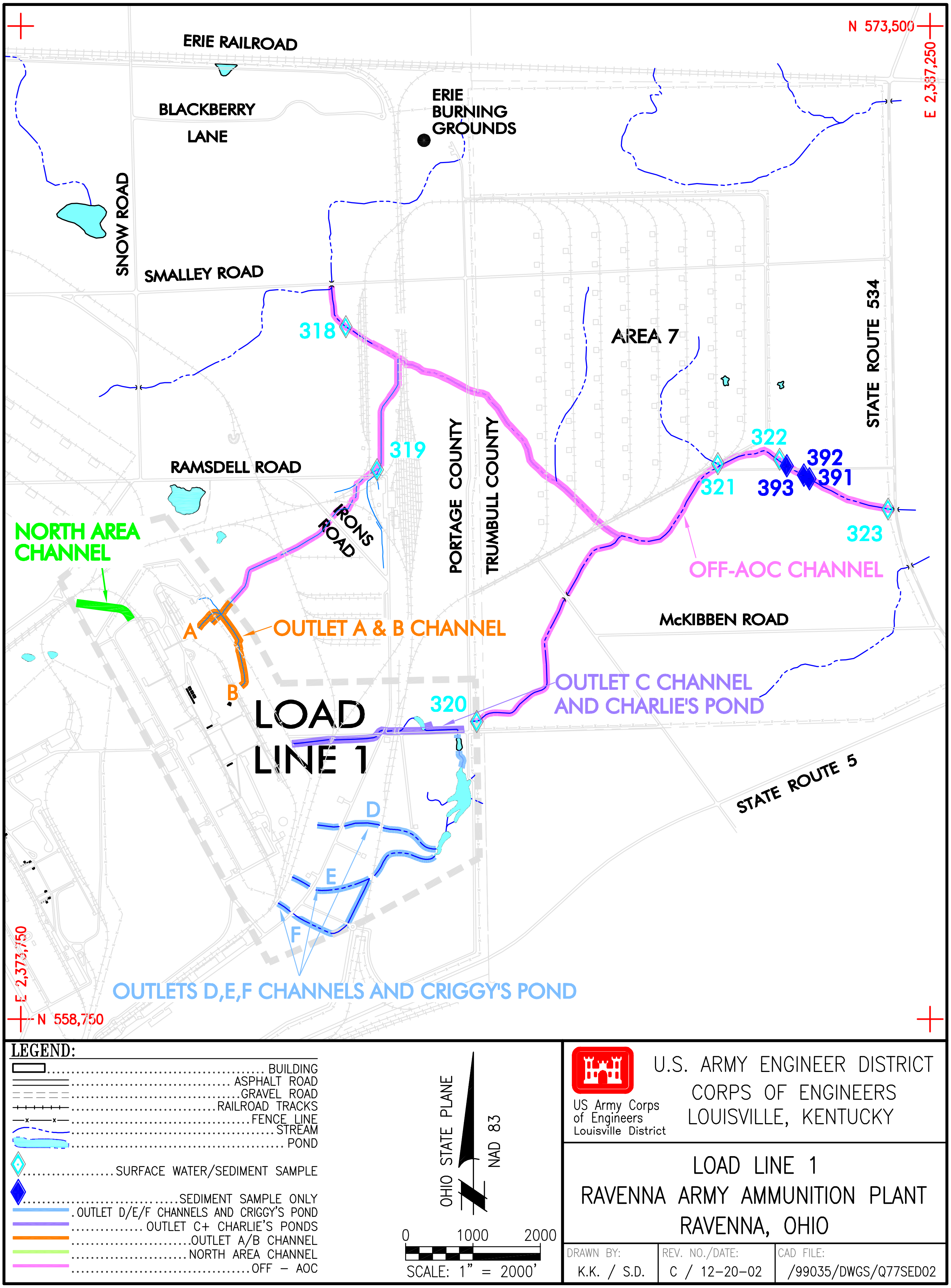


Figure 4-2. Load Line 1 Sediment Aggregates by Drainage Area

In addition to assigning qualifiers, the data review process also selected the appropriate result to use when reanalyses or dilutions were performed. Where laboratory surrogate recovery data or laboratory quality control samples were outside of analytical method specifications, a determination was made regarding whether laboratory reanalysis should be used in place of an original reported result. If results were reported for both diluted and undiluted samples, results from the diluted sample were used only for those analytes that exceeded the calibration range of the undiluted sample.

A complete discussion of the results of the data review process is contained in the QCSR in Appendix G.

The data screening process employed to identify SRCs involved first calculating data summary statistics. Site data were extracted from the database such that QC splits and field duplicates were excluded from the screening data sets. Samples that were rejected during data review were excluded from the screening process. All analytes having at least one detected value were included in the screening process. Analytes that were never detected were eliminated as SRCs. Additional screening of identified SRCs was conducted as part of the risk evaluation to identify human health and ecological COPCs (see Chapters 6.0 and 7.0).

4.1.3.2 Summary statistics and frequency of detection screen

Summary statistics calculated for each data aggregate (Table 4-2 through 4-24) included the minimum, maximum, and average (mean) detected values and the proportion of detected results to the total number of samples collected. Nondetected results meeting contract-required detection limits were set to one-half of the reported detection limit during calculation of the mean result for each compound. Nondetected results with elevated detection limits (more than 5 times the contract-required detection limit) were excluded from the summary statistics in order not to skew the calculation of mean values.

For sample aggregates containing more than 20 samples, a frequency of detection criterion was applied to identify SRCs. Inorganic analytes with a frequency of detection greater than or equal to 5% were screened against background, if applicable, to determine if they were SRCs. Organics (exclusing explosives and propellants) were identified as SRCs solely on the basis of frequency of detection. If the frequency of detection for one of these classes of analytes was less than 5%, a weight of evidence approach was used to determine if the chemical was a SRC. The weight of evidence approach involved examining the magnitude and locations of the detected results. If no clustering within a particular area was noted and concentrations were not substantially elevated relative to the detection limits, the detected results were considered spurious, and the compound was eliminated as a SRC.

All detected explosives and propellants were considered to be SRCs regardless of the frequency of detection and; thus, were subjected to the risk evaluation (Chapter 5.0). However, appropriate qualification is made in the assessment of occurrence and distribution for those explosives and propellants having a frequency of detection less than 5%.

4.1.3.3 Facility-wide background screen

For each inorganic constituent passing the frequency of detection screen, concentrations were compared against facility-wide background values. For inorganic constituents, if the maximum detected concentration of an analyte exceeded its respective background criterion, it was considered to be a SRC. In the event a constituent was not detected in the background data set, the background value was set to zero, and any detected result for that constituent was considered above background. This conservative process ensured that detected constituents were not eliminated as SRCs simply because they were not detected in the background data set. All detected organic compounds were considered to be above background, because these classes of compounds do not occur naturally.

4.1.3.4 Essential nutrients screen

Chemicals that are considered to be essential nutrients (calcium, chloride, iodine, iron, magnesium, potassium, phosphorus, and sodium) are an integral part of the food supply and are often added to foods as supplements. Thus, these constituents are not generally addressed as contaminants in contaminant nature and extent and the HHBRA (EPA 1989 and 1996a) unless they are grossly elevated relative to background values. The essential nutrient screen is not applied for the ecological risk assessment. For the LL 1 Phase II RI, analyses were conducted for calcium, iron, magnesium, potassium, and sodium. These five constituents were eliminated as SRCs in all environmental media based on comparison to background values.

4.1.4 Data Presentation

Data summary statistics and screening results to identify SRCs in each data aggregate are presented in Tables 4-2 through 4-24. Within the sections below addressing the nature and extent of contamination by media, analytical results for selected SRCs are presented on maps to depict spatial distribution. The concentration ranges presented on figures depicting inorganic chemical data are arbitrary and intended simply to convey to the reader the degree of contamination relative to background values, where available. Other figures depict concentrations of chemicals where no background values are available (e.g., explosives, organic solvents, etc.); therefore, actual concentrations are shown to illustrate the degree of contamination at various sample locations. Individual results for each analyte for each sample are presented in Tables 4-31 through 4-53. Each table presents results collected for the LL 1 Phase II RI for a specific medium. [Results for the samples taken during the Phase I RI are listed in the Phase I report (USACE 1998).] The table for each medium is divided into sections for each type of analysis (inorganics, explosives, pesticides/PCBs, SVOCs, and VOCs). Within each section, the samples are sorted by aggregate group and within group by sampling station identification number. The results for inorganic constituents that exceed the facility-wide background criteria are indicated in these tables.

4.1.5 Overview of Nature and Extent Investigation

This overview is presented to familiarize the reader with the AOC-wide findings resulting from an examination of the extensive data set of Phase II sampling results. This is intended only as a preview of the following sections that present detailed discussion of each media within each aggregate. The conclusions presented here are applicable to two large areas of the LL 1 AOC; the main process area, consisting of all the former process buildings, and the remaining perimeter (non-production) area of the AOC.

The primary findings in the main process area are

- In surface soil, the contaminant suite consists of explosives and propellants (e.g., 2,4,6-TNT and nitrocellulose), several metals, and some organic compounds (PAHs, one PCB, and one VOC) Explosives are primarily in the immediate vicinity of the building pads with the highest levels in the soils surrounding the pad of Building CB-4A. Organic compounds are more ubiquitous throughout the process area.

- In subsurface soils, concentrations of metals are generally lower than surface soil, except where the soil has been disturbed. Explosives were consistently detected only in the melt-pour area, although scattered detections occurred in other areas.

- In sediment, the highest concentration of explosives and propellants were measured in ditch sediment samples near Building CB-13 and CB-13B. Explosives migration along drainages for extensive distances is not indicated. PCBs detections were isolated, and widespread transport of PCBs via eroded surface soil is not indicated.

- In surface water, metals and explosives concentrations do not correlate with sediment concentrations, indicating a transient nature for this media.

- In groundwater monitoring wells in the process area (LL1mw-078, LL1mw-079, LL1mw-080, LL1mw-081, LL1mw-082, LL1mw-083, LL1mw-084, and LL1mw-085), metal concentrations are elevated relative to background. Low explosives and organic compounds concentrations were measured in all monitoring wells except LL1mw-080, LL1mw-083, and LL1mw-084.

The primary findings in the area exterior to the process area are:

- In surface soils, metals were only slightly elevated above background with no explosives or propellants detected. One VOC (1,2-DCE) was consistently detected, although at low concentrations.

- In surface water, metals were most abundant at Charlie's Pond at the AOC boundary. No organic compounds were detected, indicating migration of these constituents in dissolved phase from the process area is not occurring via surface water.

- Metal concentrations in groundwater in the perimeter location monitoring wells are not elevated above the background criteria.

Detailed discussion of contaminant nature and extent for each area aggregate is included in Sections 4.2 through 4.7. A complete summary of the nature and extent of contamination discussion is presented in Section 4.10.

4.2 SURFACE SOILS

Surface soil samples (from 0- to 1-ft) were collected for the Phase II RI at (1) Phase I locations that exhibited metals and/or explosives contamination in the surface soils and (2) at additional locations around the major buildings or features within the load line and from a random grid laid out across the entire load line. The Phase I sampling locations were biased in that they were based on observations of staining or located at the ends of effluent pipes or along drainages. Subsequent to the Phase I RI, the LL 1 buildings (except CB-13 and CB-801) were demolished and removed, leaving the floor slabs and most below-grade infrastructure in place. The railroad tracks and timbers were also removed, but the slag cinders in the railroad beds remained. Several Phase I locations were re-sampled in Phase II to assess whether demolition and removal operations had altered occurrences of soil contamination as documented in the Phase I RI. Samples with numerical designations between -001 and -068 were sampled during the Phase I RI, and brief comparisons of the data from the Phase I RI and the Phase II RI are made in the following text.

As mentioned above, most of the Phase II surface soil sampling was biased toward those areas and former building footprints that suggest the greatest soil contamination from Phase I data and from knowledge of historical operations. For example, Phase II sampling stations were positioned around building perimeters near door openings where washouts would occur, at drip lines (i.e., overhangs of the floor slabs), and underneath floor drains or where cracks/holes were evident in the floor slab. Plate 3-1 illustrates the distribution of surface soil sample locations in the Phase II RI.

In addition to the preplanned surface soil samples, explosives field screening results were used to determine the placement of additional contingency samples. Also, a subsurface soil sample (from 1 to 3 ft) was collected or attempted at Phase I sampling locations associated with the major buildings within the load line and at surface soil locations with field screening results ≥1.0 ppm of TNT or RDX. These subsurface soils were analyzed for a determination of vertical extent of contamination and are described and summarized in Section 4.3.

All sample collection and analysis for the Phase II RI was conducted in accordance with the SAP Addendum No. 2 (USACE 2000b), as described in Section 3.0 of this report. Surface soil samples were analyzed for field explosives, field metals, explosives/propellants, TAL metals, VOCs, SVOCs, pesticides/PCBs, and cyanide, as described in Section 3.0. Hexavalent chromium analysis, added to the original scope during the field effort, was conducted on 74 surface soil samples selected at random. A field change order, provided in Appendix F, documents this change to the analytical program.

A total of 310 surface soil samples were collected for the purpose of determining nature and extent of contamination across the load line. Each of these samples was analyzed for metals at both the field-base and fixed-base laboratories. Each of these samples was also analyzed for explosives in the field-based laboratory. In 75 samples, the surface soils tested positive for explosives using field colorimetry (i.e., results ≥1.0 ppm TNT or RDX) and were sent to the fixed-base laboratory for further analysis. In addition, of the surface soils that did not test positive for explosives, 58 samples were sent to the fixed-base laboratory for confirmation of the non-detected results. Statistical comparisons of the field-based laboratory and fixed-base laboratory explosives and metals data are provided in Sections 4.9.1 and 4.9.2**,** respectively.

The analytical results for surface soil samples collected at LL 1 are summarized by area and by analyte in Tables 4-31 through 4-35. Tables 4-2 through 4-8 present the determination of SRCs for surface soil at LL 1.

The following sections describe the distribution of explosives, propellants, and inorganic and organic constituents for each of the groupings of buildings (e.g., aggregate) based on the data from the fixed-base analytical laboratory. For each aggregate discussed, figures are presented (as appropriate) that illustrate the distribution of site-related explosives, propellants, and metals. The analytes presented in the figures represent those that occur with the greatest frequency at each aggregate and, for metals, those that occur at the highest concentrations above background. Analytical results, including non-detections are presented on the figures and represent the results only from the fixed-base laboratory. As indicated on the figures for some analytical parameter groups (i.e., explosives and propellants), many sample stations do not have a results box, indicating the samples from this station were not submitted to the fixed base laboratory.

4.2.1 Geotechnical Information for Surface Soils

Several surface soil samples were sent to a geotechnical laboratory for measurement of moisture content, Atterberg limits, and/or USCS classification. The results are provided in Appendix K and indicate that the surface soils in the LL 1 area are predominantly composed of silt and sand (USCS classifications: SM and ML). The moisture content of these soils ranged from 4 to 40%. The sample with 40% moisture content was collected at station LL1-024 near the settling basin west of the Building CA-6 pad. The liquid limit ranged from 34 to 36 and the plasticity index ranged from 8 to 9.

4.2.2 Explosives and Propellants

In the Phase I RI, explosives concentrations were highest in the soils around the doorways, drains, and vacuum pump houses associated with the major buildings in the load line (USACE 1996). For this reason, the majority of the Phase II RI surface soil sampling locations were placed very near the building footprints and, in some cases, were located under the concrete floor slab overhang. The Phase II analytical results indicate that sixteen explosive and propellant compounds were detected in the surface soil samples collected for characterization of nature and extent of contamination across the load line. The most commonly detected explosive was 2,4,6-TNT (85 detections), and nitrocellulose was the most common propellant, detected in surface soils at 65 locations.

The following sections describe the distribution of explosives and propellants for each of the major groupings of buildings. For each area discussed, figures are presented that illustrate the distribution of all detected explosives and propellants.

4.2.2.1 Buildings CB-4/-4A and CA-6/-6A and settling basins

Former buildings CB-4 and CB-4A, collectively referred to as the melt-pour complex, are located in the center of the production area. Concrete pads at CA-6 and CA-6A, which are former bulk-explosives preparation buildings, are located to the northeast of the melt-pour complex (Plate 3-1). In these two areas, 160 surface soil samples were collected and analyzed for explosives in the field laboratory. Of these 160 samples, 82 were sent to the fixed-base laboratory for explosives and propellants analysis. Twelve samples submitted to the fixed-base laboratory had no detectable quantities of explosives or propellants (stations LL1-024, LL1-140, LL1-143, LL1-331, LL1-335, LL1-349, LL1-358, LL1-361, LL1-362, LL1-375, LL1-379, and LL1-417). Of the 17 compounds provided by the laboratory explosives/propellants analysis, only tetryl was not detected.

The most commonly detected explosives in this aggregate were 2,4,6-TNT, detected in 60 samples, and 2-amino-4,6-dinitrotoluene, detected in 43 samples (Table 4-5). 2,4,6-TNT was measured at the highest average concentration (159.7 mg/kg) of the 16 detected compounds and at the maximum concentration for the aggregate (4,800 mg/kg). RDX was measured at a maximum concentration of 2300 mg/kg with the second highest average concentration of 47.9 mg/kg. Of the 16 detected compounds, nine have average concentrations of approximately equal value (~3.1 mg/kg), indicating relatively consistent concentrations where present in the surface soil.

The propellants, nitroglycerin and nitroguanidine, were detected only once (in the vicinity of the Building CB-4A pad). In contrast, the most common propellant was nitrocellulose, which was detected in 50 of 82 soil samples collected (Table 4-5). Additional descriptions of the nature and extent of contamination are provided in the following sections along with figures for each of the major buildings.

CB-4: As shown on Figure 4-3, the concentrations of explosives and propellants vary widely in the samples collected around the former building pad. For example, the maximum concentration (990 mg/kg) of 2,4,6-TNT occurred at station LL1-340 located along the north central edge of the CB-4 pad. However, at station LL1-148, approximately 65 ft to the southwest along the edge of the concrete pad, 2,4,6-TNT was not detected above detection limits. Likewise, on the eastern side of the building, 2,4,6-TNT occurs at a concentration of 150 mg/kg at station LL1-343. However, approximately 60 ft away at station LL1-150, the TNT concentration was three orders of magnitude lower (i.e., 0.55 mg/kg). The same sporadic contaminant distribution occurs for the other explosives and for the only detected propellant, nitrocellulose. This trend was also noted in data in the Phase I RI Report. The distribution of detections versus non-detects indicates that the contamination is in the immediate perimeter area of the concrete pad and that contamination does not extend a substantial distance from the pad (Figure 4-3). The two samples collected from beneath the floor slab did not have detectable concentrations of explosives as measured in the field laboratory and were not sent for further analysis.

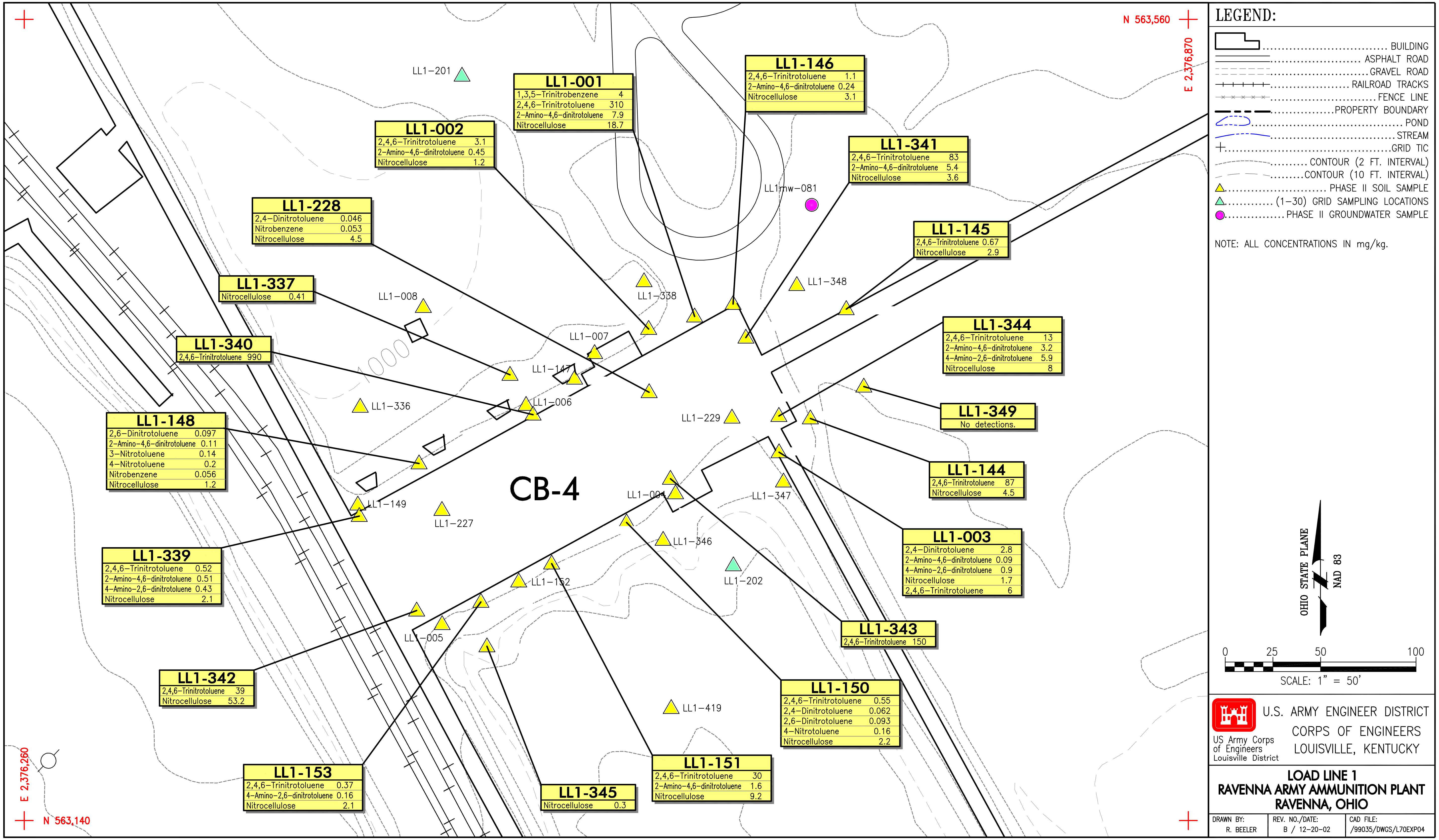


Figure 4-3. Explosives in Surface Soil at Building CB-4

CB-4A: The immediate area around the Building CB-4A pad is the most heavily contaminated area at LL 1 with respect to explosives and propellant constituents (i.e., more frequent detections and higher concentrations) (see Figure 4-4 and Table 4-5). The most heavily contaminated area occurs in the vicinity of station LL1-157, where the following concentrations were detected:

- 2,4,6-TNT - 4,800 mg/kg,
- HMX - 260 mg/kg,
- RDX - 2,300 mg/kg, and
- nitrocellulose - 388 mg/kg.

These results are the maximum concentrations for these constituents for samples collected during the Phase II RI across the entire load line. This station is located at the northwestern corner of the building (Figure 4-4). Station LL1-357, which is near the southern overhang of the floor slab, also had high concentrations of the explosives and propellants listed above. Station LL1-015 also had high concentrations in both the surface and the subsurface soil sample.

The sporadic distribution of explosives and propellants in surface soil noted at the Building CB-4 pad is also evident in the soil surrounding the perimeter of the Building CB-4A pad. For example, station LL1-158 is located nearest to station LL1-157 and has much lower concentrations of the same explosives and nitrocellulose. Contaminant concentrations also decreased with increasing distance from the pad for most of the perimeter area of this pad. An exception occurs to the south of the pad at station LL1-407, with a 2,4,6-TNT concentration of 180 mg/kg. Sample stations closer to the pad (e.g., LL1-016 and LL1-168) had concentrations at 1.2 mg/kg and non-detect for 2,4,6-TNT.

Samples from the Building CB-4A pad area had detections of HMX and RDX in both the surface and subsurface soil samples. The detections occurred in several locations at the Building CB-4A pad, yet these compounds were never detected around the Building CB-4 pad. This lack of HMX and RDX is unusual because, given the similar operational histories of these buildings, it was assumed that the contaminant distribution around the CB-4 and CB-4A pads would be alike.

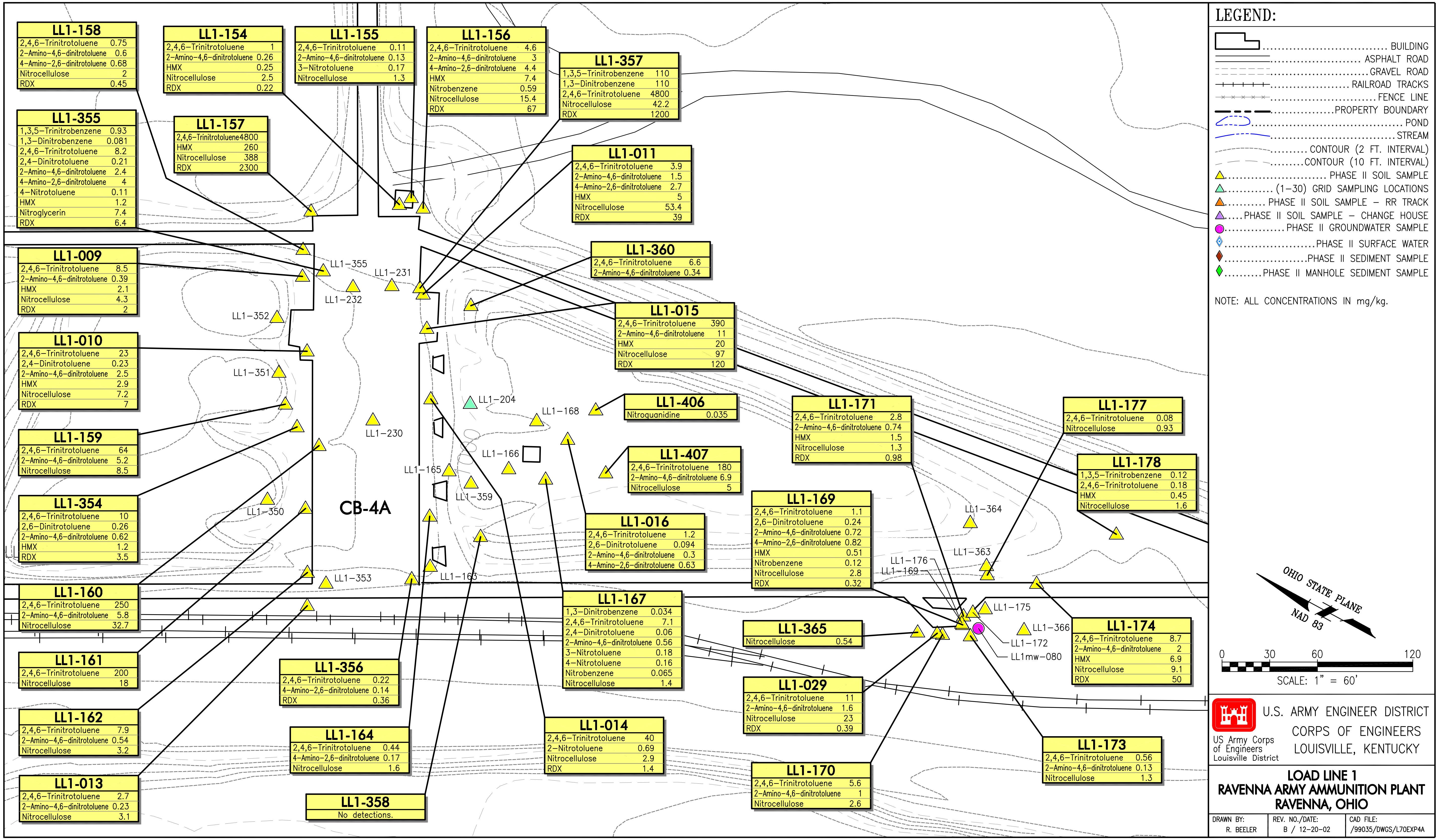
The only detections of the propellants nitroglycerin and nitroguanidine within LL 1 occurred at CB-4A

nitroglycerine at 7.4 mg/kg at station LL1-355 and

- nitroguanidine at 0.035 mg/kg at station LL1-406.

Station LL1-355 is located adjacent to the pad on the north corner and is the site of detection of 10 explosive compounds, whereas station LL1-406 is located to the south of the pad, approximately 100 ft distant, and has only a single explosive or propellant compound.

The area located along the walkway to the southeast of the Building CB-4A pad was sampled to determine the nature and extent of contamination at a former settling basin (Figure 4-4). While the number of detections in this sub-aggregate was similar to the frequency seen around the Building CB-4A pad, the overall concentrations of explosive compounds decreased, with the exception of RDX, detected at a concentration of 50 mg/kg at station LL1-174. The samples collected from beneath the floor slab did not have detectable concentrations or explosives, as measured in the field-based laboratory, and were not sent for further analysis.



LL1-158	
2,4,6-Trinitrotoluene	0.75
2-Amino-4,6-dinitrotoluene	0.6
4-Amino-2,6-dinitrotoluene	0.68
Nitrocellulose	2
RDX	0.45

LL1-154	
2,4,6-Trinitrotoluene	1
2-Amino-4,6-dinitrotoluene	0.26
HMX	0.25
Nitrocellulose	2.5
RDX	0.22

LL1-155	
2,4,6-Trinitrotoluene	0.11
2-Amino-4,6-dinitrotoluene	0.13
3-Nitrotoluene	0.17
Nitrocellulose	1.3

LL1-156	
2,4,6-Trinitrotoluene	4.6
2-Amino-4,6-dinitrotoluene	3
4-Amino-2,6-dinitrotoluene	4.4
HMX	7.4
Nitrobenzene	0.59
Nitrocellulose	15.4
RDX	67

LL1-357	
1,3,5-Trinitrobenzene	110
1,3-Dinitrobenzene	110
2,4,6-Trinitrotoluene	4800
Nitrocellulose	42.2
RDX	1200

LL1-355	
1,3,5-Trinitrobenzene	0.93
1,3-Dinitrobenzene	0.081
2,4,6-Trinitrotoluene	8.2
2,4-Dinitrotoluene	0.21
2-Amino-4,6-dinitrotoluene	2.4
4-Amino-2,6-dinitrotoluene	4
4-Nitrotoluene	0.11
HMX	1.2
Nitroglycerin	7.4
RDX	6.4

LL1-157	
2,4,6-Trinitrotoluene	4800
HMX	260
Nitrocellulose	388
RDX	2300

LL1-011	
2,4,6-Trinitrotoluene	3.9
2-Amino-4,6-dinitrotoluene	1.5
4-Amino-2,6-dinitrotoluene	2.7
HMX	5
Nitrocellulose	53.4
RDX	39

LL1-009	
2,4,6-Trinitrotoluene	8.5
2-Amino-4,6-dinitrotoluene	0.39
HMX	2.1
Nitrocellulose	4.3
RDX	2

LL1-360	
2,4,6-Trinitrotoluene	6.6
2-Amino-4,6-dinitrotoluene	0.34

LL1-015	
2,4,6-Trinitrotoluene	390
2-Amino-4,6-dinitrotoluene	11
HMX	20
Nitrocellulose	97
RDX	120

LL1-010	
2,4,6-Trinitrotoluene	23
2,4-Dinitrotoluene	0.23
2-Amino-4,6-dinitrotoluene	2.5
HMX	2.9
Nitrocellulose	7.2
RDX	7

LL1-406	
Nitroguanidine	0.035

LL1-171	
2,4,6-Trinitrotoluene	2.8
2-Amino-4,6-dinitrotoluene	0.74
HMX	1.5
Nitrocellulose	1.3
RDX	0.98

LL1-177	
2,4,6-Trinitrotoluene	0.08
Nitrocellulose	0.93

LL1-159	
2,4,6-Trinitrotoluene	64
2-Amino-4,6-dinitrotoluene	5.2
Nitrocellulose	8.5

LL1-407	
2,4,6-Trinitrotoluene	180
2-Amino-4,6-dinitrotoluene	6.9
Nitrocellulose	5

LL1-178	
1,3,5-Trinitrobenzene	0.12
2,4,6-Trinitrotoluene	0.18
HMX	0.45
Nitrocellulose	1.6

LL1-169	
2,4,6-Trinitrotoluene	1.1
2,6-Dinitrotoluene	0.24
2-Amino-4,6-dinitrotoluene	0.72
4-Amino-2,6-dinitrotoluene	0.82
HMX	0.51
Nitrobenzene	0.12
Nitrocellulose	2.8
RDX	0.32

LL1-354	
2,4,6-Trinitrotoluene	10
2,6-Dinitrotoluene	0.26
2-Amino-4,6-dinitrotoluene	0.62
HMX	1.2
RDX	3.5

LL1-016	
2,4,6-Trinitrotoluene	1.2
2,6-Dinitrotoluene	0.094
2-Amino-4,6-dinitrotoluene	0.3
4-Amino-2,6-dinitrotoluene	0.63

LL1-160	
2,4,6-Trinitrotoluene	250
2-Amino-4,6-dinitrotoluene	5.8
Nitrocellulose	32.7

LL1-167	
1,3-Dinitrobenzene	0.034
2,4,6-Trinitrotoluene	7.1
2,4-Dinitrotoluene	0.06
2-Amino-4,6-dinitrotoluene	0.56
3-Nitrotoluene	0.18
4-Nitrotoluene	0.16
Nitrobenzene	0.065
Nitrocellulose	1.4

LL1-365	
Nitrocellulose	0.54

LL1-174	
2,4,6-Trinitrotoluene	8.7
2-Amino-4,6-dinitrotoluene	2
HMX	6.9
Nitrocellulose	9.1
RDX	50

LL1-161	
2,4,6-Trinitrotoluene	200
Nitrocellulose	18

LL1-356	
2,4,6-Trinitrotoluene	0.22
4-Amino-2,6-dinitrotoluene	0.14
RDX	0.36

LL1-029	
2,4,6-Trinitrotoluene	11
2-Amino-4,6-dinitrotoluene	1.6
Nitrocellulose	23
RDX	0.39

LL1-162	
2,4,6-Trinitrotoluene	7.9
2-Amino-4,6-dinitrotoluene	0.54
Nitrocellulose	3.2

LL1-014	
2,4,6-Trinitrotoluene	40
2-Nitrotoluene	0.69
Nitrocellulose	2.9
RDX	1.4

LL1-164	
2,4,6-Trinitrotoluene	0.44
4-Amino-2,6-dinitrotoluene	0.17
Nitrocellulose	1.6

LL1-173	
2,4,6-Trinitrotoluene	0.56
2-Amino-4,6-dinitrotoluene	0.13
Nitrocellulose	1.3

LL1-170	
2,4,6-Trinitrotoluene	5.6
2-Amino-4,6-dinitrotoluene	1
Nitrocellulose	2.6

LL1-013	
2,4,6-Trinitrotoluene	2.7
2-Amino-4,6-dinitrotoluene	0.23
Nitrocellulose	3.1

LL1-358
No detections.

LEGEND:

.... BUILDING
.... ASPHALT ROAD
...........................GRAVEL ROAD
.... RAILROAD TRACKS
.........................FENCE LINE
.................PROPERTY BOUNDARY
.... POND
...................................STREAM
.... CONTOUR (2 FT. INTERVAL)
.........CONTOUR (10 FT. INTERVAL)
▲.......................... PHASE II SOIL SAMPLE
▲............ (1–30) GRID SAMPLING LOCATIONS
▲.......... PHASE II SOIL SAMPLE – RR TRACK
▲.....PHASE II SOIL SAMPLE – CHANGE HOUSE
●...............PHASE II GROUNDWATER SAMPLE
◇........................PHASE II SURFACE WATER
◆.....................PHASE II SEDIMENT SAMPLE
◆..........PHASE II MANHOLE SEDIMENT SAMPLE

NOTE: ALL CONCENTRATIONS IN mg/kg.

SCALE: 1" = 60'

US Army Corps
of Engineers
Louisville District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

LOAD LINE 1
RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	B / 12-20-02	/99035/DWGS/L70EXP4A

Figure 4-4. Explosives in Surface Soil at Building CB-4A

CA-6: In terms of concentrations, the surface soil stations around the Building CA-6 pad are less contaminated than the areas around the Building CB-4 and Building CB-4A pads. Five sample stations submitted to the fixed-base laboratory had no detections of explosives or propellants (stations LL1-024, LL1-140, LL1-143, LL1-375, and LL1-417) (see Figure 4-5). Three of these stations are on the east side of the building near the railroad tracks. The highest concentration of TNT in this area (180 mg/kg) occurred at station LL1-136, located 20 ft west of the pad perimeter. The maximum of the two nitrocellulose detections (13.4 mg/kg) in this area occurred at station LL1-137. In summary, the sampling of the area surrounding CA-6 indicates 2,4,6-TNT is the most common compound with a range of concentrations from 0.052 to 180 mg/kg. Explosives were detected primarily around the pad perimeter with the exception of station LL1-136 to the west.

Few detections occurred in the samples collected at the settling basin to the northwest of the CA-6 pad (Figure 4-5). At one time, this area contained a tank that was the collection point for process effluent (i.e., pink water). The tank has been removed. With the exception of 300 mg/kg of 2,4,6-TNT at station LL1-265, all detections of explosives and propellants at the settling basin were less than 1 ppm. As indicated in Figure 4-5, the sample station density in the area surrounding the settling basin is sufficient to delineate contaminant distribution, yet no compounds were detected. This lack of detections indicates surface soil contaminants are primarily within the immediate location of the former basin.

CA-6A: The surface soil stations around the Building CA-6A pad and the walkway to the former Building CB-4A are the least contaminated in the melt-pour and bullk explosives preparation buildings aggregate. Five samples of surface soil submitted to the fixed-based laboratory had no detections of explosives or propellants (stations LL1-331, LL1-335, LL1-361, LL1-362, and LL1-379) (see Figure 4-6). Two of these stations are located east of the pad near the railroad tracks, and two are at the end of the walkway near the former Building CB-4A.

The highest contamination occurs at station LL1-325, with 2,4,6-TNT at 22 mg/kg and nitrocellulose at 3.8 mg/kg. In addition, this station contained the maximum concentration of any explosive or propellant compound in subsurface soils (2,4,6-TNT at 4,500 mg/kg). Nitrocellulose was also present in this subsurface soil sample at 29.3 mg/kg. In both cases, the concentration of 2,4,6-TNT and nitrocellulose increased with depth at this station (see Section 4.3).

4.2.2.2 Buildings CB-10, CB-13, CB-13A, and CB-13B

The CB-10 and CB-13 buildings were associated with drill and booster activities during the operation of LL 1. In addition, during the Vietnam War era, these buildings were used for munitions rehabilitation, which involved the dismantling, component replacement, and repairing of mines with much of this work conducted in Building CB-10. During the Phase I field activities, residual propellant pellets were found on the ground beside Buildings CB-13 and CB-13B in the area of the former popping furnace. Recent demolition activities have removed many of the building structures down to the concrete pads; however, Building CB-13B has been left standing for future use by the OHARNG.

Fifty surface soil samples were collected in this aggregate and analyzed for explosives in the field laboratory. Twenty-six samples were sent to the fixed-base laboratory for explosives and propellants analysis, of which six samples had no detectable quantities of explosives or propellants (stations LL1-114, LL1-413, LL1-133, LL1-131, LL1-125, and LL1-415). Seven explosives and propellants were detected in the remaining samples, with 2,4,6-TNT (17 detections) and nitrocellulose (8 detections) occurring most frequently (Table 4-2). These two compounds were also measured at the highest concentrations, 230 and 103 mg/kg, respectively. According to the field laboratory results, the samples collected from beneath the floor slabs did not have detectable concentrations of explosives.

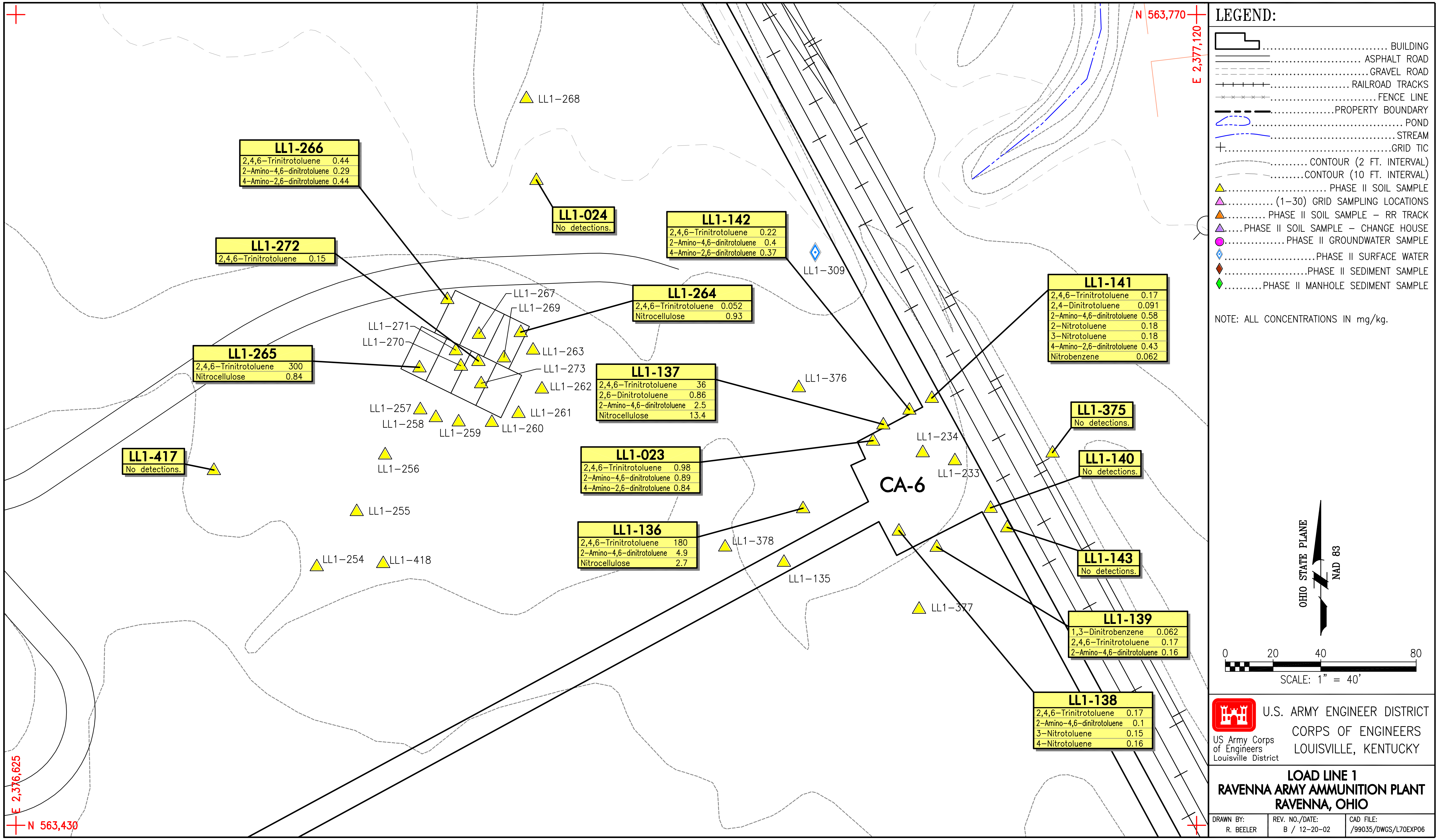


Figure 4-5. Explosives in Surface Soil at Building CA-6

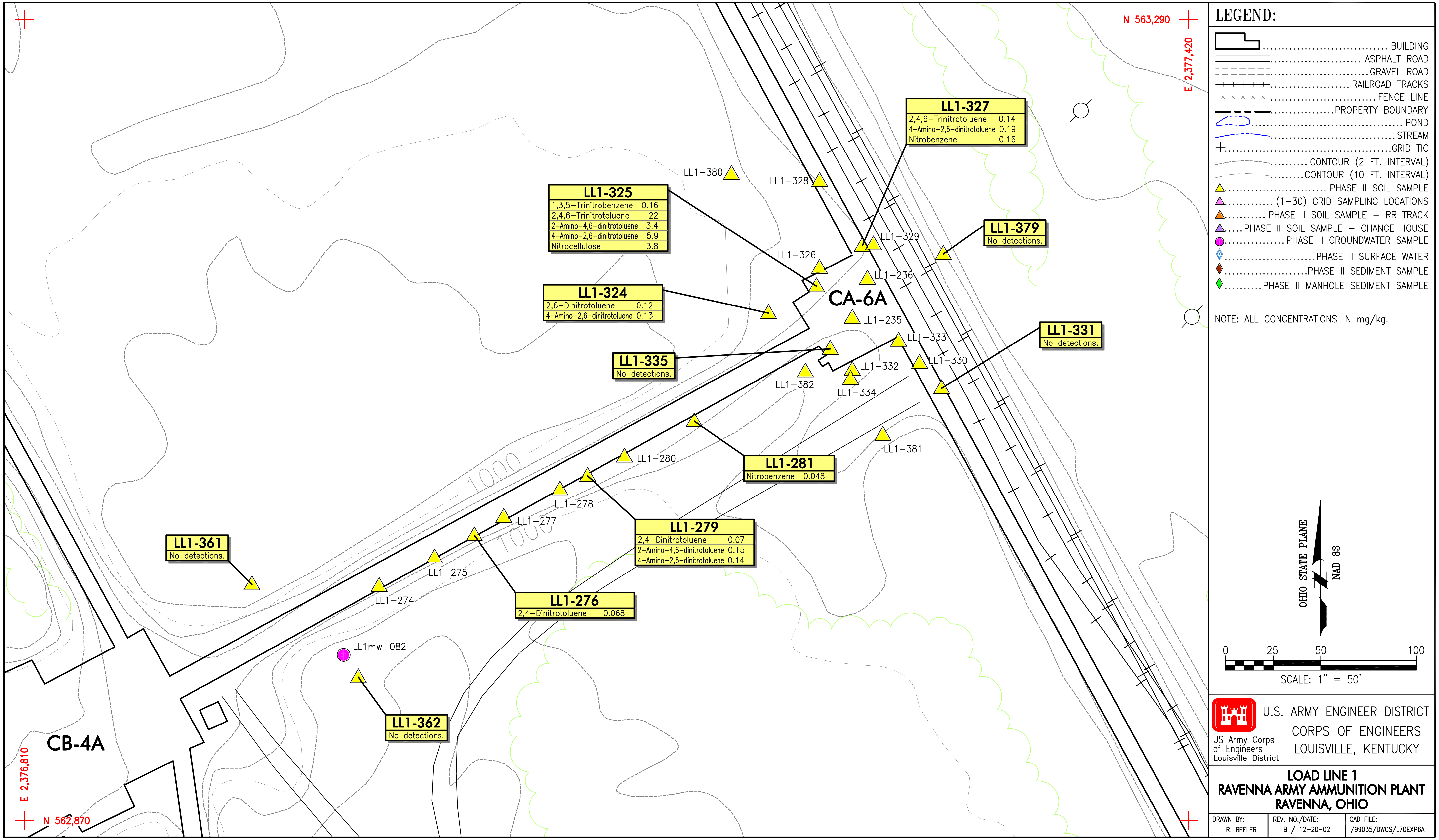


Figure 4-6. Explosives in Surface Soil at Building CA-6A

As shown on Figure 4-7, the surface soil sampling locations around the Building CB-10 pad had more frequent detections of explosive/propellant compounds than the locations around Building CB-13. Detected 2,4,6,-TNT concentrations ranged from 230 mg/kg to less than 1 mg/kg with most concentrations in the lower end of this range. The southeastern corner of the Building CB-10 pad was the most heavily contaminated, with the stations in this area showing the greatest frequency of detections and the overall highest concentrations (e.g., 2,4,6-TNT maximum concentration of 230 mg/kg at LL1-034 and RDX maximum concentration of 27 mg/kg at LL1-371). These locations are in the vicinity of former vacuum pumps associated with the handling of process wastes pulled from the building. Similar to the melt-pour buildings discussed previously, detections of explosives diminish rapidly with distance from the building pad, indicating contamination is localized to the perimeter area.

As indicated in Figure 4-7, the 16 sample stations were positioned around the pad of Building CB-13 with four stations within the pad. Seven of these samples were submitted for fixed base laboratory analysis. For the CB-13 pad, explosive contaminants are of low concentration (e.g., less than 1 mg/kg with the exception of station LL1-109) and are limited to southeastern edge of the pad. Surface soil from stations to the south of the Building CB-13B pad had the maximum concentrations of nitrocellulose (103 mg/kg) and 2,4-DNT (9.3 mg/kg). Station LL1-109 is located at the head of a drainage ditch that probably received direct discharge of pink water effluent from former process washout operations. In addition, this area is near the location of the former popping furnace, where propellant pellets were observed on the ground during the Phase I RI. Nitrocellulose concentrations are higher than the detected explosives, ranging from 103 mg/kg to 13.8 mg/kg where detected. Station LL1-109 also had a high concentration of nitrocellulose in the associated subsurface soil sample (see Section 4.3).

4.2.2.3 Buildings CB-14, CA-15, and CB-17

The CB-14, CA-15, and CB-17 buildings, located at the north end of the load line, were used for the final stages of munitions work (i.e., load-assemble-pack operations). During the Phase I RI field activities, residual propellant pellets were found on the ground near Building CB-14. Only remnant floor slabs remain in this area.

From this area, 26 surface soil samples were collected and analyzed for explosives in the field laboratory. Of these, only four were sent to the fixed-base laboratory for further explosives and propellants analysis. Two samples had no detectable quantities of explosives or propellants (stations LL1-088 and LL1-402). Six explosives and propellants were detected in the remaining samples. As shown on Figure 4-8, 2,4,6-TNT was detected at stations LL1-087 and LL1-099 at concentrations of 0.37 mg/kg and 4.5 mg/kg, respectively. The propellant, nitrocellulose, was detected at the same stations at 49.5 mg/kg and 90 mg/kg, respectively. RDX was detected at LL1-099 at a concentration of 34 mg/kg. Station LL1-087 also had detections in the subsurface sample (see Section 4.3). The two samples collected adjacent to Building CA-15 indicate no contamination based on the field screening test.

In summary, the extent and magnitude of explosive and propellant contamination in this grouping of buildings is minimal and sporadic with only two of 26 surface soil locations (stations LL1-087 and LL1-099) having detectable concentrations.

4.2.2.4 Buildings CB-3 and CB-801 and the Water Tower

Buildings CB-3 and CB-801 are located at the southern end of the load line, and were used for solvent storage, vehicle maintenance, and painting operations. Only the concrete floor slab remains at CB-3; however, Building CB-801 was not demolished.

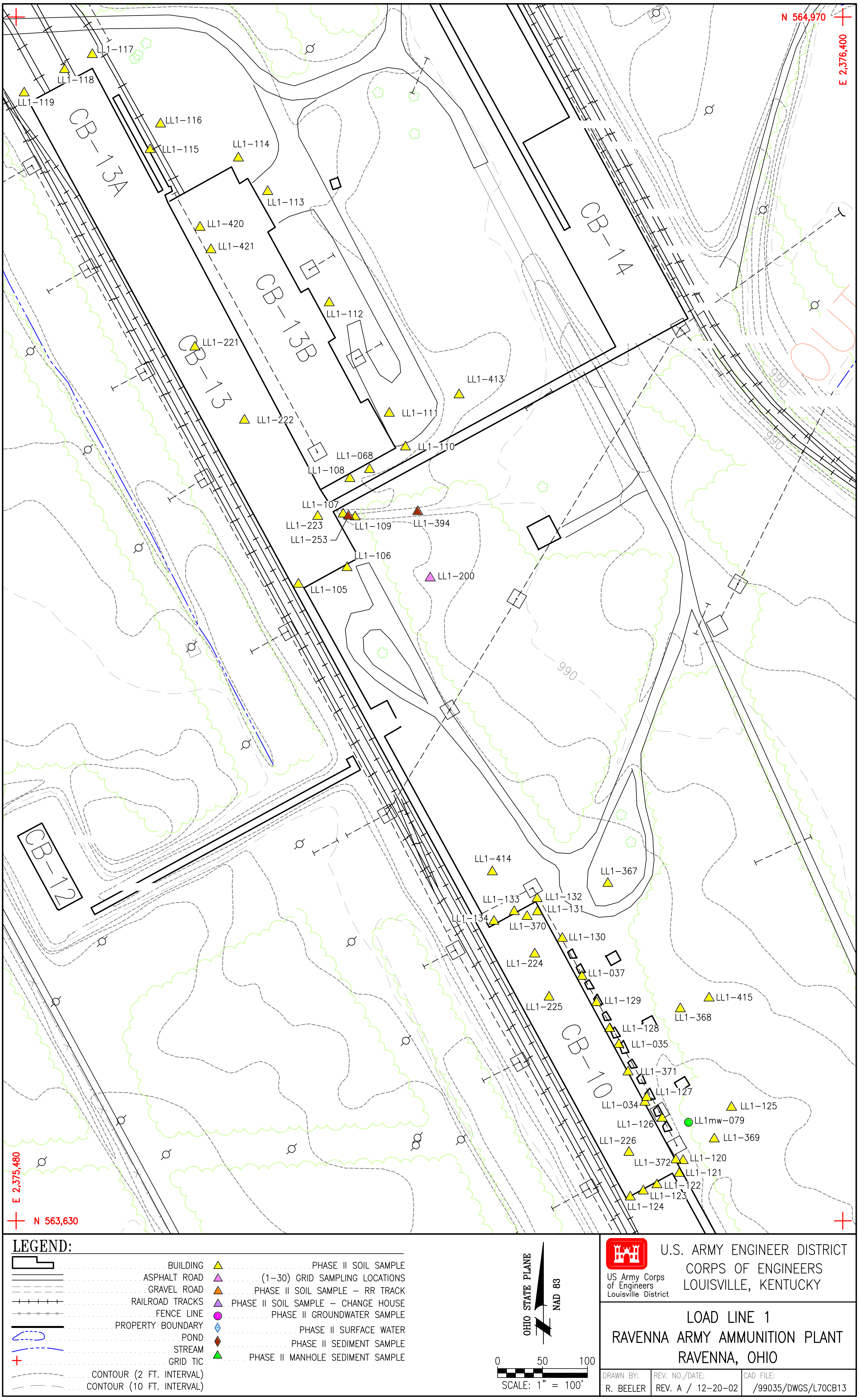


Figure 4-7. Explosives in Surface Soil at Buildings CB-10 and CB-13

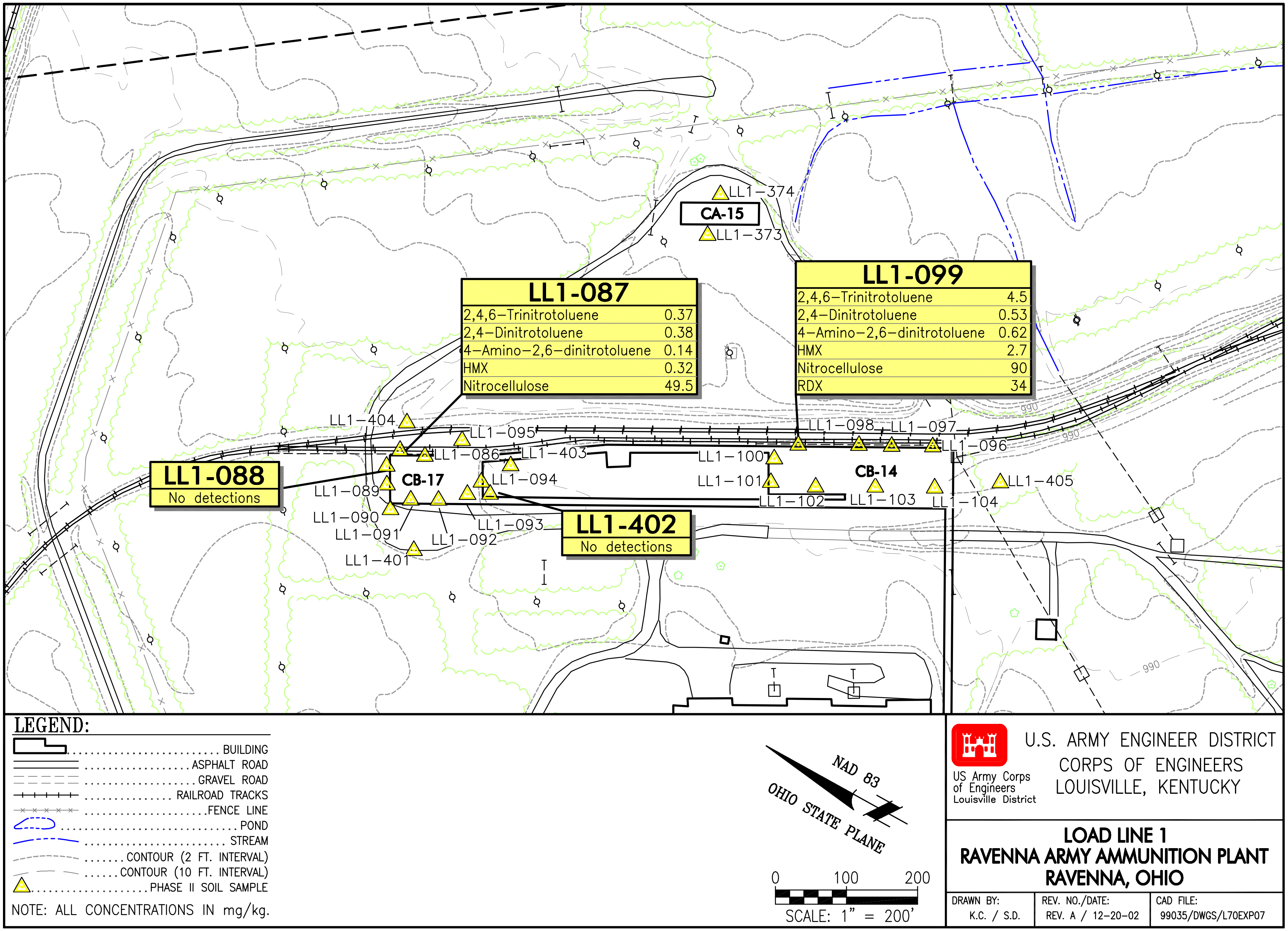


Figure 4-8. Explosives in Surface Soil at Buildings CB-14, CA-15, and CB-17

Twenty-two surface soil samples were collected during the Phase II RI in this area, with 13 samples sent to the fixed-base laboratory for explosives and propellants analyses based on the field laboratory results or on the Phase I RI data. Of the 13 samples submitted, five samples had no detectable quantities of explosives or propellants (stations LL1-027, LL1-179, LL1-180, LL1-182, and LL1-385) (see Figure 4-9). Nine explosives and propellant compounds were detected in the remaining eight samples. The concentrations of explosives and propellants in these samples were below 1 mg/kg, with the following exceptions:

- 2,4,6-TNT was detected at a concentration of 1.2 mg/kg at LL1-388; and
- nitrocellulose was detected at LL1-184 (14.9 mg/kg), LL1-185 (2.2 mg/kg), LL1-386 (2.4 mg/kg), and LL1-389 (5.6 mg/kg).

The low concentration occurrences of explosives and propellants east of Building CB-801 (stations LL1-388 and LL1-389) may be related to recent pipe decontamination operations that preceded the field sampling effort. Other occurrences are noted along the railroad tracks west of Building CB-2 (stations LL1-184 and LL1-185) and east of Building CB-3 (LL1-386) (see Figure 4-9).

The samples collected in the immediate area around the Water Tower were not analyzed for explosives or propellants.

4.2.2.5 Change houses

Former Buildings CB-8, CB-12, CB-22, and CB-23 were worker change houses. After the demolition of these buildings, the building excavations were used for the placement of clean, hard demolition debris. Twenty-one surface soil samples were collected and analyzed for explosives in the field laboratory to ascertain if the use of these areas for disposal of demolition debris had resulted in contamination. Of these, 19 samples were sent to the fixed-base laboratory for explosives and propellants analysis. None of these samples had detectable quantities of explosives or propellants based on the fixed-base laboratory data. It can be concluded that the disposal of demolition debris has not spread explosive and propellant contamination to the surface soils in the area of the change houses.

4.2.2.6 Perimeter areas

As mentioned in the introduction to this section, most of the Phase II surface soil sample locations were biased based on results of the Phase I RI and knowledge of operational history. However, in order to address all areas of LL 1, random grid samples were located across the load line to evaluate if contaminant migration had occurred. The location of these grid samples are shown on Plate 3-1.

Twenty-six grid samples were collected for field explosives analysis. Of these, eight samples were sent to the fixed-base laboratory for explosives and propellants analysis, which indicated no detectable concentrations. These analytical results indicate no measurable migration of contaminants via overland runoff or air dispersion to the non-production areas of the load line.

4.2.3 Inorganic Constituents

The Phase I RI results indicated that the maximum concentrations of inorganic constituents in surface soils were higher at LL 1 than at any of the other 10 AOCs investigated in the same study (USACE 1996). In the Phase I RI, lead, cadmium, and zinc were the most frequently detected metals exceeding the background criteria.

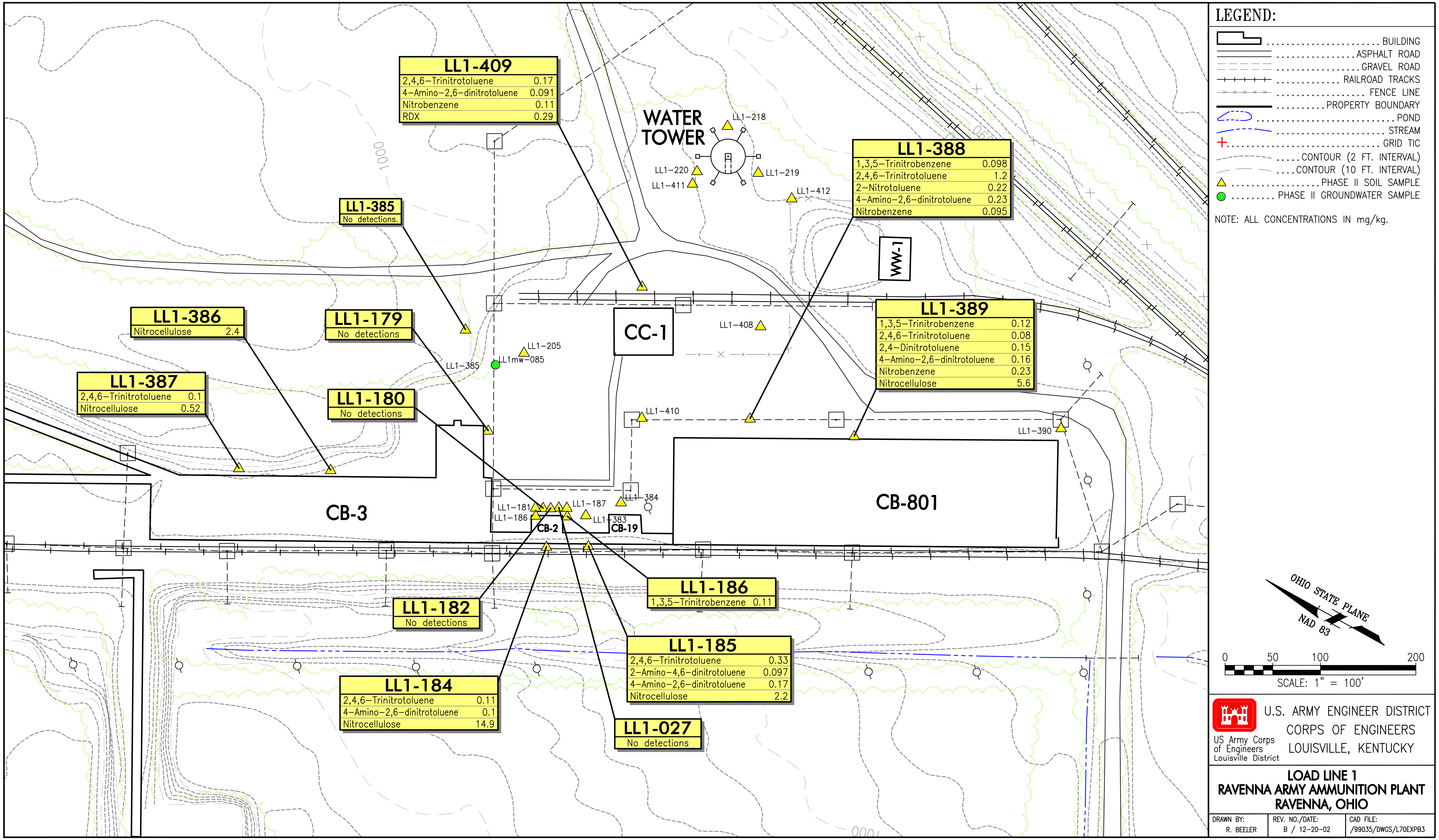


Figure 4-9. Explosives in Surface Soil at Buildings CB-3, CB-801, and the Water Tower

A consistent suite of 15 to 18 metals was determined to be SRCs in the surface soils of the aggregates investigated during Phase II RI, as described in detail in Section 4.1 of this report. As an assessment of the relative magnitude of the impact of site operations in contributing metals to the surface soils, a comparison of the average concentration of each SRC metal versus the respective site background was performed. Tables 4-2 through 4-8 list the SRC metals found in each aggregate along with average concentrations. Note that not all metals are SRCs in each aggregate, for example aluminum is not an SRC in the water tower and change house aggregates (indicated by the × symbol).

Several conclusions can be determined by examination of this comparison including the following:

- Aluminum average concentrations never exceed the site background value;
- Antimony average concentrations are similar to background except in the CB-3/CB-801 aggregate;
- Arsenic average concentrations are consistently below the site background value;
- Barium is minimally elevated in all areas except the change houses and the perimeter area where it is less than background;
- Beryllium average concentrations do not exceed the site background value;
- Chromium is elevated above background (on average) only in the water tower area;
- Cobalt is only marginally elevated above background in the water tower area;
- Copper is elevated above background in the CB-4/4A and CA-6A aggregate and the CB-13 and CB-10 aggregate;
- Lead contamination is elevated in all aggregates except the perimeter aggregate indicating a definitive site-related contribution;
- Manganese average concentrations never exceed the site background value;
- Mercury average concentrations marginally exceed background only in the CB-4/4A and CA-6A aggregate;
- Selenium is an SRC in only four aggregates, with average concentrations below the background value;
- Vanadium average concentrations never exceed the site background value; and
- Zinc contamination is elevated in all aggregates except the perimeter aggregate indicating a definitive site-related contribution.

The following subsections discuss the occurrences of inorganic constituents that were determined to be SRCs, based on the screening described in Section 4.1. The following discussion is by aggregate area and includes only the fixed-base laboratory results.

4.2.3.1 Buildings CB-4/-4A and CA-6/-6A and settling basin

A total of 160 surface soil samples were collected from within this aggregate and analyzed for the 23 TAL metals. Many of these samples were also analyzed for cyanide and hexavalent chromium. In the surface soils of this area, 18 metals are identified as SRCs, including aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc. Hexavalent chromium was never detected and, therefore, is not an SRC. The metals cadmium, cyanide, and thallium were not detected in the background data set; therefore, they have no site background value and are SRCs by default where detected. Of the remaining 15 SRC metals, nine of these metals (aluminum, antimony, arsenic, beryllium, cobalt, manganese, nickel, selenium, and vanadium) have average concentrations below their respective site background value, indicating only a few samples of high concentration may be the cause of the SRC determination. In contrast, the metals barium, chromium, copper, lead, mercury and zinc have average values for this aggregate greater than their respective background values indicating widespread, consistently elevated concentrations in the surface soil.

Figures 4-10 through 4-13 illustrate the distribution of copper, lead, mercury, and zinc in surface soils in this area. (Copper, lead, and zinc were also the most commonly detected metals above background in the subsurface soil). The symbols used in the figures are relative to background values for each of the metals and display incremental increases in concentration using colored triangles. The range of comparison is from 1 to 2 × background (green triangles) to greater than 20 × background using red triangles. For completeness and to indicate the coverage of the Phase II data set, non-detections and values less than background are indicated by gray triangles.

The concentrations of copper within this aggregate are predominately within the range of less than background to 1 to 2 × background (Figure 4-10). Copper is 2 to 5 × background at 15 locations, 5 to 20 × background at seven locations, and greater than 20 × the background concentration at two locations. The sitewide background value for copper is 17.7 mg/kg with the average measured value for this aggregate being 62.1 mg/kg or 3.5 × the background value. The higher concentrations are found around the perimeter area of the pads for the former CB-4 and CB-4A buildings (Figure 4-10). Concentrations of copper are marginally above background at only three locations at the settling basin to the west of CA-6 and at four locations around the basin to the south of CB-4A.

The distribution and relative concentrations of lead in surface soil above the background value of 26.1 mg/kg is illustrated in Figure 4-11. Lead is found at greater than 20 × this value at 12 locations, greater than 5 to 20 × background at 20 locations, and 2 to five × background at 23 locations. This number of stations (55) represents approximately one third of the 160 surface soil samples collected within this aggregate. The average concentration of lead in this aggregate is 198.5 mg/kg. The perimeter of the four pads are the areas of higher lead concentrations with samples collected along the connecting walkways below background to slightly greater than background (1 to 2 times). Note that lead was not detected above the background criteria in the immediate vicinity of the settling basin to the west of CA-6 (Figure 4-11). The settling basin to the south of CB-4A shows a definitive impact of lead contamination in surface soil with concentrations up to and greater than background at several sample stations.

The background criteria for mercury is 0.04 mg/kg and this level is exceeded by the majority of the sample stations within this aggregate area (Figure 4-12). The background value is exceeded by a factor of at least 20 times at 6 stations, a factor of 5 to 20 times at 12 stations, and a factor of 2 to 5 times background at 41 locations. The 59 stations represent approximately 37% of the 160 stations sampled. The highest concentrations are located around the western end of the CB-4 pad with only slightly lower concentrations (2 to 20 times background) around the remainder of this pad. The surface soil in the area of the northwestern settling basin contains mercury at 2 to 5 times background with only two of the sample stations at or below background concentrations (Figure 4-12).

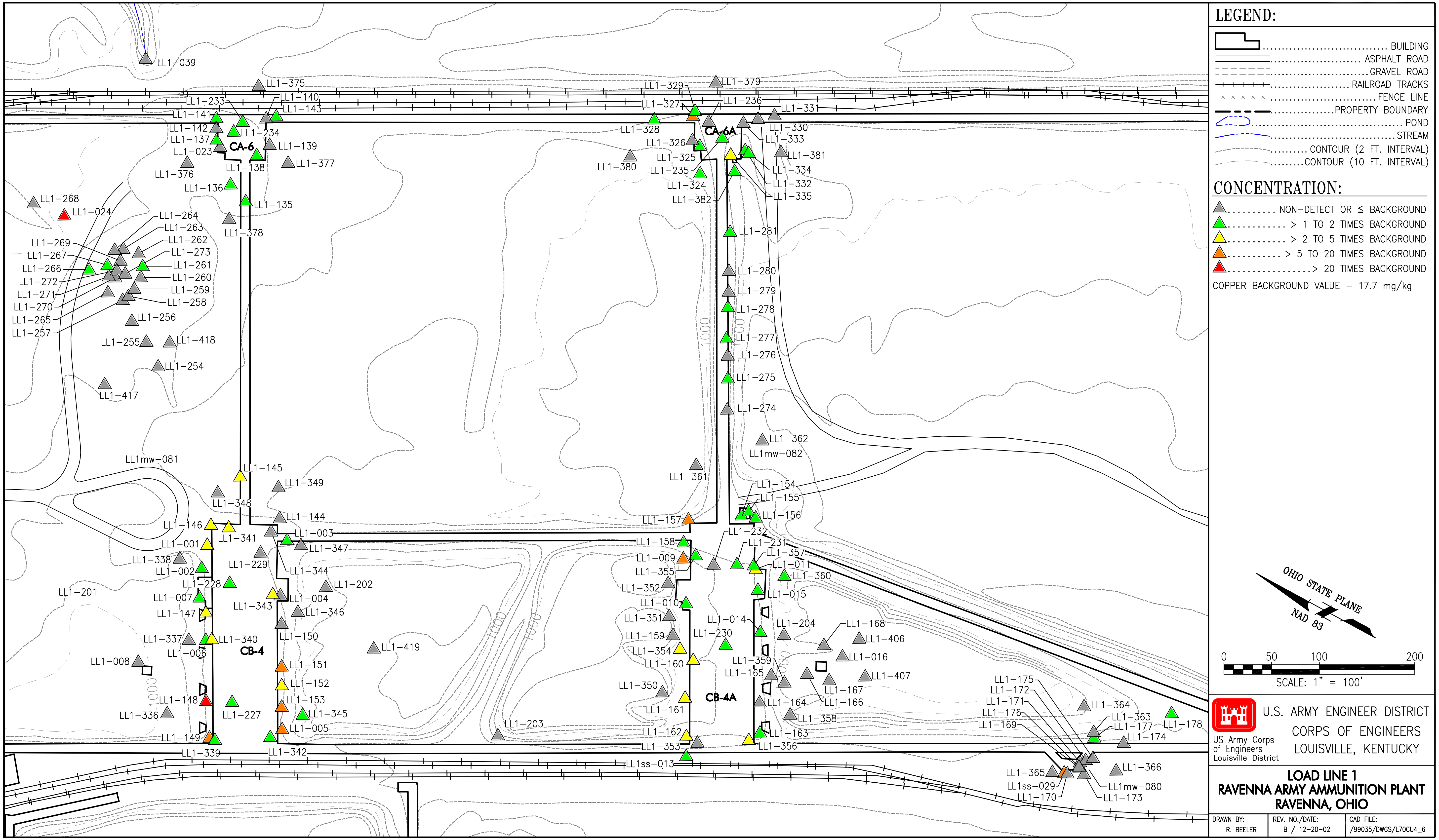


Figure 4-10. Distribution of Copper in Surface Soils at the Melt-Pour Complex

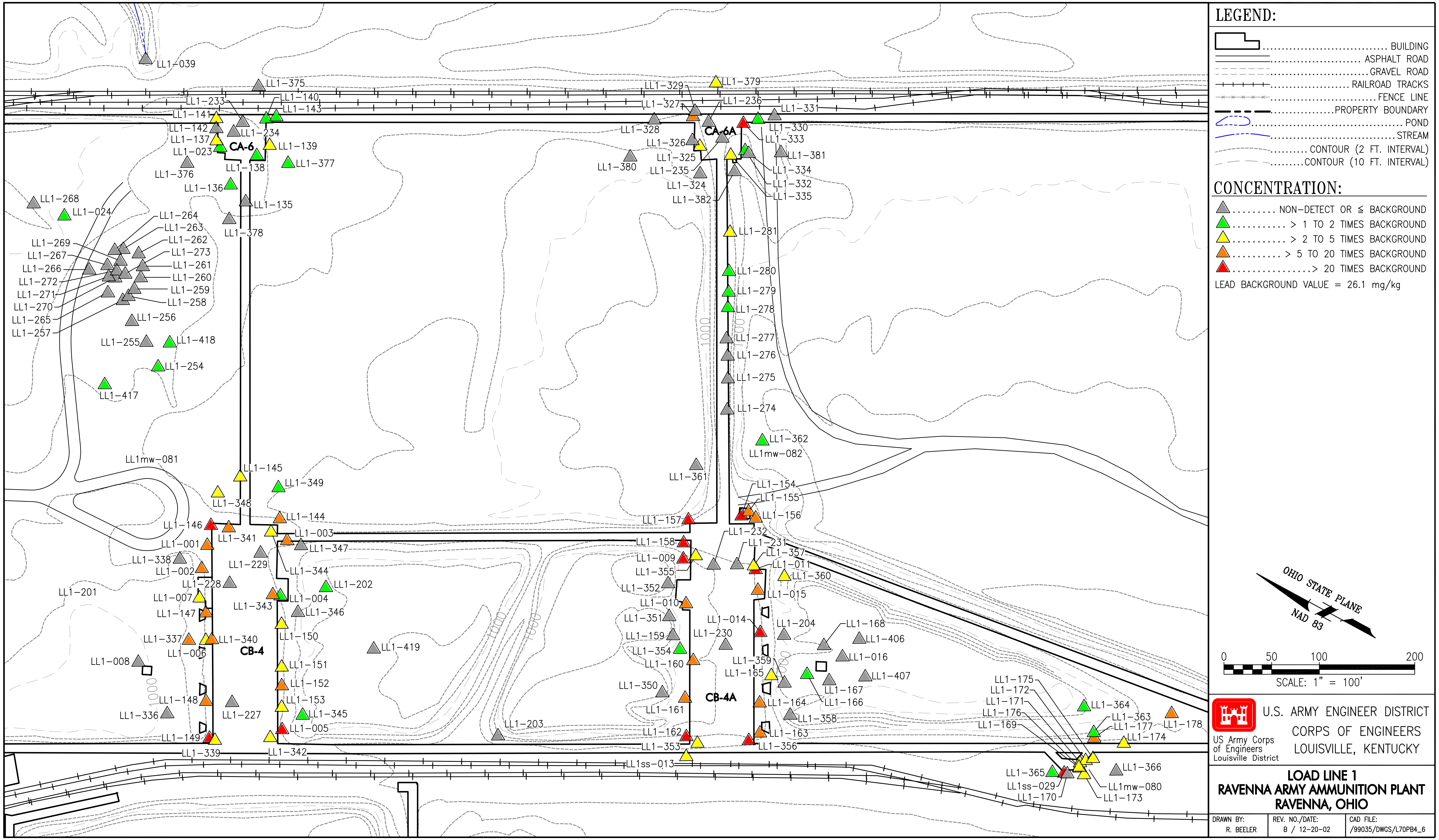


Figure 4-11. Distribution of Lead in Surface Soils at the Melt-Pour Complex

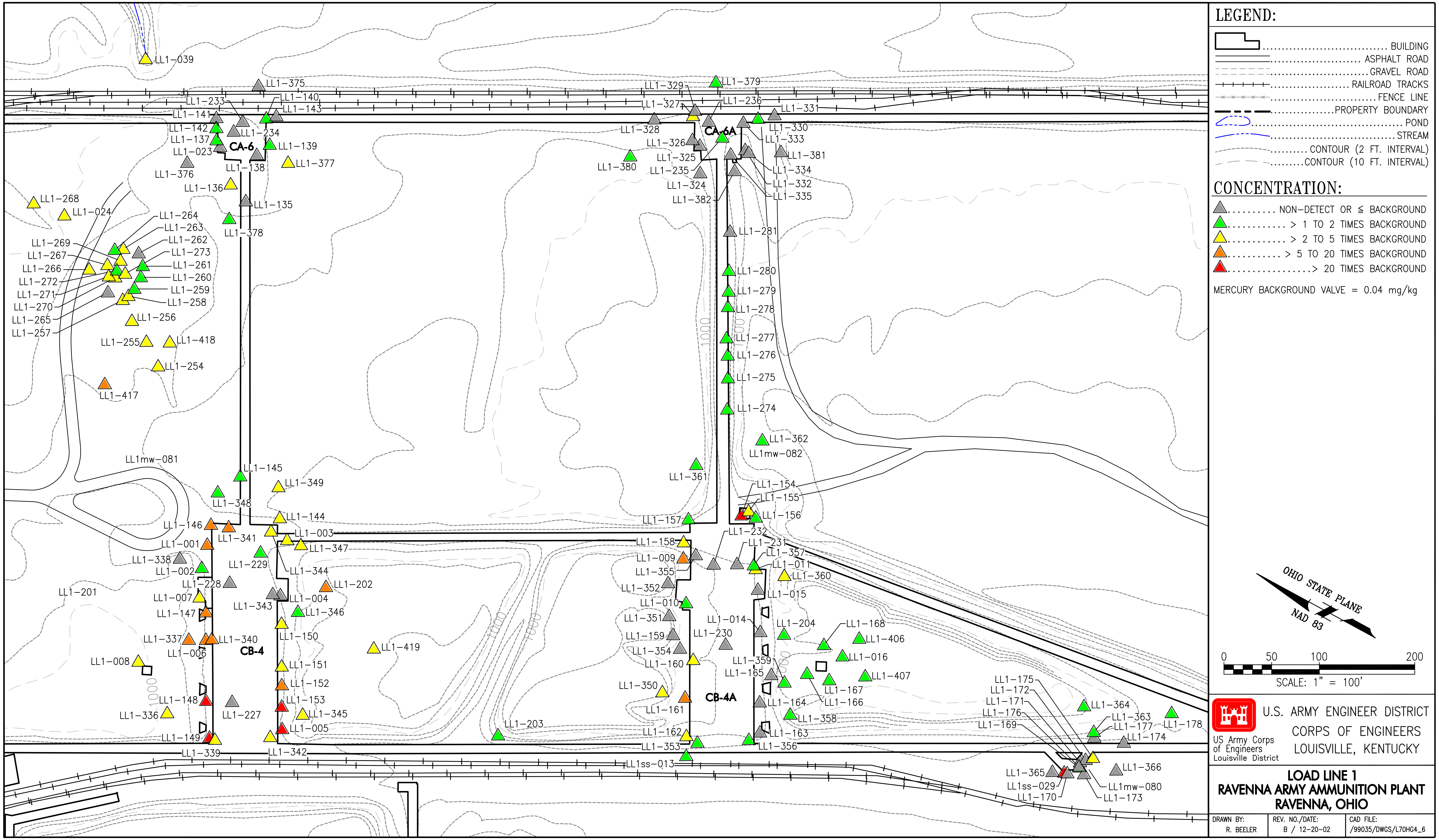


Figure 4-12. Distribution of Mercury in Surface Soils at the Melt-Pour Complex

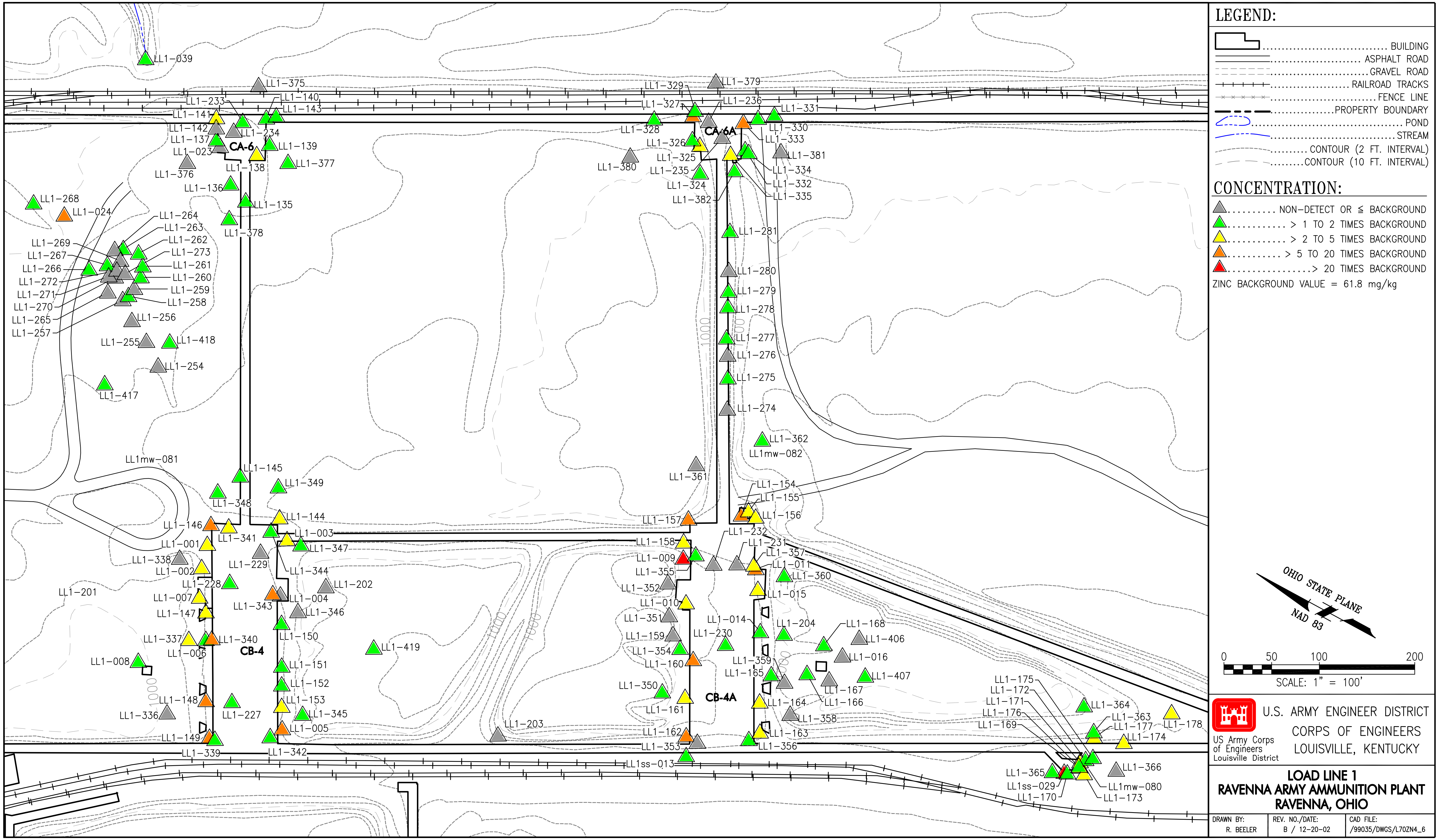


Figure 4-13. Distribution of Zinc in Surface Soils at the Melt-Pour Complex

The distribution of zinc in the surface soils of this aggregate is similar to that of copper, lead, and mercury. The highest concentration above background (61.8 mg/kg) is at the northwest corner of the CB-4A pad at station LL1-009 with a value of 1,690 mg/kg (Figure 4-13). The average concentration for zinc in this aggregate is 160.4 mg/kg, approximately 2.5 times the background value. The relative concentrations of zinc are similar for the perimeter areas of pads CB-4 and CB-4A whereas pad CA-6A has slightly higher concentrations than CA-6. The settling basin to the northwest of CA-6 shows little if any elevated zinc in surface soil, whereas the southern settling basin has several stations with zinc concentrations in the 2 to 5 time background concentration range and one station in excess of 20 times background (station LL1-029, 1,320 mg/kg).

The distributions of chromium and barium are not shown graphically. However, these metals were detected in each sample collected in this aggregate, and the highest contaminant concentrations are found at the same stations mentioned previously for copper, lead, mercury, and zinc.

In this aggregate, the average chromium concentration of 20.44 mg/kg is only slightly above the background value, indicating that few samples greatly exceeded the background criterion of 17.4 mg/kg. Only one station had a chromium value at a factor greater than 20× background: station LL1-009 had a chromium concentration of 400 mg/kg. This station also has high concentrations of copper, lead, mercury, barium, and zinc. Only two additional stations (LL1-158 and LL1-029) had chromium concentrations at a factor greater than 5× background. Station LL1-158 is located near LL1-009 at Building BC-4A and also had high concentrations of mercury, lead, and zinc. Station LL1-029 is located at a former settling basin and also had high concentrations of copper, lead, mercury, and zinc.

The average barium concentration in this aggregate is 110.1 mg/kg. As with chromium, only a few samples greatly exceeded the barium background criterion of 88.4 mg/kg. Only one station had a barium value at a factor greater than 20× background. This occurred at station LL1-153 near Building CB-4, where barium was 1,970 mg/kg. This station also had high concentrations of copper, lead, mercury, chromium, and zinc. Only two additional stations (LL1-005 and LL1-148) had barium concentrations at a factor greater than 5× background. Both of these stations are located at Building CB-4. LL1-148 is on the opposite side of the pad from LL1-153, and LL1-005 is several ft east of LL1-153 along the line of the concrete pad overhand.

In summary, 18 metals were identified as SRCs in surface soils in this aggregate. Nine metals have average concentrations below their respective site background concentrations. Barium, chromium, copper, lead, mercury and zinc have average concentrations above their respective site background value, indicating a site-related concentration and distribution. The highest concentrations of copper, lead, mercury, and zinc are around the perimeter of building pads CB-4 and CB-4A, reflecting the impact from historical site operations.

4.2.3.2 Buildings CB-10 and CB-13

Fifty surface soil samples were collected and analyzed for metals contamination at the Building CB-10 pad/Building CB-13 aggregate. Each of the 23 TAL metals and cyanide was detected at least once above background in the surface soils associated with this area. Eighteen of these metals are evaluated as site related (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc). Cadmium, cyanide, and thallium were not detected in the background data set and have no corresponding site background value; therefore, they are SRCs by default where detected. Aluminum, antimony, arsenic, beryllium, cobalt, manganese, nickel, selenium, and vanadium have average concentrations below their respective background values. The average concentrations for barium, chromium, copper, lead, mercury, and zinc are present, on average, at concentrations ranging from 1.25 to 6.6 times their background value.

Figure 4-14 is a composite map of chromium and copper concentrations (relative to background) in surface soil for this aggregate. The maximum concentration for chromium (312 mg/kg) in this aggregate occurs at station LL1-109 along the eastern edge of the building CB-13 building pad. This station also has the highest metals concentrations in this area (and for some metals across the entire load line) for subsurface soils (see Section 4.3). As mentioned in the previous section on explosives and propellants, this station to the south of the CB-13B pad is in a ditch which probably received discharge of pink water effluent from former process operations and is also near the former location of a popping furnace.

Chromium was detected in 50 out of 50 samples from this aggregate with the average concentration of 24.7 mg/kg, a value 1.4 times the site background value of 17.4 mg/kg. This low average concentration is reflected in the lack of many stations with values in excess of two times background, especially at sample stations along the three sides of the CB-10 pad (Figure 4-14). Note one station at CB-13B and three stations at CB-10 have values in the 2 to 5 times background range, and only a single station (LL1-109) has a concentration in the 5 to 20 times background range. As such, chromium is a prevalent SRC within this aggregate.

Copper was measured at an average concentration of 109.6 mg/kg, approximately six times the site background concentration of 17.7 mg/kg. Fifty measurements above the detection limit were recorded with a range in concentration from 5.3 mg/kg to 2,390 mg/kg (station LL1-112). Copper distribution is indicated in Figure 4-14 and indicates the highest concentrations are along the north and east perimeter of the CB-13B pad. Stations LL1-107 and -109, indicated by the red triangles, have concentrations of 434 and 570 mg/kg, respectively. The concentration along the perimeter of the CB-10 building pad range from below background to 20 times background, as indicated by the orange triangles in Figure 4-14. Note concentrations at sample stations only a few ft beyond the CB-10 building perimeter are at or below background concentrations.

Lead concentrations in the surface soils of this aggregate range from 9.4 to 1,770 mg/kg with an average value of 170.9 mg/kg for the 50 detections, approximately 6.6 times the site background value. Figure 4-15 indicates the higher concentrations are at stations LL1-107 and -109 along the eastern end of the CB-13B pad and along the entire sampled perimeter of the CB-10 pad. Note the variation in lead concentration from station to station along this pad, with the variation from below background concentrations to in excess of 20 times background (Figure 4-15).

The distribution of elevated zinc concentrations is very similar to lead with the higher concentrations occurring at the same or nearby sample stations (Figure 4-15). The site background value for zinc is 61.8 mg/kg, a concentration significantly lower than the average value of 336.3 measured in the surface soils of this aggregate. Zinc concentrations range from 20 to 2,060 mg/kg, with this latter value representing the maximum concentration across LL 1. The location of this measurement is station LL1-109, a location that is the site of the maximum concentration of several metals and explosives.

The distributions of barium and mercury are not shown graphically. However, these metals were detected frequently in this aggregate, and the highest contaminant concentrations are found at the same stations mentioned previously for chromium, copper, lead, and zinc.

The average barium concentration in this aggregate is 110.1 mg/kg. Only a few samples greatly exceeded the barium background criterion of 88.4 mg/kg. No sample exceeded the background criterion by a factor of 5 times. The maximum barium concentration in aggregate (410 mg/kg) occurred at LL1-118 at the northern end of Building CB-13A. Around the Building CB-10 pad, no sample exceeded the barium background criterion by a factor of 2 times.

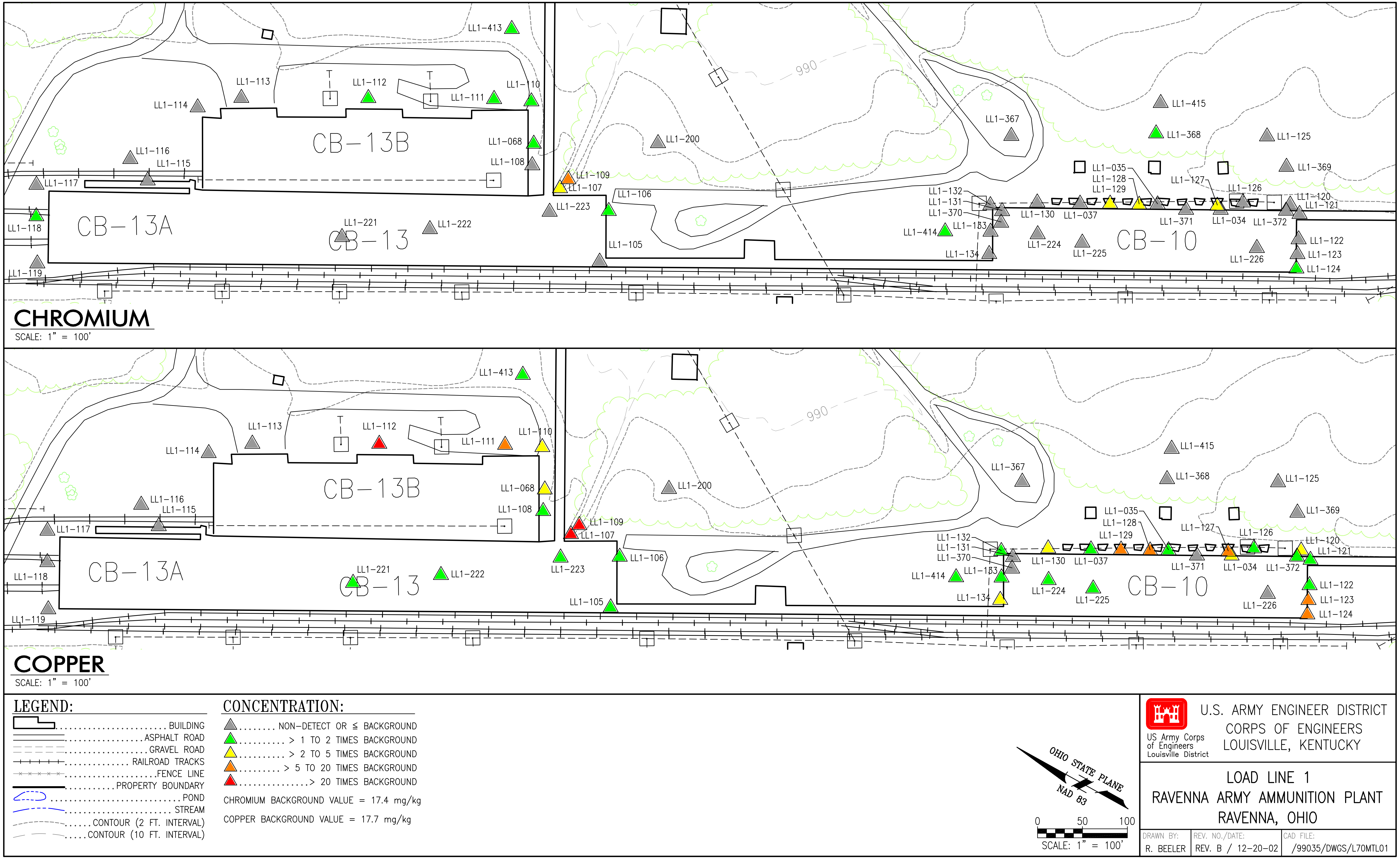


Figure 4-14. Distribution of Chromium and Copper in Surface Soils at Buildings CB-10 and CB-13

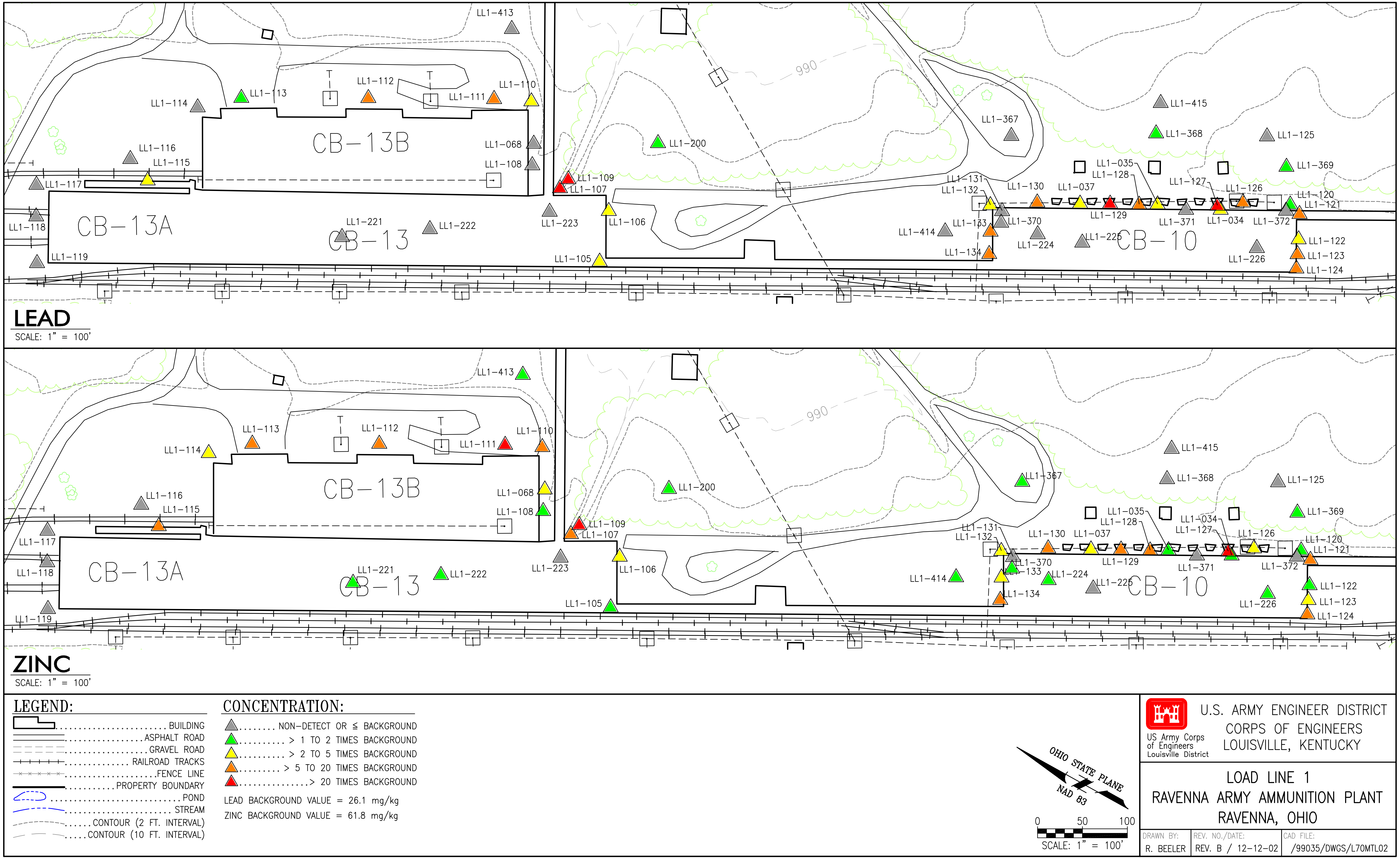


Figure 4-15. Distribution of Lead and Zinc in Surface Soils at Buildings CB-10 and CB-13

The average mercury concentration in this aggregate is 0.07 mg/kg. No sample exceeded the mercury background criterion (0.04 mg/kg) by a factor > 20×. Three samples exceeded the background criterion by a factor of 5 times or more

- LL1-107 had a mercury concentration of 0.38 mg/kg,
- LL1-109 had a mercury concentration of 0.41 mg/kg, and
- LL1-112 had a mercury concentration of 0.25 mg/kg.

These three stations are located around the overhangs the Building CB-13B pad, which are also the locations of high concentrations of barium, chromium, copper, lead, and zinc.

Relative to the building perimeter, samples of surface soil collected through the building pads have lower metals concentrations. The three samples taken through the CB-10 floor slab (stations LL1-224, LL1-225, and LL1-226) had the fewest metals detected above background (e.g., at LL1-224, only cobalt, copper, thallium, and zinc were detected above background). Similarly, at Building CB-13, the three samples taken through the floor slab (LL1-221, LL1-222, and LL1-223) had fewer metals detected above background when compared to the samples collected from around the building perimeter. The samples collected through the floor slabs also indicated metals at lower concentrations (at the most, only 2 times background) when compared with the samples collected at the floor slab perimeter.

In summary, the mapping of the metals chromium, copper, lead, and zinc, all with average concentrations above their respective background values, indicates that metals contamination is most prevalent along the northern and eastern perimeter of the building CB-13B pad and along the three sides of the CB-10 that were sampled during Phase II. In this aggregate, chromium was measured at concentrations above background, but only marginally elevated at most sample stations. Station LL1-109, at a drainage ditch at the eastern end of the CB-13B pad, exhibited many elevated metals and explosives.

4.2.3.3 Buildings CB-14, CA-15, and CB-17

Twenty-six surface soil samples were collected and analyzed for TAL metals. All of the metals were detected above background at least once, except for hexavalent chromium, which was never detected. The suite of SRC metals for this aggregate is similar to the two previous aggregates discussed, with the following exceptions: antimony and selenium are not SRCs and silver was detected in 3 of 26 samples (Table 4-27), qualifying it as an SRC. The metals most frequently detected above background criteria and/or at the greatest concentrations above background are copper, lead, and zinc. These three metals, along with chromium, mercury, and nickel, all have average concentrations in excess of their respective site background values. However, the chromium average value for this aggregate is 19.9 mg/kg, slightly above the background value of 17.4 mg/kg, mercury averages 0.06 mg/kg versus a background level of 0.04 mg/kg, and nickel averages 22.31 mg/kg with a background value of 21.1 mg/kg. This comparison indicates each of these metals are only marginally above natural levels and overall site-related contaminant contributions are likely minimal.

In general, metals concentrations above background are widely dispersed around the concrete slabs in this area. Station LL1-095, located at on north perimeter of the CB-17 represents the maximum concentration of 9 TAL metals across the entire load line (including arsenic at 112 mg/kg, cobalt at 72.3 mg/kg, nickel at 160 mg/kg, and vanadium at 179 mg/kg). At station LL1-087, at the western corner of this building pad, both copper and lead occur at concentrations greater than 20 times background. At this same station the concentration of lead remained 20 times the background criteria in the subsurface soil sample (see Section 4.3). Metals concentrations above background around the CB-14 and CB-15 pads are lower both in terms of frequency and magnitude when compared with the concentrations around the Building CB-17 pad. For example, lead occurs at a maximum concentration of 602 mg/kg at the CB-17 pad; however, while still above background, lead occurs at lower concentrations at CB-14 and -15 pads at 142 mg/kg and 47.6 mg/kg, respectively. Figures 4-16 and 4-17 illustrate the distribution of copper, lead, and zinc in surface soils in the Building CB14/15/17 pads area. The following discussions will focus on their distribution within this aggregate area.

Copper was detected in all of the 26 samples of surface soil collected within this three building aggregate area. The average concentration was 34.5 mg/kg, approximately two times the background value of 17.7 mg/kg. Concentrations ranged from 8.0 to 199.0 mg/kg. The distribution of the detections are indicated in Figure 4-16. Of the 26 stations, four have concentrations greater than 2 times background (e.g., yellow and orange triangles) and are located at the perimeter of CB-17 and the within the pad area of CB-14. Based on the abundance of green and gray triangles, it can be concluded that the occurrence of this metal resulting from site operations is minimal.

Figure 4-16 illustrates the distribution of lead in surface soils of this aggregate. Lead concentrations range from 12.8 to 602 mg/kg with an aggregate average concentration of 70.3 mg/kg. This value is 2.7 times the background value of 26.1 mg/kg. Similar to the distribution of copper, lead significantly above background levels occurs around the perimeter of CB-17 and the within the pad area of CB-14. Zinc occurs at concentrations at a factor of 5 times the background criterion (61.8 mg/kg) at two stations in this aggregate: LL1-087 and LL1-095. The maximum zinc value of 881 mg/kg occurs at LL1-087, where copper and lead concentrations are also elevated.

4.2.3.4 Buildings CB-3 and CB-801 and the Water Tower

A total of twenty-two surface soil samples from within this aggregate were collected and analyzed for TAL metals. All of the metals were detected above background at least once, except for vanadium, which was never detected above background. Eighteen metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc) are considered SRCs for this aggregate (Table 4-4). The metals cadmium, cyanide, silver, and thallium qualify by default as SRCs (when detected) due to a lack of background values. Seven of the remaining metals have average concentrations above their respective background value including antimony, barium, chromium, copper, lead, mercury, and zinc. Aluminum, arsenic, beryllium, cobalt, manganese, nickel, and selenium all have average aggregate concentrations below their respective background values. The metals most frequently detected above background criteria and/or at the greatest concentrations above background were cadmium, chromium, lead, and zinc. Figures 4-18 and 4-19 illustrate the distribution of these four metals in surface soils in the Buildings CB-3 and CB-801 area.

Cadmium concentrations in this aggregate were measured above the detection limit in 20 of 22 samples with a range from 0.07 to 27.3 mg/kg. The site average value for this metal is 2.62 mg/kg. As illustrated in Figure 4-18, cadmium concentrations at 14 of the sample stations in the vicinity of the CB-3 and CB-801 buildings are less than 1 mg/kg. Variable concentrations are apparent at the cluster of sample stations at Building CB-2 in the center part of the two larger buildings, with non-detects adjacent to stations with elevated concentrations.

Chromium concentrations in surface soil for this aggregate average 30.1 mg/kg and range from 6.8 to 174 mg/kg versus a site background value of 17.4 mg/kg. The higher concentrations for this metal occur at stations along the perimeter of building CB-3 and at the sample stations in the along the rail line near building CB-2 (Figure 4-18). Although chromium was measured above the detection limit in all 22 samples, the majority of these concentrations were less than 2 times the background value, as indicated by the 17 gray or green triangles in this figure.

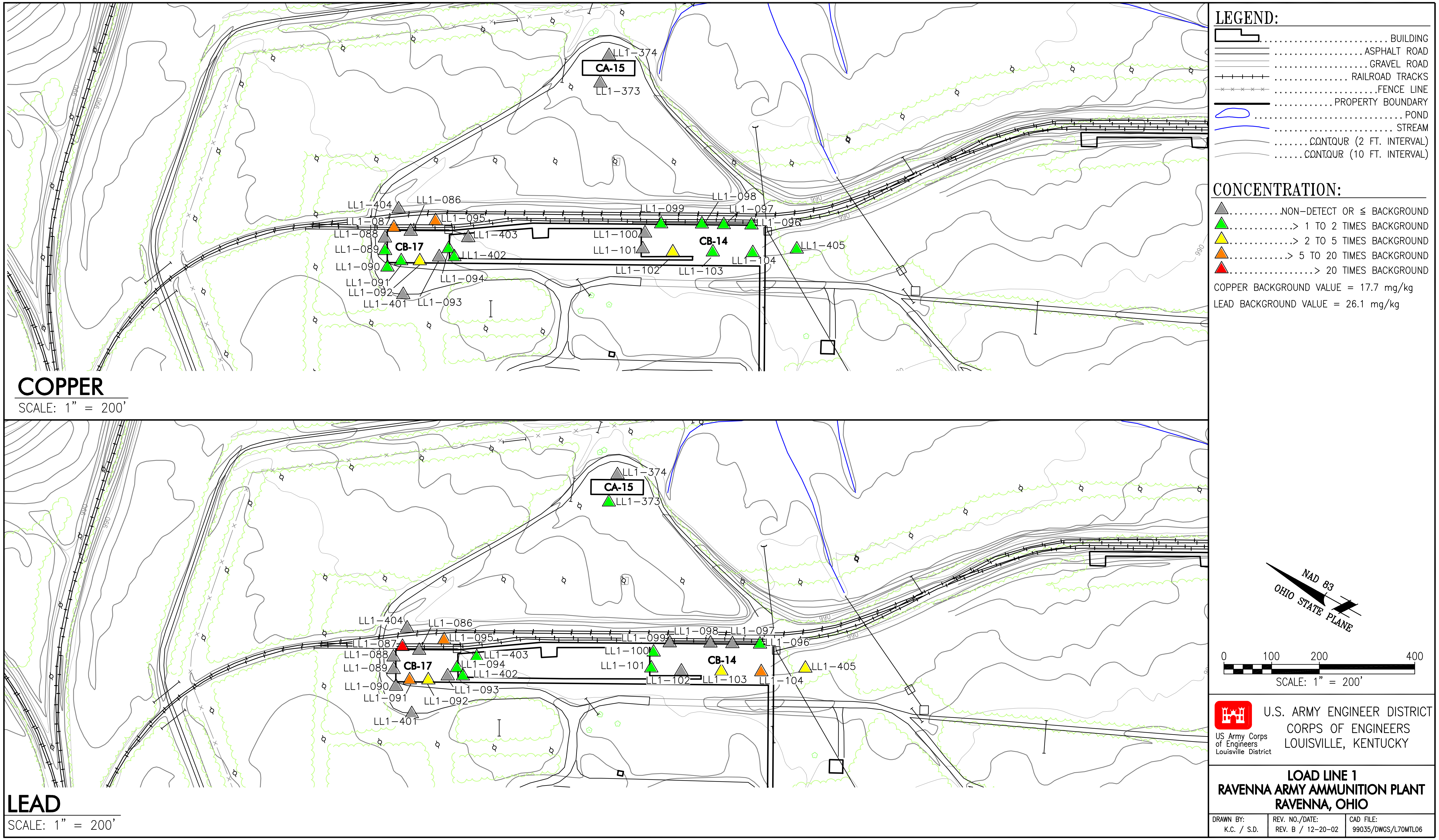


Figure 4-16. Distribution of Copper and Lead in Surface Soils at Buildings CB-14, CA-15, and CB-17

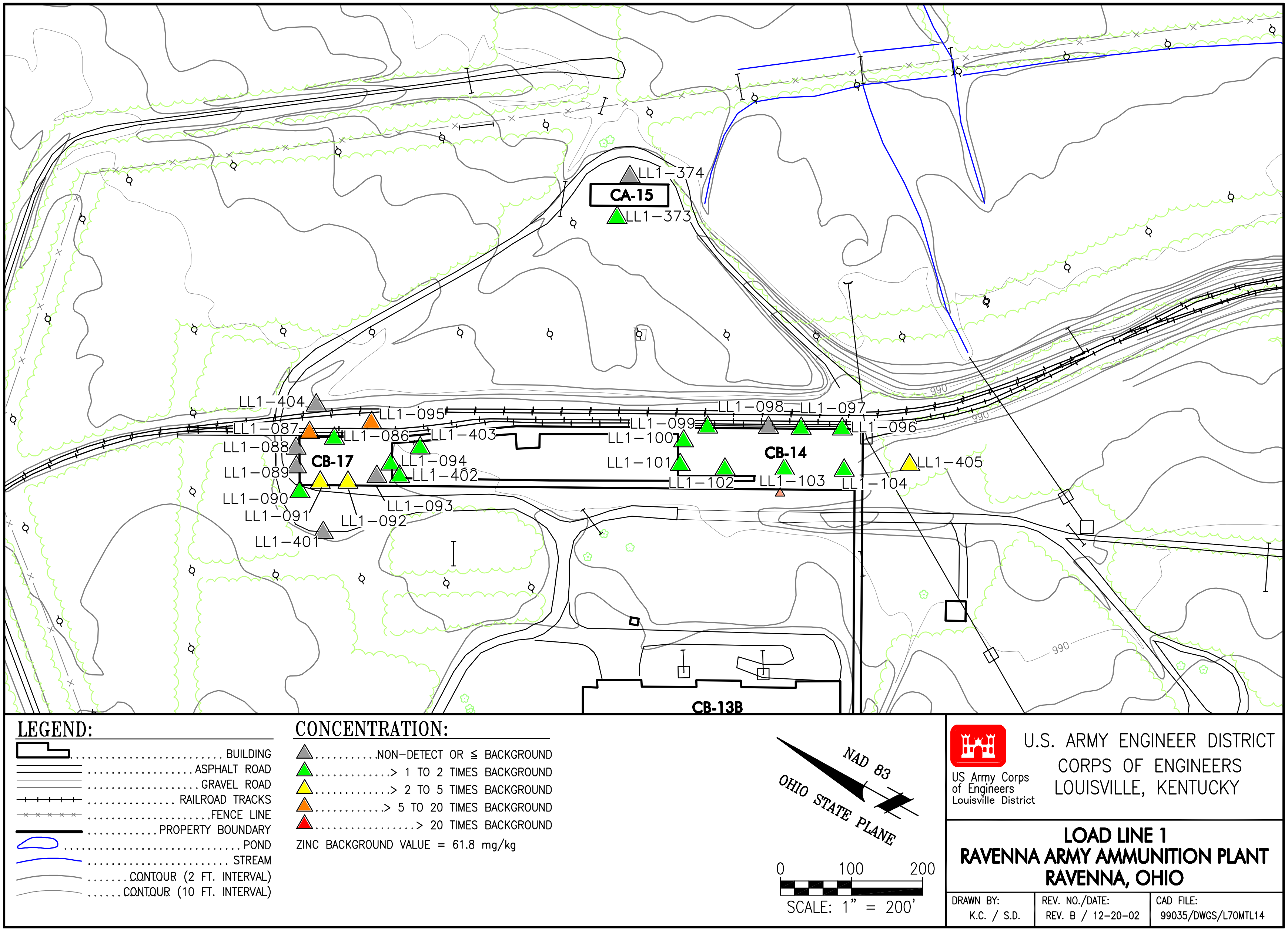


Figure 4-17. Distribution of Zinc in Surface Soils at Buildings CB-14, CA-15, and CB-17

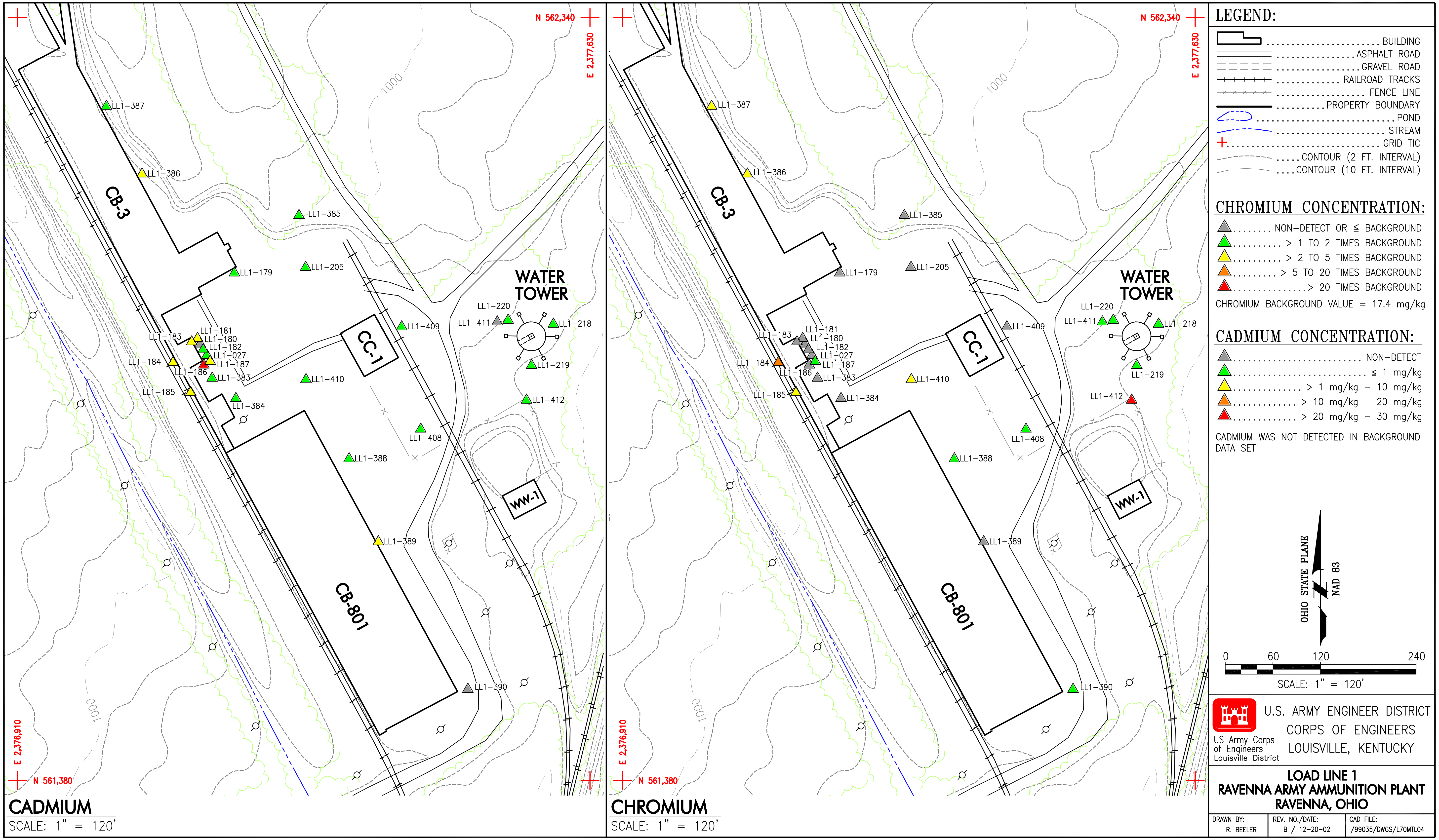


Figure 4-18. Distribution of Cadmium and Chromium in Surface Soils at Buildings CB-3, CB-801, and the Water Tower

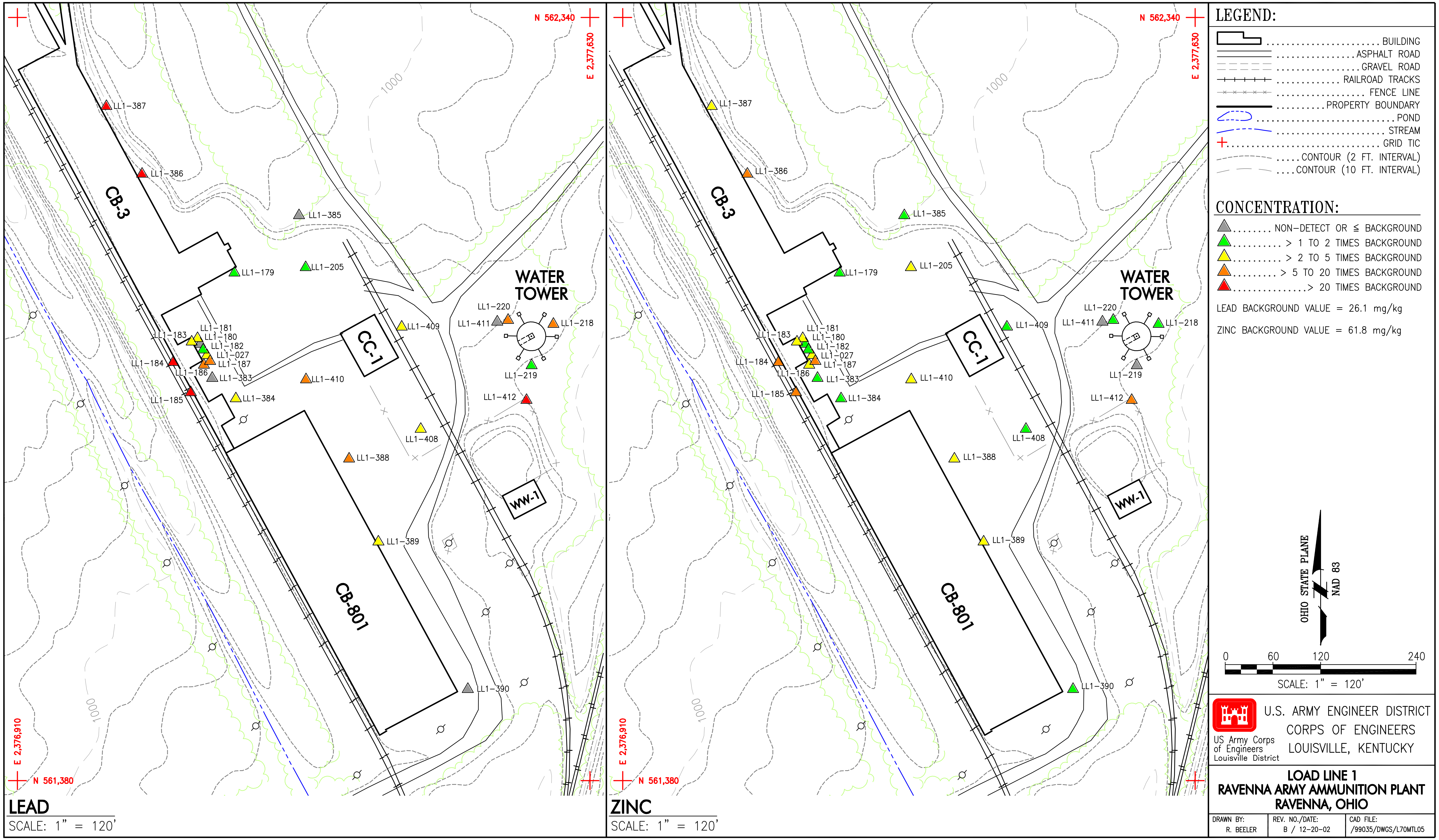


Figure 4-19. Distribution of Lead and Zinc in Surface Soils at Buildings CB-3, CB-801, and the Water Tower

Lead is found in this aggregate at levels consistently elevated above the background value of 26.1 mg/kg. As shown on Figure 4-19, four stations have concentrations greater than 20 times background (red triangles), four stations in the range of 5 to 20 times background (orange triangles), and 7 stations in the range of 2 to 5 times background (yellow triangles). Detected concentrations in surface soil range from 16 to 1,620 mg/kg with an average concentration of 244.6 mg/kg. The distribution of this contaminant is area wide in this aggregate with the higher levels in the area of the CB-2 building.

The average zinc concentration (194.1 mg/kg) for this aggregate is 3.2 times the background value of 61.8 mg/kg. Concentrations range from 72.1 to 674 mg/kg with the higher values distributed similar to lead (Figure 4-19). Note that all concentrations of this metal at the stations in the vicinity of the buildings are in excess of the background value, which, in addition to the high average concentration, suggests a definitive impact due to past site operations.

In general, metals concentrations above background are widely dispersed throughout this area. More detections and higher values of many metals on the west side of former Building CB-2 (stations LL1-184 and LL1-185 along the former railroad track) may be associated to some degree with the metals-rich slag used as railroad ballast along the track, which still remains. Many of the surface soil samples were collected in areas of active or past vehicle traffic, and metals concentrations above background in those areas may reflect deposition from vehicle exhaust. Samples east of Building CB-3 (LL1-385, LL1-386, and LL1-387) exhibit relatively lower concentrations above background, possibly because the area was not accessible by vehicles.

Hexavalent chromium, analyzed only at stations LL1-184 and LL1-185, was detected at 1.4 mg/kg in LL1-184. Cyanide was analyzed in nine samples and was detected above background twice, at stations LL1-409 and LL1-410 (at 1 and 0.58 mg/kg, respectively).

Five surface soil samples were collected beneath the drip-line of the former Water Tower at the south end of LL 1. The purpose of this sampling was to evaluate the nature and extent of possible contamination resulting from the removal of paint from the Water Tower during its operation, maintenance, and demolition. Analysis of the surface soils was restricted to TAL metals and PCBs.

At the Water Tower, eleven metals qualify as SRCs based on the screening process described in Section 4.1. These metals include antimony, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, thallium, and zinc. Cadmium and thallium were not detected in the background date set and; therefore, are SRCs by default where detected. Concentrations of cadmium, chromium, cobalt, copper, lead, mercury, nickel, thallium, and zinc were above their respective background in three or more of the samples. The metals cobalt, copper, and nickel have average concentrations marginally above their background value. In contrast, the average lead concentration is 23 times the background value, the average chromium concentration is 5.6 times background and the average zinc concentration is 3.9 times background.

Figures 4-18 and 4-19 illustrate the distribution of cadmium, chromium, lead, and zinc in surface soils in the Water Tower area. The highest concentrations of chromium, lead, and zinc were observed in station LL1-412 is south of the Water Tower, which had the maximum concentrations of lead (2,510 mg/kg) and zinc (933 mg/kg).

Samples collected from stations LL1-218 and LL1-220 exhibited a higher number of metals detected above background than station LL1-219, although all three samples are located close to the Water Tower. Lead levels in these samples ranged from 43.2 mg/kg at LL1-219 to 244 mg/kg at LL1-218. LL1-411 had chromium, cobalt, copper, nickel, and thallium above background criteria.

In summary, the sampling of the surface soils in the area of the water tower indicate an impact from the removal of paint from the tower. Elevated lead, chromium, and zinc are likely due to residues of paint in the soils of this area.

4.2.3.5 Change houses

Twenty one surface soil samples were collected in the area of the four change houses and analyzed for TAL metals and cyanide. These samples were taken prior to removing soils for use as clean hard fill disposal areas. All TAL metals and cyanide were detected at least once with 15 metals and cyanide screened as SRCs including antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, thallium, vanadium, and zinc. Of this suite, cyanide, arsenic, cadmium, chromium, cobalt, manganese and vanadium were each detected only once above background. The metals most frequently detected above background criteria and/or at the greatest concentrations above background are copper, lead, and zinc. Figure 4-20 illustrates the distribution of these three metals in surface soils in the area of the four former change house buildings.

At former change house CB-12, station CB12-02 had the maximum concentrations of chromium, iron, lead, mercury, and zinc when compared with the other sampling locations at all the change house areas. Lead (532 mg/kg) and zinc (1,590 mg/kg) were 20 times greater than their respective background criteria at this station.

At former change house CB-23, station CB23-01 had the maximum concentrations of copper and silver when compared with the other sampling locations at all the change house areas. Copper (51.1 mg/kg) was approximately 3 times greater than the background criteria at this station. Lead and zinc concentrations were also high at this station (lead at 315 mg/kg and zinc at 740 mg/kg), as well as at station CB23-02 (lead at 315 mg/kg and zinc at 725 mg/kg).

In contrast, at former change house CB-8, station CB08-02 was the only location where copper, lead, and zinc exceeded 5 times the background criteria. At this station, lead occurred at approximately 6 times the background criteria at 150 mg/kg.

In contrast, at former change house CB-22, copper, lead, and zinc never exceeded the background criteria by 5 times. The only arsenic detection (27.8 mg/kg) above background at any of the change house areas occurred at CB22-01.

As shown on Figure 4-20, the stations mentioned previously in this section are located immediately adjacent to one of the former change house building footprints. However, five samples were collected in the outlying areas (e.g., LL1-249), and four samples were collected at the beginning of the walkways leading to the change houses (e.g., station CB12-04). These nine stations are relatively uncontaminated when compared with the sampling locations closer to the change house areas. For example, none of these stations had copper, lead, or zinc concentrations that exceeded the background criteria. With 10 metals detected above background, station LL1-249 had the highest number of metals above background than any other station in the area of the former change houses. This station had the only detections of cobalt (15.1 mg/kg) and vanadium (39.3 mg/kg). In addition, this station had the only detection of cyanide (3 mg/kg) in this aggregate.

4.2.3.6 Perimeter areas

Twenty six samples were collected in the perimeter areas of the load line with a total of seventeen metals classified as SRCs (aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc). The perimeter sample station

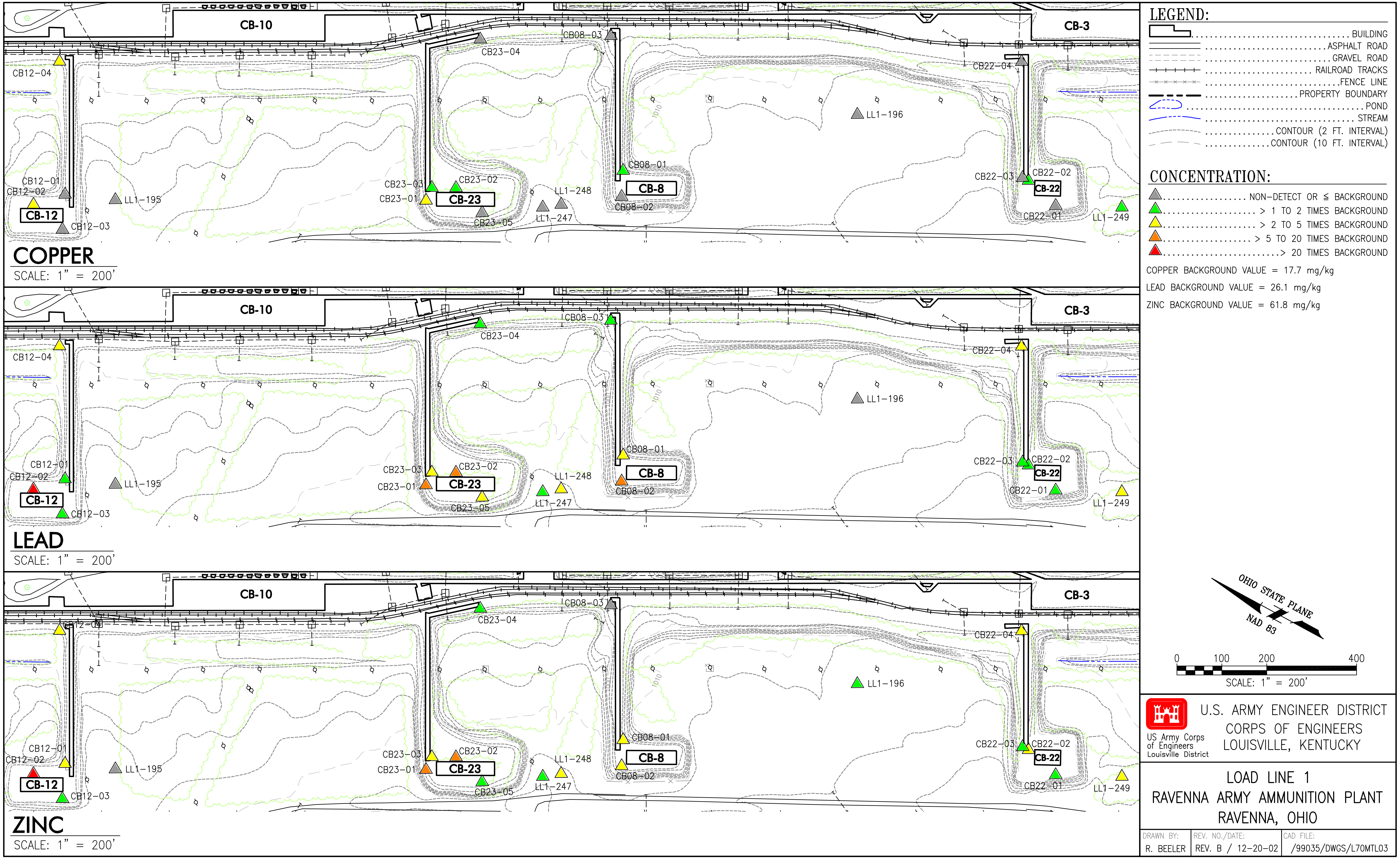


Figure 4-20. Distribution of Copper, Lead, and Zinc in Surface Soils at the Change House Buildings Area

locations are shown on Plate 3-1. Of the 17 SRC metals, the average concentration for all, except mercury, is less than their respective site background value, suggesting no impact from site operations. Mercury was detected in 26 of 26 samples with an average concentration of 0.05 mg/kg as compared to a site background value of 0.04 mg/kg and, thus, also is not significantly elevated above natural concentrations. Mercury was detected at a factor of 2 times background in only four of the stations in this aggregate. These stations (LL1-194, -206, -207, and -208) are located in the northern part of the load line. The maximum mercury concentration (0.093 mg/kg) in this aggregate occurred at station LL1-208 approximately 600 ft north of the Building CA-6 pad. The maximum detected concentration of arsenic (24.6 mg/kg) at station LL1-189 is above the background criteria of 15.4 mg/kg, but the average concentration for arsenic in the perimeter area is 11.36 mg/kg, less than the background criteria.

4.2.4 Semivolatile Organic Compounds, Volatile Organic Compounds, and Polychlorinated Biphenyls

Detection of organic compounds across the LL 1 area was minimal. The majority of detections were polyaromatic hydrocarbons, which are a common chemical signature of all industrial facilities. Many of these compounds are the products of incomplete combustion of fossil fuels and are from vehicle exhaust.

4.2.4.1 Buildings CB-4/-4A and CA-6/-6A and settling basin

Four VOCs were detected in surface soil samples at the melt-pour complex: acetone, methylene chloride, and trichloroethene (TCE). 1,2-DCE was detected consistently in 17 of 18 samples, whereas the remaining three compounds were detected at the lower frequency of 2 out of 18 samples (Table 4-5). The maximum concentration of 1,2-DCE was 0.018 mg/kg, and it occurred at station LL1-001 near the Building CB-4 pad. TCE was detected at concentrations of 0.0026 and 0.0067 mg/kg, with the higher value occurring at station LL1-346, which is also near the Building CB-4 pad (Plate 3-1).

Detections of 21 SVOCs occurred sporadically across the melt-pour complex and bulk-explosive preparation buildings. The frequency of detection for 18 samples ranged from 1 (8 different compounds) to 8 detections (fluoranthene). Fluoranthene is a commonly detected PAH that can be derived from coal tar and occurs ubiquitously as a byproduct of the incomplete combustion of fossil fuels. Benzo(b)fluoranthene was detected in six samples whereas phenanthrene and pyrene were each detected in 5 samples. Several other compounds were detected from two to four times. Average concentrations were consistent and ranged from 0.35 to 0.55 mg/kg. The maximum measured concentration was fluoranthene at 2.90 mg/kg.

SVOCs were seldom detected in the areas surrounding the Building CB-6 and Building CB-6A pads and at the settling basin. Alternatively, stations near the Building CB-4 and Building CB-4A pads had the highest frequency of SVOC detections of any area in the load line. For example (see Plate 3-1 for locations)

- At station LL1-001, 11 SVOCs were detected.
- At station LL1-168, 19 SVOCs were detected.
- At station LL1-173, 12 SVOCs were detected.

The melt-pour complex had the most frequent and highest detections of pesticides and PCBs. A total of 11 pesticides/insecticides and 2 PCBs were identified in this aggregate's samples. The most frequently detected compounds included 4,4'-DDE (12 of 17 samples), endrin aldehyde (10 of 17), PCB-1254 (15 of 17), and gamma-chlordane (5 of 17). Station LL1-148, which is near the Building CB-4 pad, exhibited the highest concentrations of this compound group, including

- 4,4-DDE – 6.7 mg/kg,
- endrin aldehyde – 4.4 mg/kg,
- PCB-1254 – 1100 mg/kg, and
- gamma-chlordane – 5.3 mg/kg.

PCB-1254 was measured in the surface soils at a range from 0.05 to 1,100 mg/kg with an average concentration of 69.92 mg/kg.

4.2.4.2 Buildings CB-10 and CB-13

The detection of volatile organic compounds at the Buildings CB-10 and CB-13 area was minimal and consisted of 1,2-DCE, acetone, methylene chloride, toluene, and TCE, with only 1,2-DCE detected consistently (five of six samples) (Table 4-2). Toluene was detected in two samples and TCE in three samples. The maximum detected concentration for each of these compounds was 0.01 mg/kg or less. The maximum concentration of 1,2-DCE (0.0072 mg/kg) occurred at station LL1-108 south of Building CB-13 (Plate 3-1).

Sixteen SVOCs were detected in the surface soils of this aggregate at low concentrations (≤1 ppm) and with a frequency of detection ranging from 1 to 3 of six samples. Average concentrations range from 0.16 to 0.30 mg/kg. The maximum concentration measured for all 16 detected compounds was 1.0 mg/kg of fluoranthene.

Six compounds within the pesticide/insecticide group of chemicals (4,4'-DDE, 4,4-DDT, endrin aldehyde, heptachlor, and gamma-chlordane) were detected in this aggregate. PCB-1254 was detected at three stations around the Building CB-10 pad (LL1-120, LL1-130, and LL1-369) with concentrations ranging from 1.0 to 2.4 mg/kg. The maximum concentration occurs at station LL1-130, east of the Building CB-10 slab.

4.2.4.3 Buildings CB-14, CA-15, and CB-17

Two surface soil samples each were analyzed for VOCs, and SVOCs at former Buildings CB-14 (stations LL1-101 and LL1-103) and CB-17 (stations LL1-091 and LL1-094). No analyses for organics were conducted for the samples at former Building CA-15.

Three volatile organic compounds were detected in the samples submitted for this analysis, including 1,2-DCE, methylene chloride, and toluene, with only 1,2-DCE detected in all four samples (Table 4-3). The maximum concentration of 1,2-DCE (0.0031 mg/kg) occurred at station LL1-091 adjacent to the Building CB-17 pad on the west side. Toluene was also detected at the station at 0.0017 mg/kg. Methylene chloride was detected at both of the stations at former Building CB-14, with the maximum detection of 0.0021 mg/kg occurring at station LL1-103 (Plate 3-1).

Twenty SVOCs were detected at low concentrations with average concentrations ranging from 0.16 to 0.65 mg/kg. The higher concentrations detected included

benzo(b)fluoranthene (1.1 mg/kg) at station LL1-091 at former Building CB-17, and

- fluoranthene (1.4 mg/kg) at station LL1-103 at former Building CB-14.

The sample collected at station LL1-094 near former Building CB-17 did not have any SVOCs detected above the detection limits.

Pesticide and PCB analyses were conducted on three samples with a total of seven pesticides/insecticides and one PCB compound detected. 4,4-DDE, endrin aldehyde, PCB-1254, and gamma-chlordane were detected in each sample. The maximum of each of these chemicals occurred at station LL1-091 (4,4-DDE at 0.2 mg/kg, endrin aldehyde at 0.3 mg/kg, PCB-1254 at 4.7 mg/kg, and gamma-chlordane at 0.13 mg/kg).

4.2.4.4 Building CB-3/801

Five of the 22 surface soil samples were analyzed for VOCs and SVOCs (LL1-027, LL1-179, LL1-181, LL1-185, and LL1-409); four of these were additionally analyzed for PCBs. VOCS that were detected include

- 1,2-DCE was detected in all five samples (Table 4-4), at concentrations ranging from 0.0007 to 0.0079 mg/kg. The maximum value was identified at LL1-027 near former Building CB-2 (formerly used for truck maintenance);

- 0.003 mg/kg methylene chloride in LL1-185 near the railroad tracks east of former Building CB-2; and

- 0.0044 mg/kg TCE at LL1-409 in the pipe decontamination area east of Building CB-801.

Twenty-two SVOCs were identified in all five samples analyzed. The range of concentrations of PAHs was 0.046 mg/kg for naphthalene at LL1-185 to 39 mg/kg for fluoranthene at LL1-179. The average concentration range is 0.47 mg/kg (dibenzofuran, one detection) to 8.7 mg/kg (pyrene, five detections). Because all of these sample locations have been subject to vehicle traffic or pavement maintenance either in the recent past or during the active life of the load line, these activities are possible sources for the observed occurrences of PAHs and other SVOCs. In addition, maintenance and servicing activities associated with the historical uses of these buildings may have contributed to the occurrences of these contaminants in surface soils.

Samples from stations LL1-027, LL1-179, LL1-181, and LL1-185 were analyzed for pesticides/PCBs (Plate 3-1). Eight compounds were detected, with most of them occurring in LL1-179 and LL1-185. Pesticide 4,4’-DDE was present in both of these samples (0.12 and 0.048 mg/kg), as was endrin aldehyde (0.21 and 0.073 mg/kg), beta-BHC (0.22 and 0.018 mg/kg), and gamma-chlordane (0.052 and 0.04 mg/kg). 4,4’-DDT, dieldrin, and methoxychlor were present at LL1-185, at 0.041, 0.036, and 0.026 mg/kg, respectively. Endrin ketone was also detected at LL1-179 (0.081 mg/kg). LL1-027 and LL-181 each contained only one detectable PCB—Aroclor 1254—at 0.69 and 0.33 mg/kg, respectively.

PCBs have been detected in paints on piping in LL 1. For this reason, the stations around the former Water Tower (LL1-218, LL1-219, and LL1-220) were analyzed for PCBs to evaluate the Water Tower paint as a possible source contamination in soils. None of the three samples had detectable quantities of the seven PCBs analyzed.

4.2.4.5 Change houses

Only two samples (CB22-04 and CB23-04) were collected in the change house areas for analysis of organic compounds (Plate 3-1). Methylene chloride and toluene were the only two volatile organic compounds detected above detection limits, with maximum concentrations of 0.0019 mg/kg and 0.0031 mg/kg, respectively (Table 4-6). Several SVOCs were detected at low (<1 ppm) levels. Station CB23-04 had detections of 4,4-DDE (0.0016 mg/kg), endrin aldehyde (0.0014 mg/kg), and PCB-1254 (0.11 mg/kg).

4.2.4.6 Perimeter areas

Two of the samples collected at the 26 perimeter area stations were sent for organic analyses (stations LL1-193 and LL1-197, Plate 3-1)). 1,2-DCE and TCE were detected at both stations at maximum concentrations of 0.0041 mg/kg and 0.0066 mg/kg, respectively. Only two SVOCs were detected, both at station LL1-197. Benzo(b)fluoranthene (0.042 mg/kg) and fluoranthene (0.057 mg/kg) were both detected. No pesticides/PCBs were detected in the two perimeter area surface soil samples analyzed for SVOCs.

4.2.5 Surface Soil Summary

Although concentrations of some explosives, nitrocellulose, and some metals are very high at some surface soil stations at LL 1, the extent of contaminants appear to be sporadic in the soils as evidenced by spatial contaminant distribution. For example, one station may have a metal at a concentration of 20 times background and an explosive at a concentration greater than 1,000 mg/kg, and the next closest stations will have the same metal at concentrations near background and the explosive at concentrations three orders of magnitude lower (i.e., 1 mg/kg). Most of the contamination occurred closest to the buildings and former building footprints. This is because during building washdowns, loose flakes of explosives and process effluent (i.e., pink water) were occasionally swept out of doorways and onto the ground.

- Across the entire load line, the most commonly detected explosive was 2,4,6-TNT and the most commonly detected propellant was nitrocellulose.
- Across the entire load line, the most commonly detected metals and/or the metals detected at the highest concentrations above background were cadmium, chromium, copper, lead, mercury, and zinc.
- Organic contamination at LL 1 is minimal, with only one volatile organic compound detected consistently 1,2-DCE, usually at concentrations less than 1 ppm. The majority of the SVOC detections were PAHs. These were detected at low levels typical of the chemical signature of many industrial facilities where fossil fuels are burned. Sporadic pesticide and PCB detections also occurred, usually at low levels.

At the former Buildings CB-4, CB-4A, CA-6, CA-6A, and settling basins area

- The immediate area around the Building CB-4A pad is the most heavily contaminated area at LL 1 with respect to explosives, propellants, and metals.
- HMX and RDX were frequently detected at the Building CB-4A pad, but were not detected at the Building CB-4 pad.
- While nitrocellulose was detected frequently across the entire load line, the propellants nitroglycerine and nitroguanidine, were detected only once at the load line, at stations near the Building CB-4 pad.
- The settling basins were less contaminated than the areas immediately near the former buildings.
- The former bulk explosive preparation buildings were less contaminated than the former melt-pour complex.
- The areas under the floor slabs show little contamination.

At the Building CB-10/13 area

- Stations LL1-107 and LL1-109, which are in a ditch southeast of the Building CB-13 pad, are a hot spot for metals and explosives contamination.
- The areas under the floor slabs show little contamination.
- The southeastern sides of the buildings are more heavily contaminated than any other area around the buildings, suggesting that this is where the washdown effluent was directed.

At the Buildings CB-14, CA-15, and CB-17 area

- This area contains few detectable explosive compounds.
- This area also has less metals contamination when compared to the other aggregates in the load line. However, lead is elevated in some stations in both surface and subsurface soils.

At the Building CB-3/801/Water Tower area

- The highest metals contamination in this area may be associated with slag on the railroad bed.
- In the area of the water tower, paint residue is the likely cause of elevated lead, chromium, and zinc.
- This area contains few detectable explosive compounds.
- There is no PCB contamination associated with paint chips from the operation, maintenance, and demolition of the Water Tower.

In the Perimeter Area

- There is minimal metals contamination (a few metals at 2 times background); however, mercury was consistently detected above background.
- There were no explosives or propellants detected in the perimeter area indicating little migration of contamination from the major production areas to the outlying areas of the load line.

4.3 SUBSURFACE SOILS

Subsurface (from 1- to 3-ft) soil samples were collected in the Phase II RI at Phase I locations that exhibited heavy metals and/or explosives contamination in the surface soils and at Phase II locations that tested positive for TNT or RDX in the field screening of surface soils. At a minimum, a 1- to 3-ft sample was attempted at Phase I sampling locations associated with the major buildings within the load line, for a determination of vertical extent of contamination. Thereafter, the surface soil field screening results were used to determine the placement of additional samples.

A total of 29 subsurface samples from depths of 1- to 3-ft were collected for the purpose of determining nature and extent of contamination. An additional 10 samples were collected from 2 to 2.2 ft beneath the railroad ballast along Track CB. Out of 61 possible locations where surface soils tested positive for explosives (generally around the melt-pour complex), 32 had bedrock within 1 ft of the surface. Subsurface soil sample collection was not possible at these locations. At 13 locations, the 1- to 3-ft sample exhibited potential explosive contamination as determined with the field laboratory method; however, deeper subsurface samples (e.g., 3- to 5-ft interval) could not be collected because of refusal on bedrock. In the remaining 16 samples, the 0.3- to 0.9-m (1- to 3-ft) interval exhibited no explosives contamination above the field screening detection level. Analytical capacity from unexpended subsurface samples was used to increase the number of contingency surface soil samples. Only two contingency sampling locations had both surface and subsurface soil samples: LL1-325 and LL1-335 near CA-6A.

There are six locations where the surface soils tested negative in the field for explosives, but a subsurface sample was collected. Three of these locations (LL1-068, LL1-004, and LL1-008) were Phase I sampling locations. Subsurface sampling was performed in these locations as an assurance that some Phase I locations would have both surface and subsurface characterization. Stations LL1-420 and LL1-421 are considered subsurface samples because they were taken below the railroad ballast, which was not sampled, inside Building CB-13. LL1-268, taken at the former settling basin north of the melt-pour complex, was collected to ensure thorough characterization of the area.

There are five locations where surface soils tested positive for explosives in the field and refusal was not documented, but the boring was not advanced to retrieve subsurface soil samples: LL1-126, LL1-132, and LL1-133 near CB-10; LL1-138 near CA-6; and LL1-272 near the former settling basins. Of these five locations, only LL1-126 had detectable quantities of explosives in the laboratory analysis of the surface soil sample (0.51 mg/kg 2,4,6-TNT, 0.11 mg/kg 2,6-DNT, 0.37 mg/kg 2-amino-4,6-DNT, 0.49 mg/kg 4-amino-2,6-DNT).

The subsurface sampling is biased toward those areas and building footprints that suggest the greatest surface soil contamination. Plate 3-1 and Figure 3-2 illustrate the distribution of subsurface soil samples in the Phase II RI.

All sample collection and analysis for the Phase II RI were conducted in accordance with the SAP Addendum No. 2 (USACE 2000b), as described in Chapter 3.0 of this report. Subsurface soil samples were analyzed for field explosives, field metals, explosives, TAL metals, VOCs, SVOCs, pesticides/PCBs, and cyanide, as described in Chapter 3.0. Hexavalent chromium was analyzed in 15 samples selected at random following publication of the final SAP Addendum. A field change order, provided in Appendix F, documents this change to the analytical program.

Tables 4-9 through 4-13 present the statistical summary of subsurface soil data and the determination of SRCs for this media at LL 1. The analytical results for subsurface soil samples collected at LL 1 are provided by sample station and by analyte in Tables 4-36 and 4-37. The following sections describe the distribution of explosives, propellants, and inorganic and organic constituents for each of the groupings of buildings. For each area discussed, figures are presented (as appropriate) that illustrate the distribution of site-related explosives, propellants, and metals. The analytes presented in the figures represent either those that occur with the greatest frequency at each building or those that represent the distribution of a suite of correlative chemicals.

4.3.1 Geotechnical Results

One subsurface soil (LL1-145) was collected for geotechnical analysis of moisture content, Atterberg limits, and USCS classification. This soil sample is located at the east end of Building CB-4 and met refusal at 2 ft bgs. The sample had a moisture content of 16%, a liquid limit of 25, a plastic limit of 8, and is classified as MH elastic silt. Appendix K presents the geotechnical results in their entirety.

4.3.2 Explosives and Propellants

Nine explosive and propellant compounds were detected in 16 subsurface soil samples collected for characterization of nature and extent of contamination. The most commonly detected explosives were 2,4,6-TNT (13 detections), RDX (9 detections), and 2,4-DNT (8 detections). Nitrocellulose was the only propellant detected in subsurface soils with occurrences limited to the melt-pour area, Building CB-13, Building CB-17, and Track CB. Figure 4-21 illustrates the distributions of key explosives and propellant compounds in LL 1 subsurface soils.

4.3.2.1 Buildings CB-4/-4A and CA-6/-6A and settling basins

The occurrence of explosives and propellants was observed in 12 samples from the melt-pour area, the former settling basin north of the melt-pour complex, and one sample location each at Buildings CA-6 and CA-6A. RDX was present in subsurface soils only in four locations around the melt-pour buildings (LL1-001 at 29 mg/kg, LL1-004 at 0.27 mg/kg, LL1-011 at 3.5 mg/kg, and LL1-015 at 58 mg/kg). HMX was present only at two locations, both at CB-4A: LL1-011 (0.62 mg/kg) and LL1-015 (8.1 mg/kg). 4-Amino-2,6-DNT occurred in six soil samples in the melt-pour complex (LL1-002, LL1-004, LL1-006, LL1-011, LL1-023) and the former north settling basin (LL1-268). The maximum concentration of this explosive was 0.84 mg/kg at LL1-011. 2-Amino-4,6,-DNT was present in eight of the twelve samples in this area, with the maximum concentration of 2.0 mg/kg at LL1-015. Note that the surface soil at this location had a concentration of this compound of 11 mg/kg. 1,3,5-TNB and 2,6-DNT were limited to one occurrence each in the subsurface soil samples (LL1-001 with 11 mg/kg 1,3,5-TNB; LL1-011 with 0.14 mg/kg 2,6-DNT).

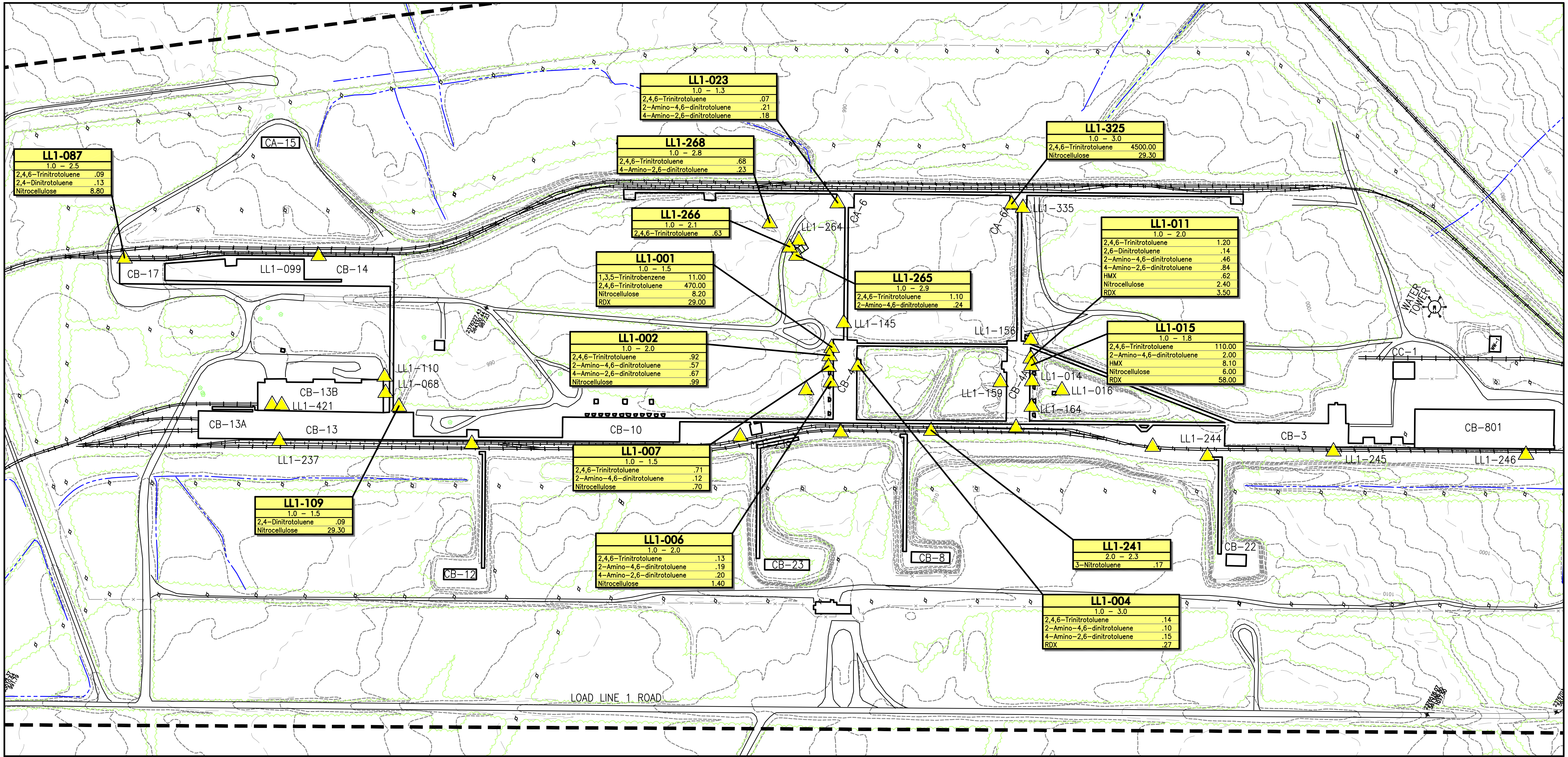
The maximum concentration of any explosive or propellant compound in subsurface soils was encountered at LL1-325 near building CA-6A. 2,4,6-TNT was present at a concentration of 4,500 mg/kg. Note that, at this location, the concentration of 2,4,6-TNT in the surface soil was 22 mg/kg. The next highest concentration of explosives was 470 mg/kg 2,4,6-TNT at LL1-001, adjacent to Building CB-4. At this location, the surface soil had a concentration of 2,4,6-TNT at 310 mg/kg. 2,4,6-TNT was also present at 110 mg/kg at LL1-015, adjacent to Building CB-4A. The associated surface soil sample concentration of 2,4,6-TNT at LL1-015 was 390 mg/kg.

The maximum concentration of nitrocellulose in subsurface soils in the melt-pour area was 29.3 mg/kg from the 1- to 3-ft interval at LL1-325. Refusal was encountered at this depth and no additional samples could be collected. Nitrocellulose in surface soils at this location was present at 3.8 mg/kg. No other propellants were detected in the subsurface soils.

All other concentrations of explosives and propellants ranged from non-detects to 3.5 mg/kg, with most occurrences below 1 mg/kg.

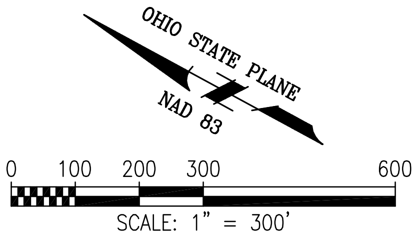
4.3.2.2 Buildings CB-10 and CB-13

One sample location near Building CB-13 (LL1-109) contained explosive and propellant compounds. This sample, located in the ditch south of the building, had 2,4-DNT at a concentration of 0.086 mg/kg and nitrocellulose at a concentration of 29.3 mg/kg in the 1- to 1.5-ft interval (equal to the maximum concentration of this compound in subsurface soils). The concentration of nitrocellulose in the surface soil at this location was 103 mg/kg. Note that nitrocellulose is a component of the propellant pellets that were found on the ground near LL1-109 in the Phase I RI.



LEGEND:

ASPHALT ROAD
GRAVEL ROAD
RAILROAD TRACKS
FENCE LINE
STREAM
CONTOUR (2 FT. INTERVAL)
CONTOUR (10 FT. INTERVAL)
▲ SUBSURFACE SOIL SAMPLE
EXPLOSIVE CONCENTRATIONS SHOWN IN mg/kg



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY
US Army Corps of Engineers Louisville District

LOAD LINE 1
RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	C / 12-20-02	/99035/DWGS/L70SUB02

Figure 4-21. Explosives in Subsurface Soil at Load Line 1

4.3.2.3 Buildings CB-14, CA-15, and CB-17

Explosives were detected once in subsurface soil in this aggregate. Sample LL1-087, at the northeast corner of Building CB-17, contained 2,4,6-TNT (0.088 mg/kg), 2,4-DNT (0.13 mg/kg), and nitrocellulose (8.8 mg/kg). All detections were lower than those encountered in the associated surface soil sample.

4.3.2.4 Buildings CB-3 and CB-801

There were no explosives or propellants detected in the subsurface soil samples taken from this aggregate.

4.3.2.5 Track CB

In the Track CB samples taken beneath the railroad ballast (which consisted of slag), two samples exhibited evidence of contamination with explosives. Station LL1-241 had 0.17 mg/kg of 3-nitrotoluene; station LL1-238 had a field explosives result for 2,4,6-TNT of 1 mg/kg, with the fixed-base laboratory results showing no detects. There were no other detections of explosives or propellants in Track CB soils.

4.3.2.6 Perimeter areas

One random-grid sample in the perimeter areas (LL1-211) was analyzed for subsurface soil contamination. No explosives or propellants were detected in the subsurface soils at LL1-211, which is located east of the main production area.

4.3.3 Inorganic Constituents

The 23 TAL metals were consistently identified in every subsurface soil sample, with the following exceptions (see Table 4-37). Mercury was detected in 19 of 29 samples. Antimony was detected twice, at LL1-109 and LL1-268. Beryllium was present in 18 samples. Cadmium was detected in 14 samples, and selenium was detected in 11 samples. Silver occurred in one sample, LL1-109. Hexavalent chromium occurred in only one subsurface soil sample. Analytes never detected above the background criteria include arsenic, cobalt, magnesium, manganese, nickel, thallium, and vanadium.

Field determinations of metals concentrations were made on ex-situ subsurface soil samples only and are not considered as part of the discussion of nature and extent of contamination. The XRF data set is discussed in Section 4.1 and presented in its entirety in Appendix J.

The following subsections discuss the occurrences of metals that exceed facility-wide background criteria for metals in subsurface soils. Four metals (Cd, Cr, Pb, and Zn) were most frequently detected and at the highest levels above background. Figure 4-22 shows the distribution of these four key metals in LL 1 subsurface soils.

4.3.3.1 Buildings CB-4/-4A and CA-6/-6A and settling basins

Barium, beryllium, cadmium, chromium, copper, lead, mercury, selenium, and zinc were detected above background criteria for metals in the melt-pour complex. The maximum detections of these metals above background came from LL1-006 (barium at 252 mg/kg and beryllium at 1.5 mg/kg), LL1-001 (cadmium at 9.9 mg/kg, chromium at 67.4, mercury at 0.78 mg/kg, lead at 254 mg/kg, and zinc at 395 mg/kg), LL1-007 (copper at 416 mg/kg), and LL1-264 (selenium at 1.7 mg/kg). Other occurrences of these metals above background were observed at LL1-002, LL1-004, and LL1-008,

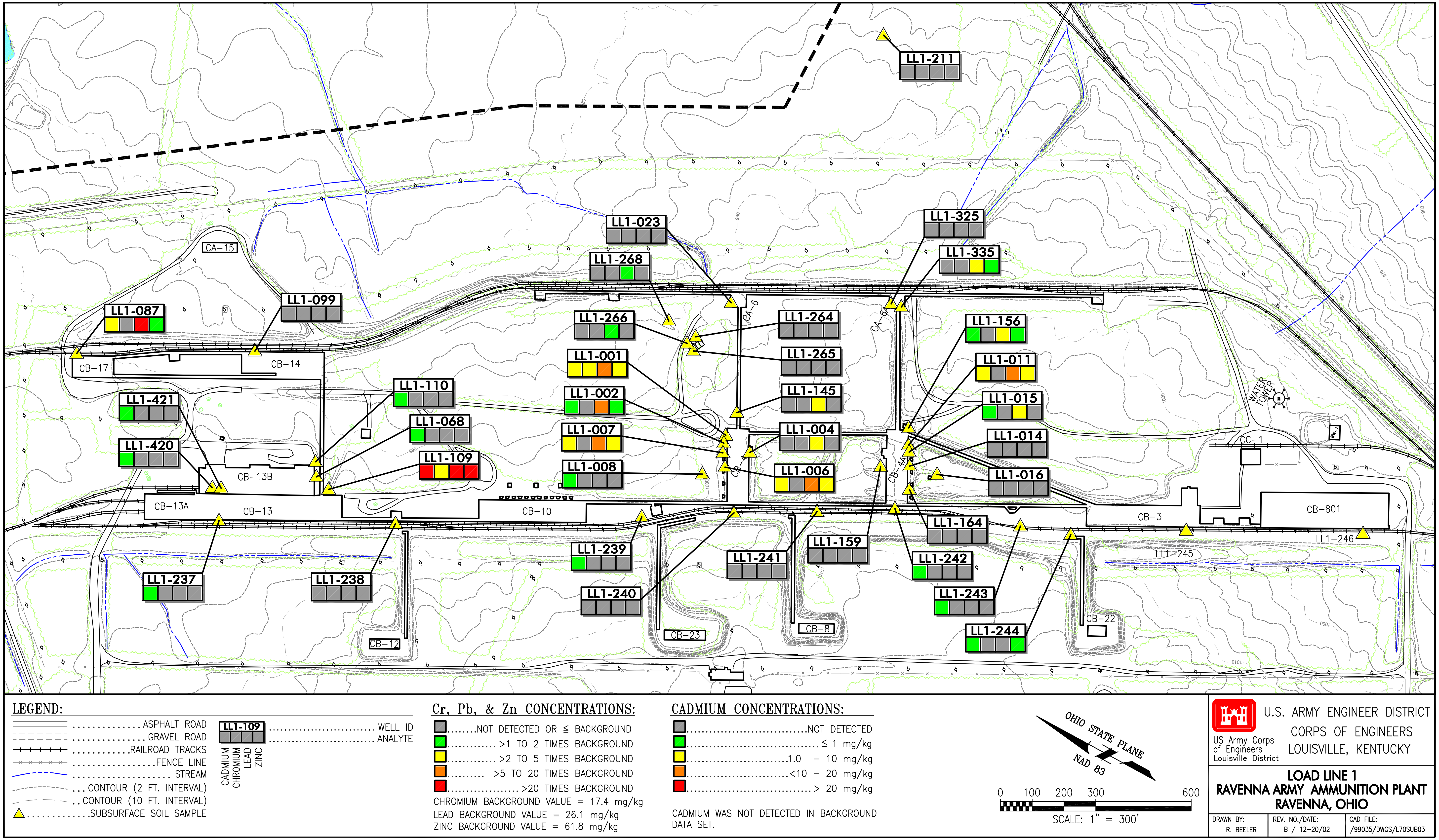


Figure 4-22. Representative Metals in Subsurface Soil at Load Line 1

LL1-011, LL1-015, LL1-016, LL1-145, LL1-156, LL1-335, and at the settling basin at LL1-265, LL1-266, and LL1-268.

Cadmium, copper, lead, and zinc were the metals most commonly detected above background. Lead was present above background in 12 sample locations, zinc in 7, and cadmium and copper in 5. Cadmium and copper concentrations above background appear to be associated with Buildings CB-4 and CB-4A and the former settling basins only. Copper occurrences above background were encountered in LL1-006, LL1-007, LL1-001, LL1-268, and LL1-266. Lead concentrations above background are less localized, whereas zinc concentrations above background are limited to the north side of Building CB-4A, the southeast corner of Building CB-4, and the southwest corner of Building CA-6A. Selenium concentrations above background are associated with the former settling basins. There were no metals present at concentrations exceeding background at Building CA-6.

The observed metals concentrations in the subsurface soils are consistent with surface soil distributions in both Phase I and Phase II of the RI. Generally, metals that exceeded background criteria in the subsurface soils were also present above background in the corresponding Phase II surface soil sample. Subsurface soil concentrations of metals are generally lower than concentrations of the same metals in the surface soils. Exceptions to this pattern appear to be associated with areas where soil was disturbed during demolition of the buildings—most notably at LL1-006 and LL1-007 at Building CB-4 and at LL1-265 and LL1-266 at the former settling basin. At these locations, concentrations of cadmium, copper, lead, and mercury were higher in the subsurface soils than in the overlying surface soils.

There was one detection of hexavalent chromium among 15 locations where it was analyzed; station LL1-006 at Building CB-4 had 13.6 mg/kg of this metal. Hexavalent chromium transforms readily to trivalent chromium under natural conditions.

Cyanide was detected in LL1-001 at CB-4 and in LL1-156 at CB-4A, at 1.2 and 0.63 mg/kg, respectively. There were no other detections of cyanide in LL 1 subsurface soils.

4.3.3.2 Buildings CB-10 and CB-13

Antimony, barium, cadmium, chromium, copper, lead, mercury, selenium, and zinc were detected above background criteria for metals in three subsurface samples at Building CB-13. The occurrences of these metals above background come principally from LL1-109, in the ditch south of CB-13. Antimony, at 98.1 mg/kg, exceeds the background value by more than 100 times. The concentration of zinc is more than 40 times the background criterion at 4,160 mg/kg, and more than twice the amount found in the overlying surface soil (2,060 mg/kg). The occurrence of lead is 36 times higher than background (680 mg/kg) but less than half the concentration of lead in the surface soil sample (1,770 mg/kg). Chromium is present at a concentration of 85.8 mg/kg. These subsurface values are higher than those observed anywhere else in the subsurface soils at LL 1. With the exception of cadmium (0.15 mg/kg in LL1-110, 0.091 mg/kg in LL1-420, and 0.078 mg/kg in LL1-421), there were no other detections of metals above the background values. Concentrations of metals in LL1-110 were relatively much lower than those for the same metals in the surface soil from this location. Note that samples LL1-420 and LL1-421 were collected from beneath the railroad ballast (slag) inside Building CB-13.

There are no Phase I sampling locations near LL1-109 and LL1-110. The closest sampling point from the Phase I RI is LL1-068, which is south of Building CB-13. This surface soil sample had antimony, barium, beryllium, cadmium, chromium, copper, magnesium, manganese, selenium, thallium, and zinc above surface soil background concentrations in the Phase II RI sample. However, none of these concentrations is as great as that observed at LL1-109. The observation of isolated and anomalously high metals concentrations in the subsurface at LL1-109 suggests some localized disturbance of soils, spills of chemical solutions, or burial of waste material at this location.

4.3.3.3 Buildings CB-14, CA-15, and CB-17

Cadmium, lead, and zinc were detected above the background criteria for these metals in one of the two subsurface samples in this area. The occurrence above background was observed at Building CB-17, at LL1-087. The concentration of lead (558 mg/kg) was greater than 20 times the background value in this sample. Occurrences of site-related metals in this sample are much lower in the subsurface soil than in the overlying surface soil. Concentrations of barium, chromium, mercury, nickel, silver, and thallium were above background criteria in the surface soil sample but are below background or detection levels in the subsurface interval. At LL1-099 near Building CB-14, there were no concentrations of metals greater than the background values. Because there were no Phase I samples collected near these two locations, no comparisons can be drawn between the Phase I and Phase II observations of contaminant distributions.

4.3.3.4 Buildings CB-3 and CB-801

There are no subsurface data associated with these buildings.

4.3.3.5 Track CB

Cadmium was detected in 9 of the 10 locations (i.e., all samples except LL1-246). Concentrations ranged from 0.07 to 0.1 mg/kg. The maximum concentration was observed at LL1-244. Cadmium was not detected in the background data set; therefore, the site background value for cadmium was set to zero. Therefore, the site background value for cadmium was set to zero. Zinc was present at a concentration above background at LL1-244 and LL1-245 (at 99.6 mg/kg and 121 mg/kg, respectively). All other occurrences of metals were below the background values. Cyanide and hexavalent chromium were not detected.

4.3.3.6 Perimeter areas

The single subsurface sample among the random-grid sampling locations (LL1-211) had no detections of inorganic constituents above background criteria. The surface soil sample at this location exceeded background criteria for barium, cobalt, mercury, and thallium. Cyanide and hexavalent chromium were not detected in the subsurface sample.

4.3.4 Semivolatile Organic Compounds, Volatile Organic Compounds, and Pesticides/ Polychlorinated Biphenyls

Organic compounds were not analyzed in subsurface soil samples. According to the SAP Addendum No. 2 (USACE 2000b), VOC, SVOC, and PCB/pesticide samples were planned at four stations. However, at each of these stations (see Figure 3-2), the borings refused on bedrock before the subsurface interval could be attained; thus, no subsurface soil sampling was completed

LL1-038 – refusal at 0.7 ft,
LL1-034 – refusal at 0.3 ft,
LL1-030 – no soil, root mat only, and
LL1-181 – refusal at 0.5 ft.

The analyses for these samples were not reassigned to other subsurface soil sampling locations during the field effort due to the presence of shallow bedrock in much of the AOC. Therefore, no data are available on subsurface soil concentrations of these constituents.

4.3.5 Subsurface Soil Summary

The 29 subsurface soil samples collected during the Phase II RI were biased to areas that manifest the greatest surface soil contamination, where bedrock did not prevent sampling of this interval. Ten additional subsurface samples were collected along Track CB beneath the rail ballast. The findings of the subsurface soil investigation are as follows:

General

- Soils are generally thin to nonexistent throughout the production area of LL 1. The maximum thickness of soils as determined by subsurface soil borings during the Phase II RI is 3 ft, but generally refusal of borings occurred before this depth was achieved. Thicker soil profiles are often present where building demolition operations resulted in the reworking and mounding of soil against building floor slabs.

- Out of the 61 possible locations where subsurface soil sampling was indicated, 32 of these had bedrock within 1 ft of the ground surface.

- There are five locations where subsurface soil sampling was indicated; there was no refusal within 1 ft of the ground surface, but no subsurface soils were collected.

- Organic compounds were not evaluated in subsurface soils.

Explosives and propellants

- Occurrences of these compounds in the subsurface soils are limited to the melt-pour area (including the former settling basin) and to one location each at Building CB-13, Building CB-17, and Track CB. The maximum concentration of any explosive in subsurface soils was encountered at LL1-325 near Building CA-6A, with 2,4,6-TNT at 4,500 mg/kg. The maximum concentration of nitrocellulose (the only propellant identified in subsurface soils), at 29.3 mg/kg, was also encountered in this sample.

- HMX and RDX are present at their maximum concentrations (8.10 and 58.0 mg/kg, respectively) at LL1-015 in Building CB-4A. HMX was detected only at this building in two locations, and RDX was present at Buildings CB-4A and CB-4 only.

- The ditch south of Building CB-13 also had 29.3mg/kg nitrocellulose in the subsurface soil at LL1-109, although none was detected in the surface soil. One sample at Building CB-17 (LL1-087) contained nitrocellulose at 8.8 mg/kg and 2,4,6-TNT and 2,4-DNT at concentrations < 1 mg/kg.

- Track CB is generally free of explosives contamination, except for one detection at LL1-241. Two of 10 samples collected on Track CB had evidence of explosives, but only LL1-241 contained detectable quantities in the confirmatory laboratory analysis (0.17 mg/kg 3-nitrotoluene).

Inorganics and cyanide

- Generally, metals that occurred at concentrations above background criteria in the subsurface soils were present above the background criteria in the corresponding Phase II surface soil sample. Concentrations of metals in the subsurface are generally lower than in the surface soils, except were soils were disturbed during the demolition of buildings—most notably at LL1-006 and LL1-007 at Building CB-4 and at LL1-265 and LL1-266 at the site of the former settling basin.

- There was one detection of hexavalent chromium out of the 15 randomly selected locations where it was evaluated: LL1-006 had 13.6 mg/kg of this anion. Its source is unknown. Chromium was detected at 16.3 mg/kg at this location, which is below the background criteria.

- Cyanide was present at the two melt-pour buildings, at LL1-001 and LL1-156, at 1.2 and 0.63 mg/kg, respectively.

- Cadmium, lead, and zinc were the metals most commonly detected above background in the subsurface soils. Cadmium, lead, and zinc are found above the background values throughout the load line, and their occurrence may be more widespread than the Phase II subsurface soil sampling indicates. The highest concentrations of cadmium, zinc, and lead come from one sample, LL1-109 between Buildings CB-10 and CB-13. At LL1-087 at Building CB-17, these three metals were the sole exceedences of background values.

- Barium, chromium, mercury, and selenium were only detected above background in the melt-pour area and at LL1-109. The highest concentrations of antimony, silver, and chromium in LL 1 subsurface soils come from LL1-109. Selenium occurrences above background appear to be associated exclusively with the former settling basin and LL1-109.

- LL1-244 and LL1-245 on Track CB are the only railroad bed samples that have detections of metals that exceed background. Cadmium and zinc were found above the background values in both samples.

4.4 SEDIMENT

In the Phase I RI, discrete sediment samples were collected at 22 locations (stations LL1-024 through LL1-077) in the drainage ditches at exit points from the AOC, at known pink water effluent discharge points, and along upstream reaches of ditches prior to their outfall to settling ponds (Plate 3-1 and Figure 3-1). Analysis of Phase I RI data showed that sediments in drainage ditches did not contain significant concentrations of explosives and did not convey explosives to the ponds on the eastern edge of the AOC. High concentrations of explosives were detected near the concrete settling tank, and metals were concentrated near Building CB-3 and in a drainage ditch at the south end of the AOC. PCBs in sediment were detected in the southern third of the plant, primarily in drainage ditches near Building CB-3.

A total of 38 sediment samples were collected at depths of 0.0- to 0.2-m (0- to 0.5-ft) from 32 locations during the Phase II RI to determine nature and extent of contamination. Six stations (LL1sd-318 through LL1sd-323) were sampled twice during the Phase II effort, in September 2000 and again in November 2000. Ten of the Phase I RI stations were resampled during the Phase II RI: LL1sd-046, LL1sd-047, LL1sd-048, LL1sd-049, LL1sd-050, LL1sd-051, LL1sd-060, LL1sd-061, LL1sd-070, and LL1sd-077.

All sample collection and analysis for the Phase II RI were conducted in accordance with the SAP Addendum No. 2 (USACE 2000b), as described in Section 3.0 of this report. Sediment samples were analyzed for field explosives, XRF metals, explosives, TAL metals, VOCs, SVOCs, PCBs/pesticides, cyanide, TOC, and grain-size distribution. Hexavalent chromium, added as part of a field change order, was analyzed in two samples (Appendix G).

Tables 4-14 through 4-19 provide the statistical summary and determination of SRCs for sediment. The analytical results for sediment samples collected at LL 1 are provided by sample aggregate, station, and analyte in Tables 4-38 through 4-42. The following sections describe the distribution of explosives, propellants, and inorganic and organic constituents in the five aggregate areas: Outlets A and B, Outlet C and Charlie's Pond, Outlets D, E, and F and Criggy's Pond, North Area, and off-AOC (see Figures 4-1 and 4-2). Figures are presented as appropriate for each aggregate based on frequently detected constituents and to highlight relative "hot spots" for some constituents. Not all detected constituents could be shown on the figures, so only the most commonly detected and/or those detected with highest concentration are shown.

4.4.1 Geotechnical Results

Thirty-three sediment samples were examined for grain-size distribution and Total Organic Carbon (TOC) content. Geotechnical grain-size distribution curves are presented in Appendix K. The highest TOC concentration (120,000 mg/kg) was detected in the Drainage A aggregate at station LL1-253; the highest concentrations of many inorganics were also detected at this station. Overall, TOC ranged from 2,500 mg/kg to 120,000 mg/kg in Drainage A; 8,100 mg/kg to 35,000 mg/kg in Drainage C and Ponds; 11,000 mg/kg to 75,000 mg/kg in Drainage E/F; 18,000 mg/kg in the North Area; and 8,000 mg/kg to 23,000 mg/kg in the off-AOC area.

4.4.2 Explosives and Propellants

Twelve explosive and propellant compounds were detected in 17 sediment samples collected to determine nature and extent of contamination. Eight of these samples tested positive for field explosives; the others tested negative but were analyzed for laboratory explosives and propellants as dictated by the scope of work. Within the laboratory data, the most commonly detected explosives compounds were 2,4-DNT, 4-amino-2,6-DNT, 2,4,6-TNT, and 2-amino-4,6-DNT. Three propellants were detected in sediments at 11 locations. The most commonly detected propellant was nitrocellulose (3 detections).

4.4.2.1 Outlets A and B

Eight explosive and propellant compounds were detected in three of four sediment samples collected in Outlets A and B. Distributions of selected explosives (2,4,6-TNT, 2,4-DNT, HMX, and RDX) in Outlets A and B are presented in Figure 4-23. 2,4-DNT was present in two locations (LL1-253 at 2 mg/kg and LL1-394 at 0.39 mg/kg). Nitrocellulose was also present at the same locations (LL1-253 at 66.9 mg/kg and LL1-394 at 333 mg/kg). No other compounds were detected at station LL1-394. The explosives 1,3,5-TNB, 2,4,6-TNT, 2-Amino-4,6-DNT, 4-Amino-2,6-DNT, and HMX were limited to one detection each in the other two sediment samples (Table 4-38).

The maximum concentrations for any explosive or propellant compounds in sediment were encountered in Outlets A and B, in ditches adjacent to Buildings CB-13 and CB-13A. Note that nitrocellulose is a component of the propellant pellets that were found on the ground near these buildings in the Phase I RI. The highest field explosive concentration (2,4,6-TNT at 13 mg/kg) and the highest laboratory explosive concentration (2,4-DNT at 2 mg/kg) in sediment were detected at LL1-253.

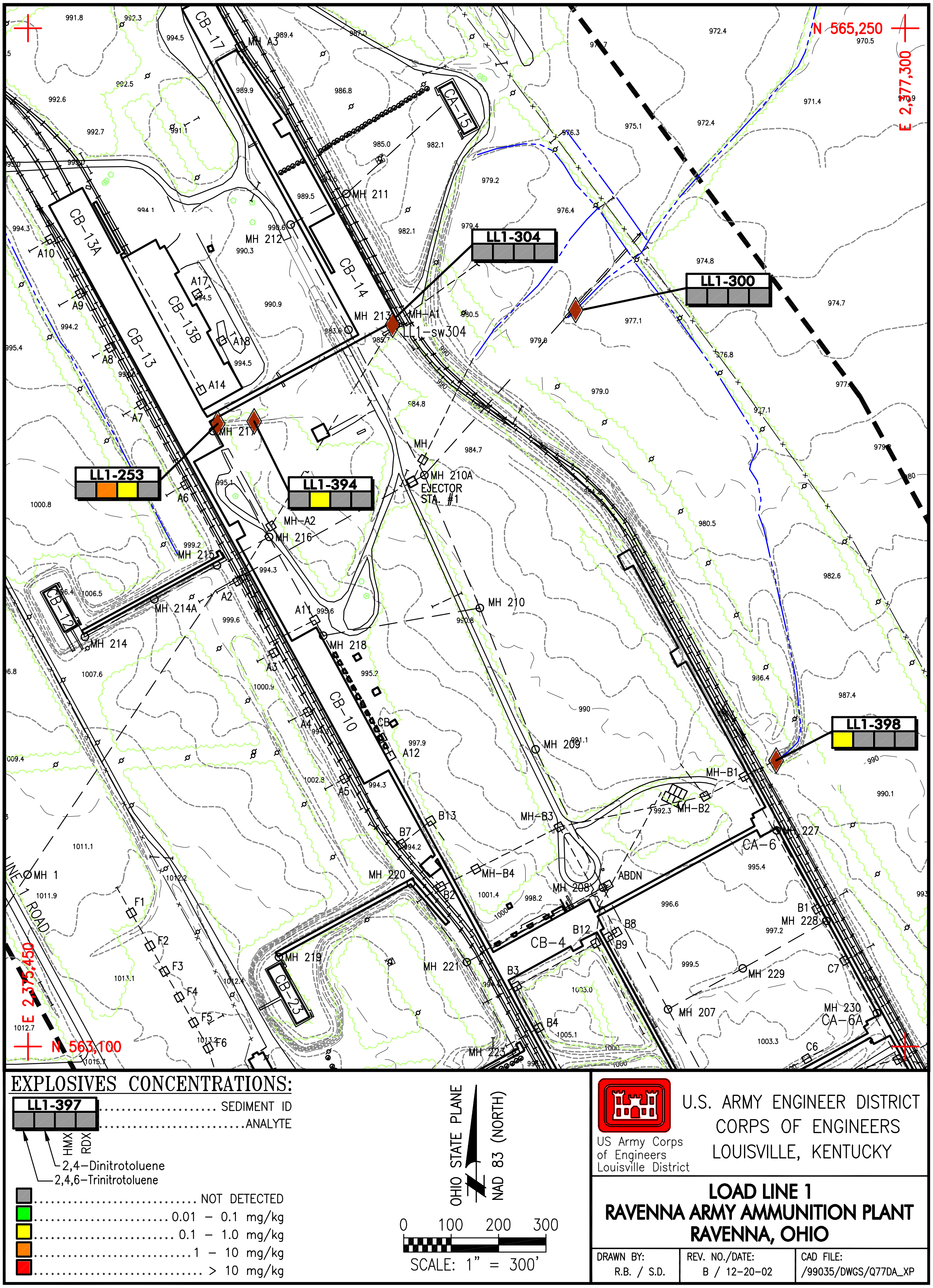


Figure 4-23. Explosive Concentrations in Sediment at Outlets A and B

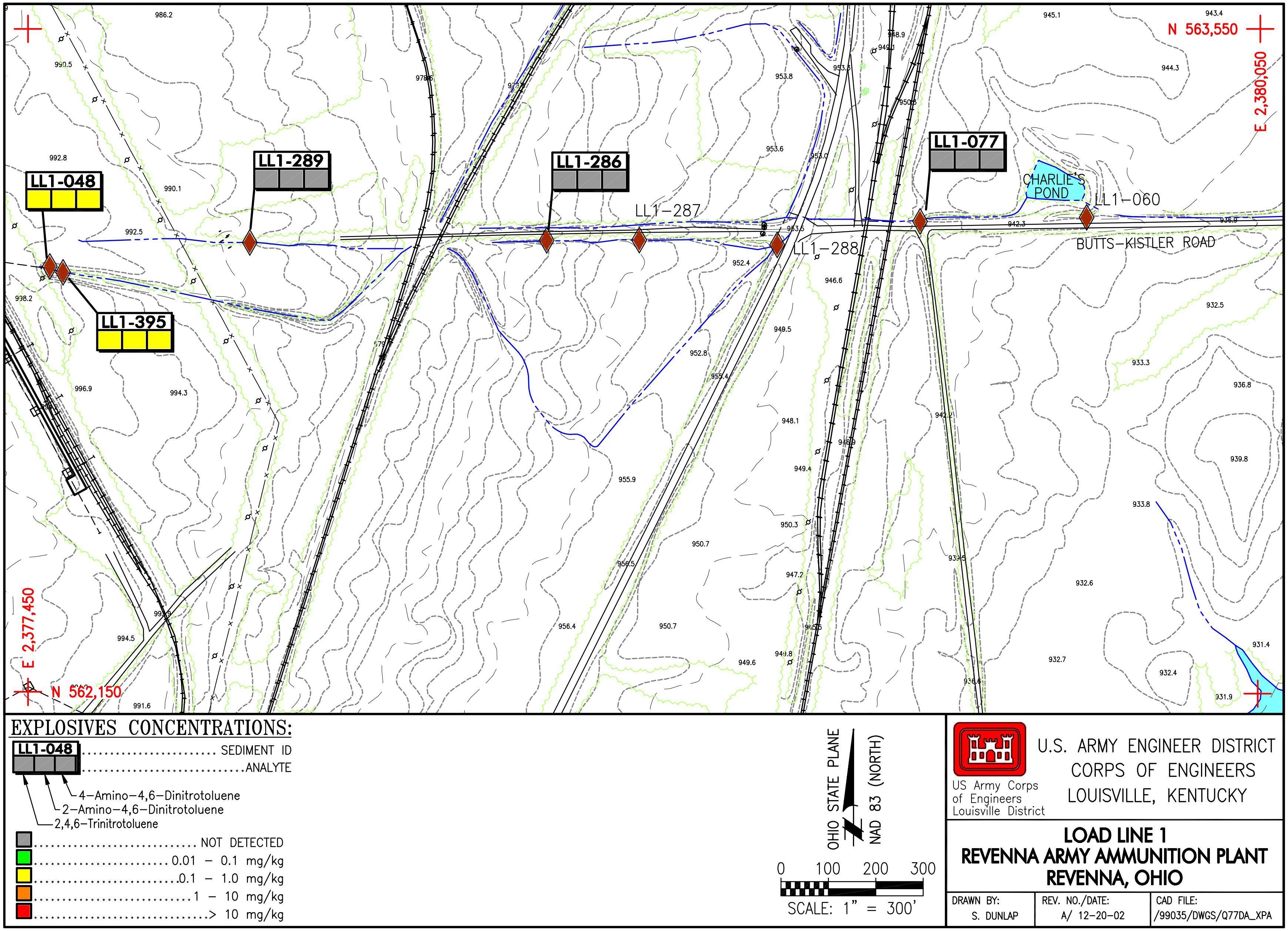


Figure 4-24. Distribution of Explosives/Propellants in Sediments along Outlet C and Charlie's Pond

4.4.2.2 Outlet C and Charlie's Pond

Four explosive compounds were detected in two of five sediment samples collected in the Outlet C and Charlie's Pond area. 2,4,6-TNT, 2-Amino-4,6-DNT, and 4-Amino-2,6-DNT were all detected at stations LL1-048 and LL1-395, which are located proximal to the load line (Figure 4-24). Additionally, 2,6-DNT was detected at Station LL1-395 at an estimated concentration of 0.14 mg/kg. No explosive or propellant compounds were detected at remaining stations LL1-077, LL1-286, and LL1-289 (Table 4-38).

Sediment sampling in the Outlet C and Charlie's Pond area confirms the Phase I finding that drainage ditches in the process areas do not appear to contribute many explosives to streams that drain LL 1 to the east.

4.4.2.3 Outlets D, E, and F and Criggy's Pond

One explosives and one propellant compound were detected in one of two sediment samples at Outlet D, E, and F and Criggy's Pond. 2,4-DNT was detected at 0.07 mg/kg, and nitrobenzene was detected at 0.14 mg/kg, both at LL1-050. No explosive or propellant compounds were detected at the second station, LL1-397 (Table 4-38).

4.4.2.4 North Area

Field analysis of the 46 samples collected in the North Area aggregate showed TNT and RDX <1 ppm, therefore explosive or propellant compounds were not analyzed for in the single sediment sample in the North Area.

4.4.2.5 Off-area of concern

As shown in Figure 4-25 seven explosive and propellant compounds were detected in the three sediment samples analyzed for these compounds in off-AOC areas (LL1-322, -323, and -393). 1,3-DNB, 2,4-DNT, 4-Amino-4,6-DNT, nitrobenzene, nitrocellulose, nitroguanidine, and RDX were all detected once at concentrations ranging from 0.048 mg/kg to 5.7 mg/kg (Table 4-38).

4.4.3 Inorganic Constituents

The 23 TAL metals were consistently detected in every sediment sample, with the following exceptions: antimony was detected in 10 of 25 samples, beryllium was detected in 17 of 27 samples, cadmium was detected in 35 of 37 samples, magnesium was detected in 36 of 37 samples, mercury was detected in 32 of 37 samples, selenium was detected in 28 of 37 samples, sodium was detected in 6 of 25 samples, thallium was detected in 33 of 37 samples, and silver was not detected in any of the samples. Hexavalent chromium was detected in only one sediment sample. Cyanide was not detected in any sediment sample in which it was analyzed. (Hexavalent chromium, silver, antimony, and sodium were not analyzed for in North Area or off-AOC sediment samples.)

The following subsections describe the inorganic constituents that exceed facility-wide background criteria in each sample aggregate.

4.4.3.1 Outlets A and B

All TAL metals except manganese and silver were detected above background criteria for metals in Outlets A and B. Distributions of selected metals (cadmium, chromium, lead, and mercury) in Outlets A and B are presented in Figures 4-26 through 4-29. These metals were either detected most frequently or

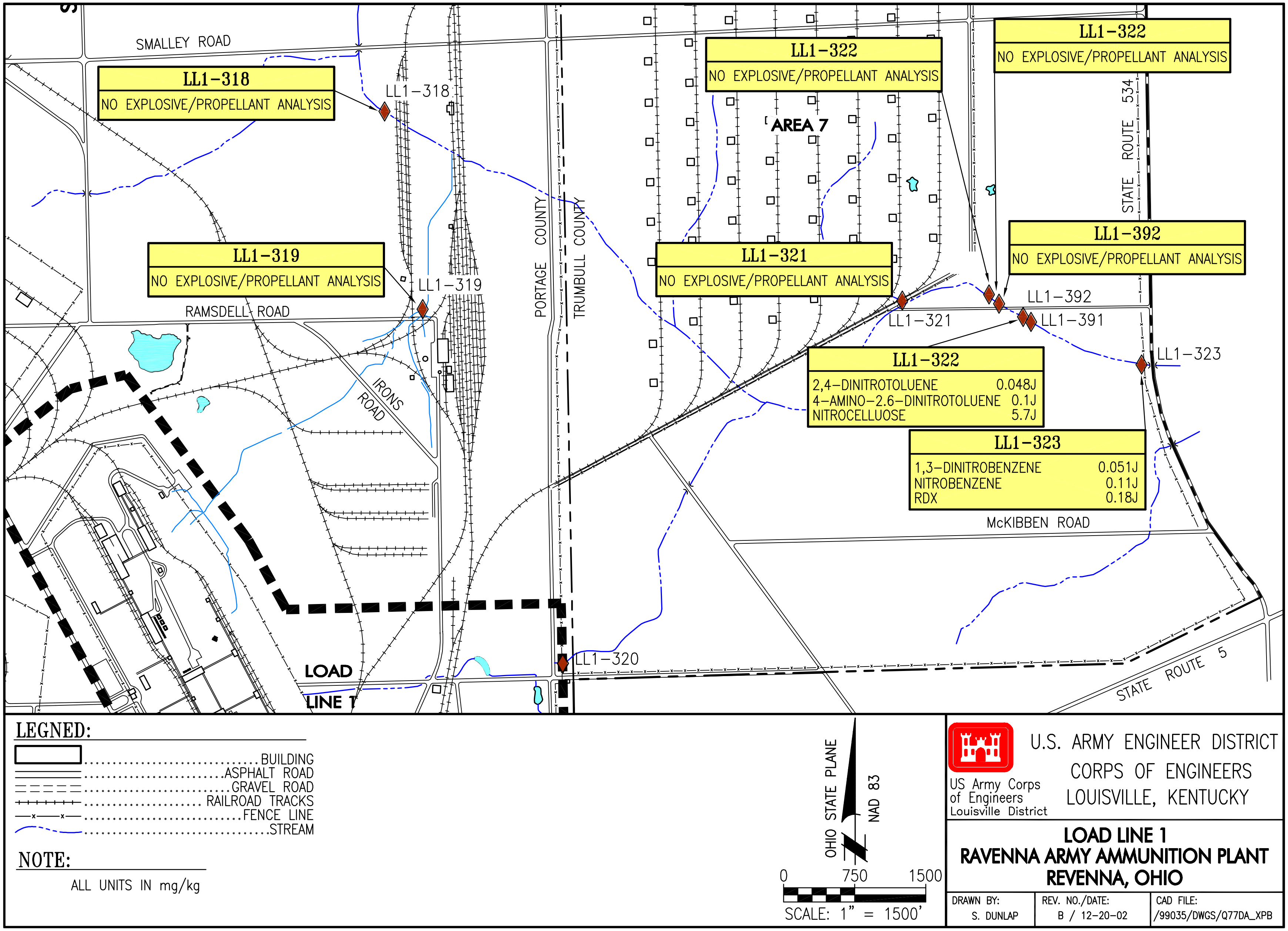
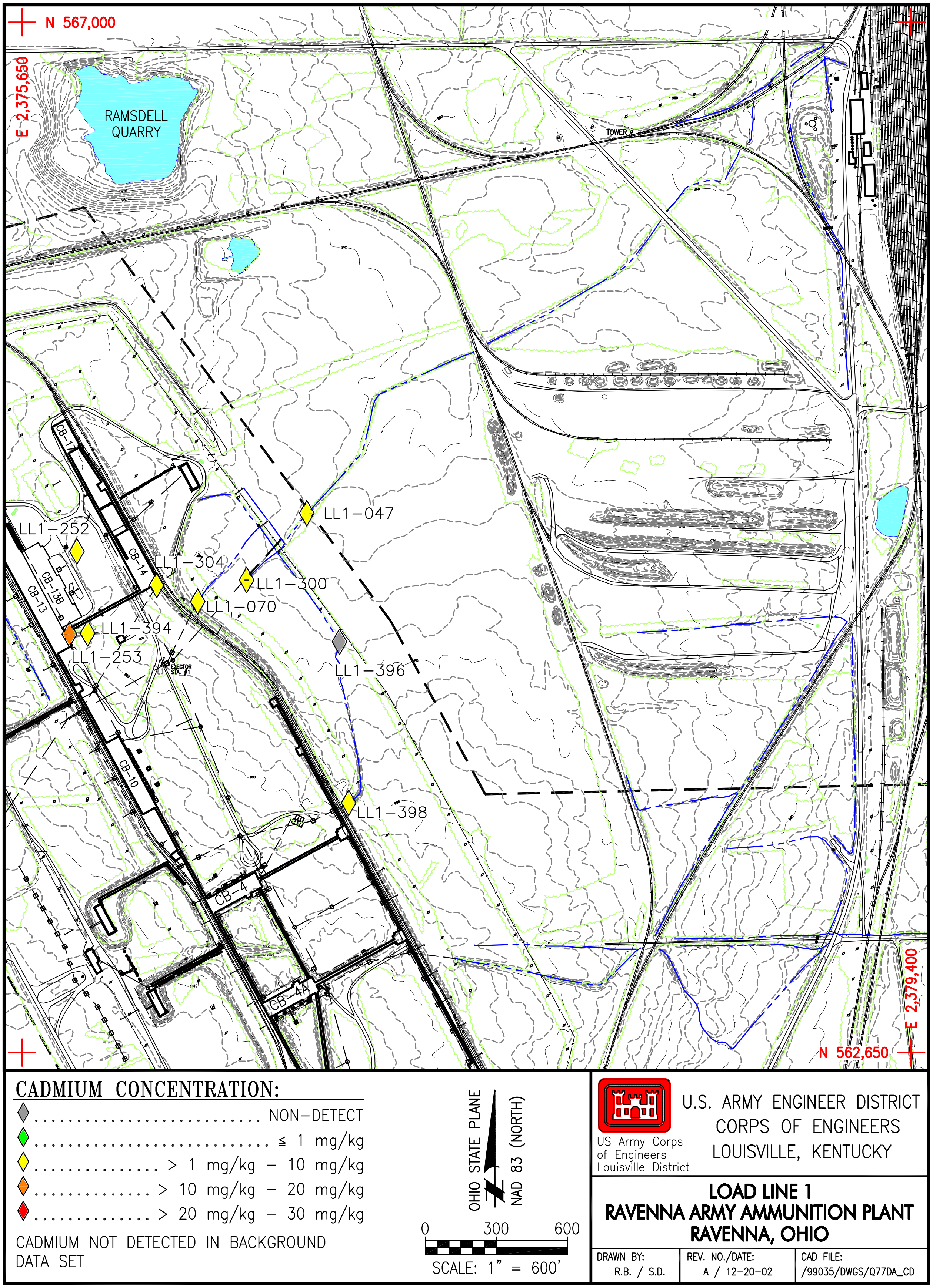


Figure 4-25. Distribution of Explosives/Propellants in Sediment in Off-AOC Sample Locations



CADMIUM CONCENTRATION:

- ◆ .... NON-DETECT
- ◆ .... ≤ 1 mg/kg
- ◆ .... > 1 mg/kg – 10 mg/kg
- ◆ .... > 10 mg/kg – 20 mg/kg
- ◆ .... > 20 mg/kg – 30 mg/kg

CADMIUM NOT DETECTED IN BACKGROUND DATA SET

US Army Corps
of Engineers
Louisville District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

LOAD LINE 1
RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R.B. / S.D.	A / 12-20-02	/99035/DWGS/Q77DA_CD

Figure 4-26. Distribution of Cadmium in Sediment at Outlets A and B

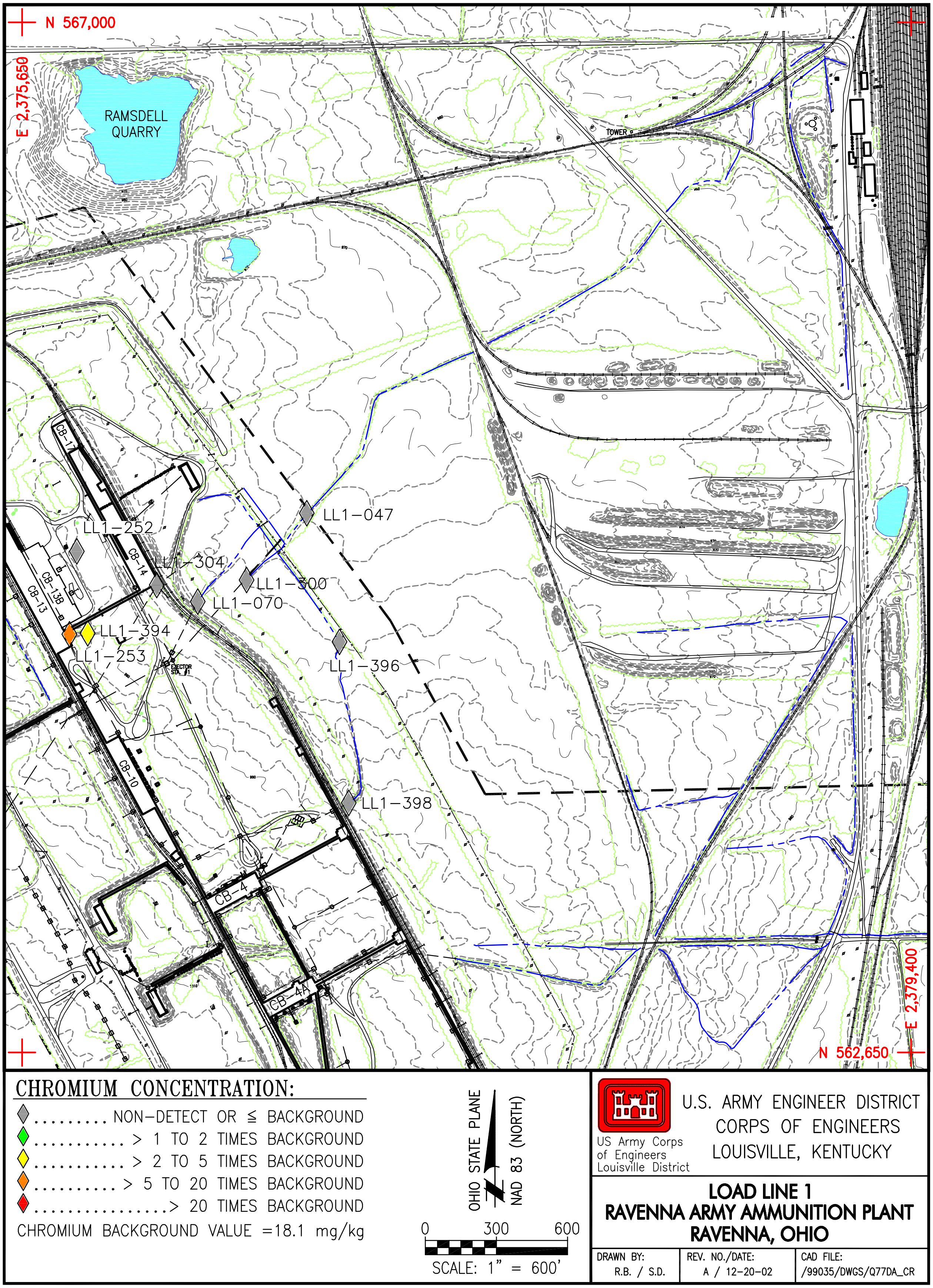


Figure 4-27. Distribution of Chromium in Sediment at Outlets A and B

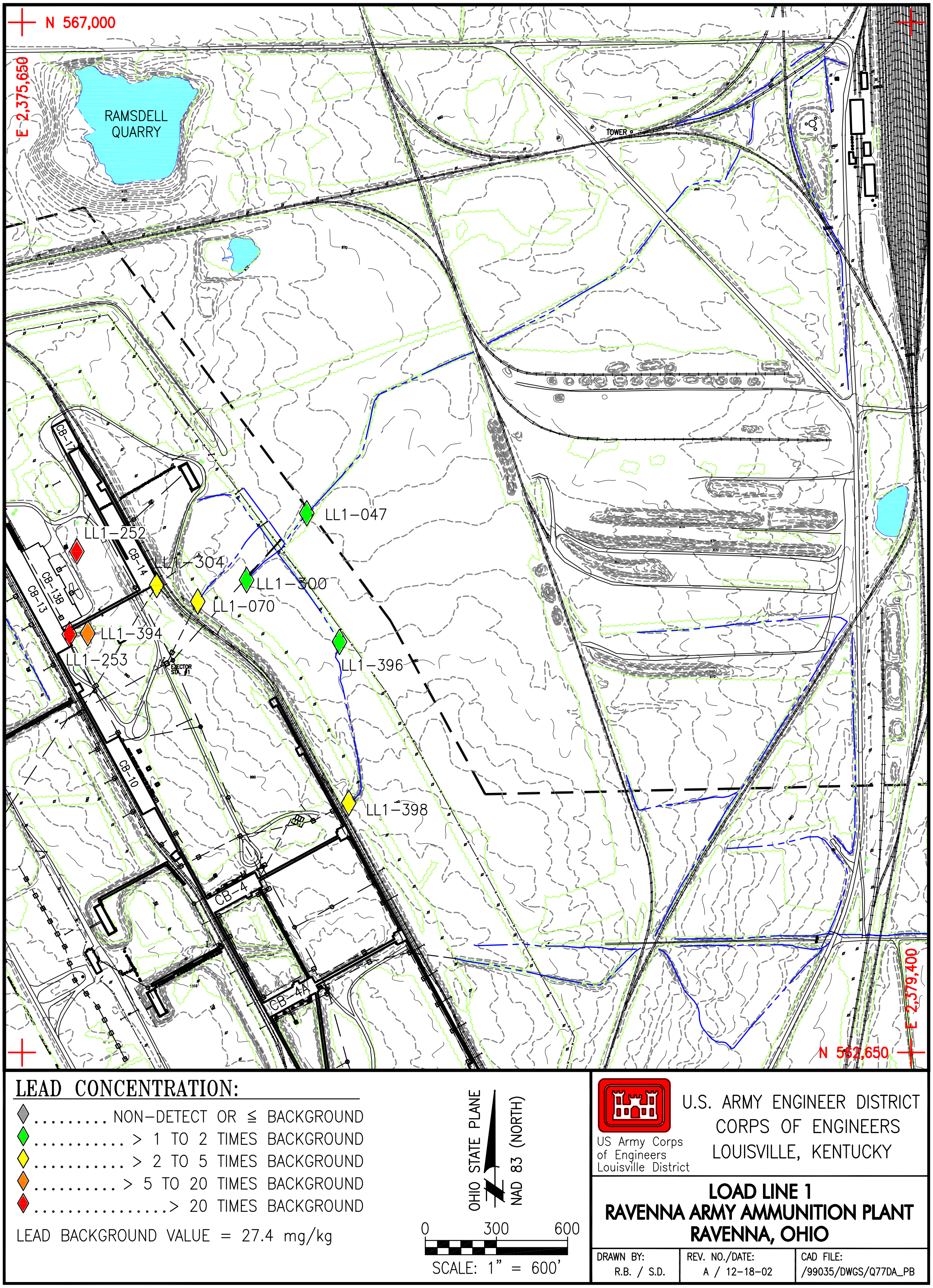


Figure 4-28. Distribuition of Lead in Sediment at Outlets A and B

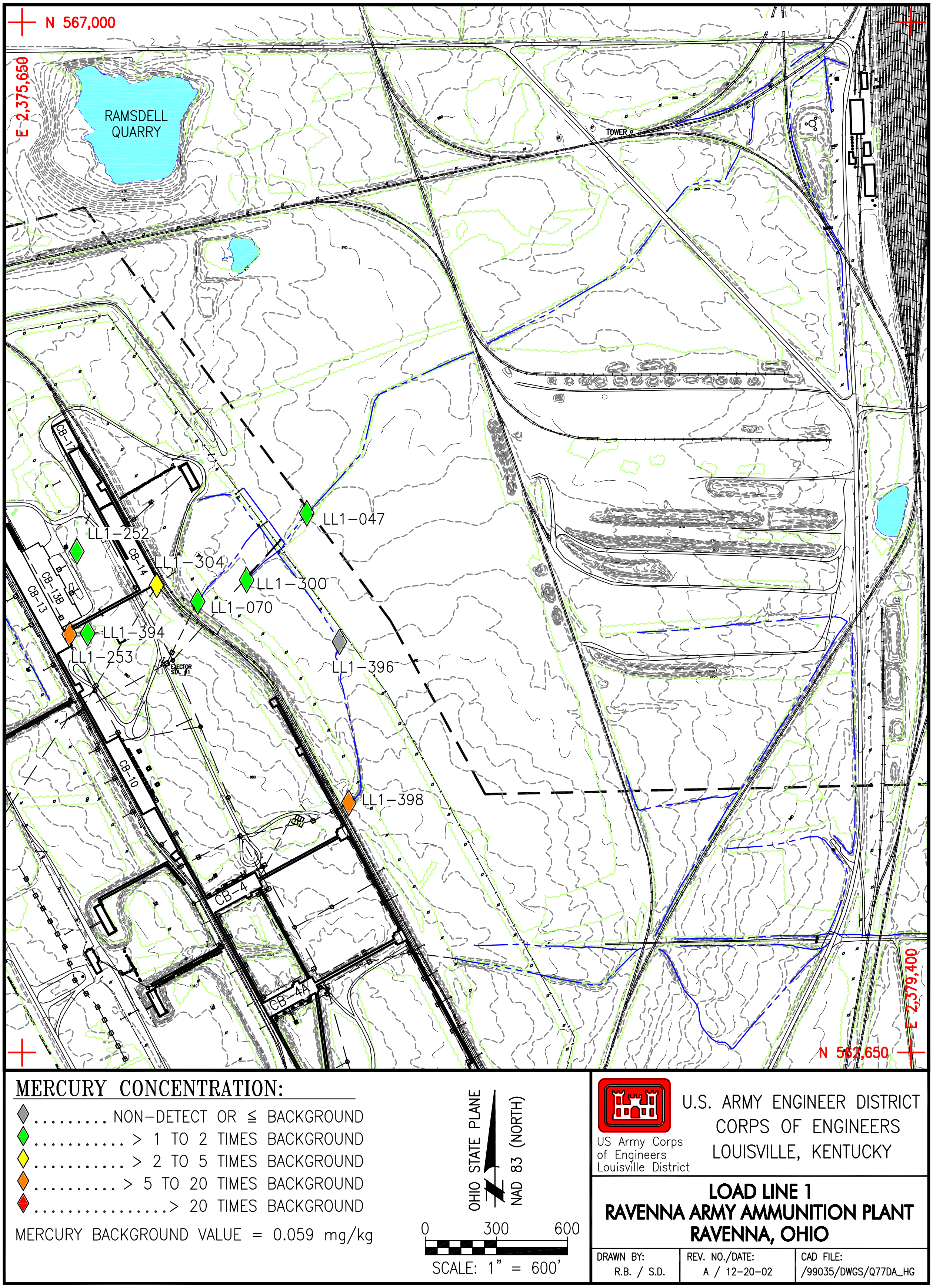


Figure 4-29. Distribution of Mercury in Sediment at Outlets A and B

had comparatively high concentrations relative to background values. Samples collected from station LL1-253 had the most inorganic constituents detected above background; this station is near Buildings CB-13 and CB-13B and is also the location of the highest explosive detection in sediment at LL 1. Maximum detections of metals above background occurred at four stations: LL1-253 for aluminum, antimony, barium, cadmium, chromium, copper, mercury, nickel, selenium, vanadium, and zinc; LL1-396 for arsenic, beryllium, and cobalt; LL1-070 for thallium; and LL1-252 for lead (see Table 4-39 for concentrations). Lead, copper, mercury, and chromium were detected at the highest concentrations with respect to their background values; their maximum concentrations exceeded background by factors of 42, 16, 9, and 8 times, respectively.

The highest detections of several metals in any LL 1 sediment sample occurred within Outlets A and B. The highest detections of cadmium, chromium, mercury, nickel, and zinc occurred at LL1-253; the highest detection of lead occurred at LL1-252; the highest detection of thallium occurred at LL1-070; and the highest detection of cobalt occurred at LL1-396.

Several metals were detected above background at station LL1-047, which lies at the AOC boundary within the main ditch that drains LL 1 to the northeast. However, only two non-nutrient metals (beryllium and cadmium) were detected slightly above background at the off-AOC station LL1-319, which lies within the same ditch further downstream and off-site. Therefore, most site-related metals are not migrating far from the AOC along this route.

4.4.3.2 Outlet C and Charlie’s Pond

All TAL metals except aluminum, silver, thallium, vanadium, and zinc were detected above background criteria for metals in Outlet C and Charlie’s Pond area. Distributions of selected metals (arsenic, cadmium, mercury, and lead) in Outlet C are presented in Figures 4-30 and 4-31. These metals were either the most frequently detected or had the highest concentrations relative to background. Maximum detections on metals above background criteria occurred at five stations: LL1-048 for antimony, cadmium, lead, and selenium; LL1-288 for barium, cobalt, and manganese; LL1-286 for beryllium; LL1-060 for arsenic; and LL 1 for mercury (Table 4-39).

The highest detection of arsenic in any LL 1 sediment sample occurred within Outlet C, at station LL1-060.

Detections of several metals at station LL1-320 indicate that many metals are being transported down the length of Outlet C and past the off-AOC boundary.

4.4.3.3 Outlets D, E, and F and Criggy’s Pond

All TAL metals except aluminum, magnesium, potassium, silver, sodium, and thallium were detected above background criteria for metals in Outlets D, E, and F and Criggy’s Pond. Distributions of selected metals (cadmium, copper, mercury, and lead) in Outlets D, E, and F and Criggy’s Pond are presented in Figures 4-32 and 4-33. These metals were either the most frequently detected or had the highest concentrations relative to background. Maximum detections on metals above background criteria occurred at three stations: LL1-397 for arsenic, beryllium, cadmium, copper, nickel, selenium, vanadium, and zinc; LL1-049 for antimony, chromium, cobalt, and lead; and LL1-399 for barium, manganese, and mercury. Lead and copper were detected at unusually high concentrations with respect to their background values in this drainage; their maximum concentrations exceeded background by 44 and 37 times, respectively (see Table 4-39).

Hexavalent chromium was detected at one station, LL1-397, which is the station with the most inorganic compounds detected above background and the greatest number of maximum detections (Table 4-37).

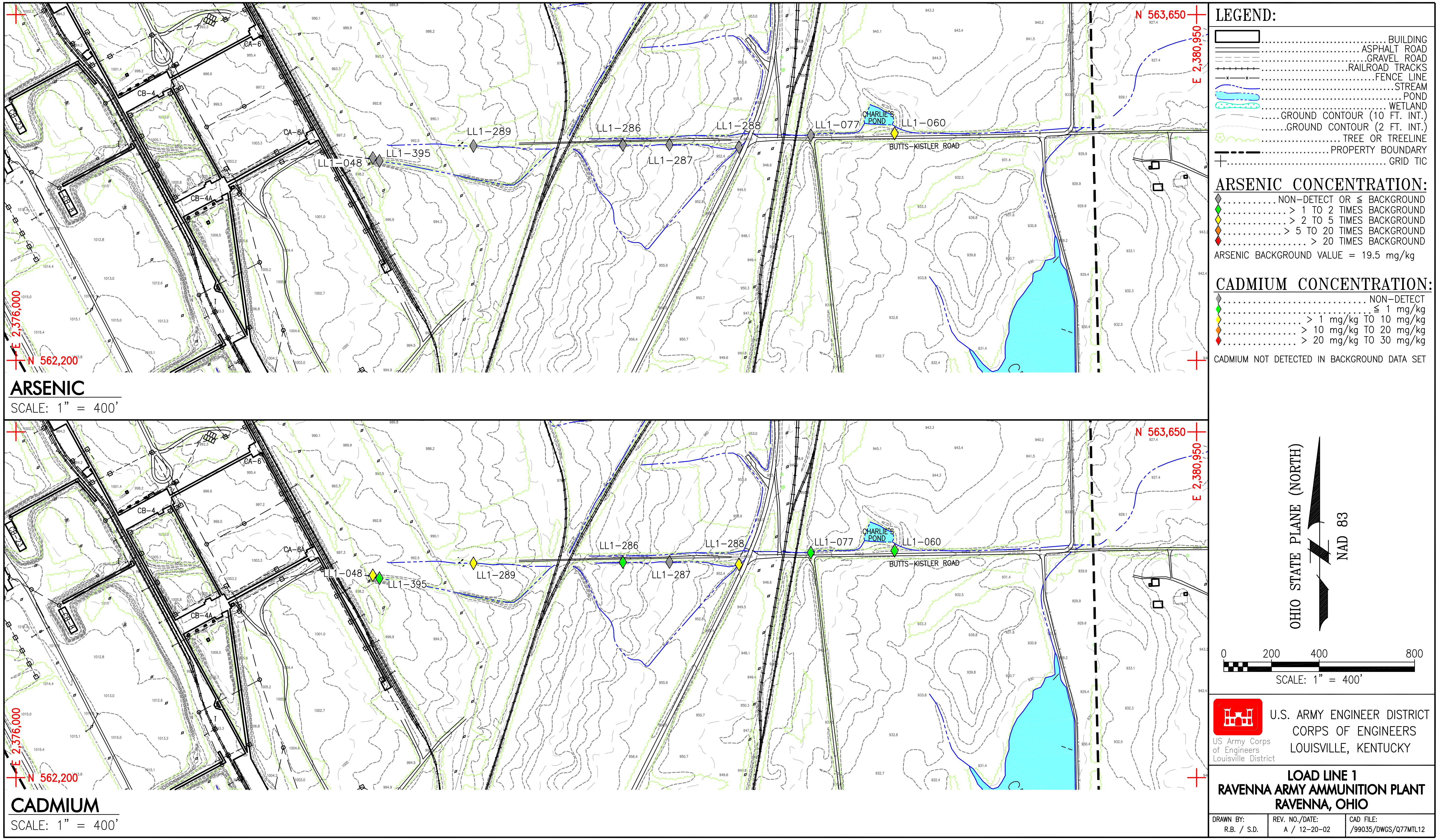


Figure 4-30. Distribution of Arsenic and Cadmium in Sediment at Outlet C and Charlie's Pond

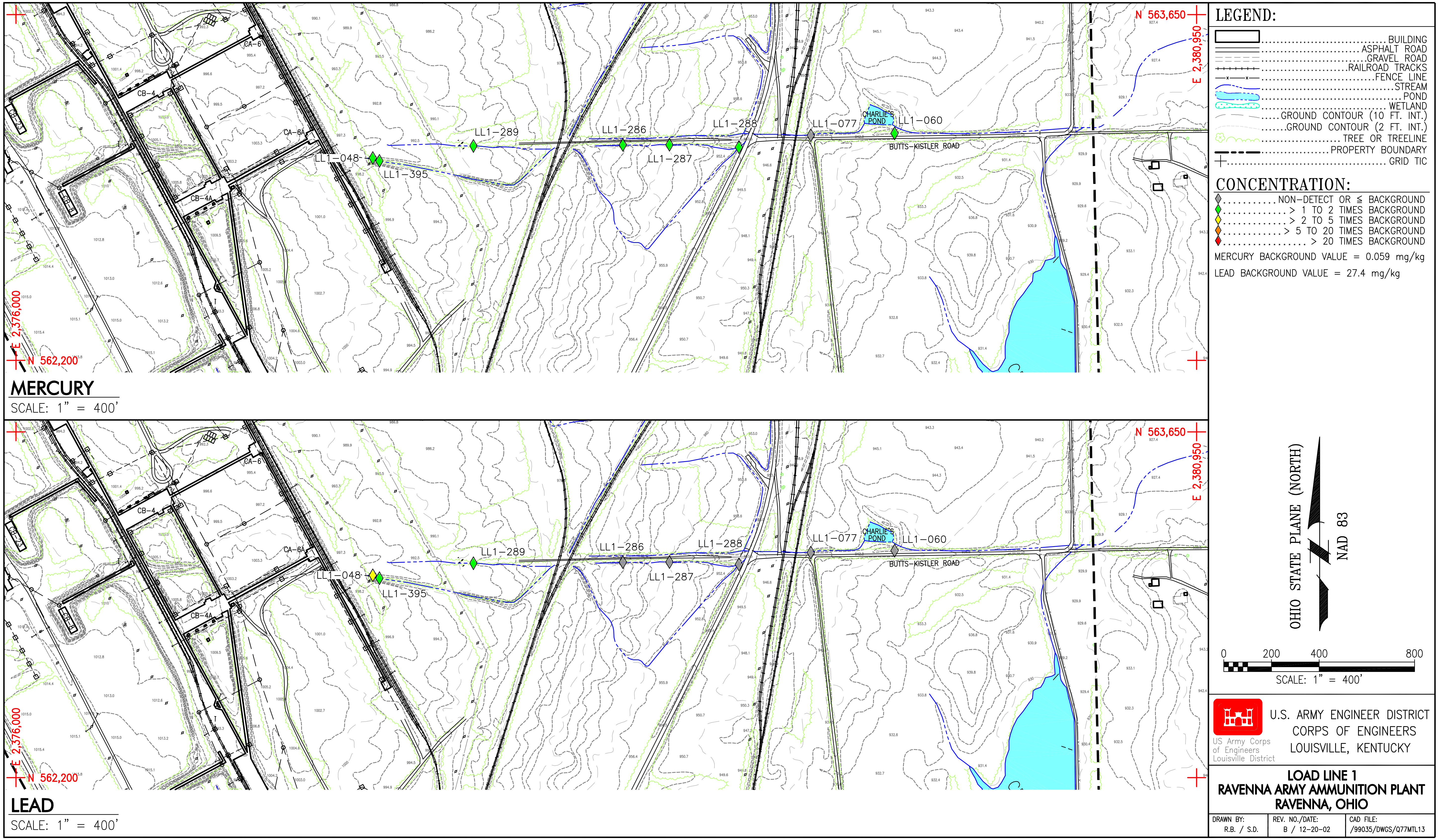
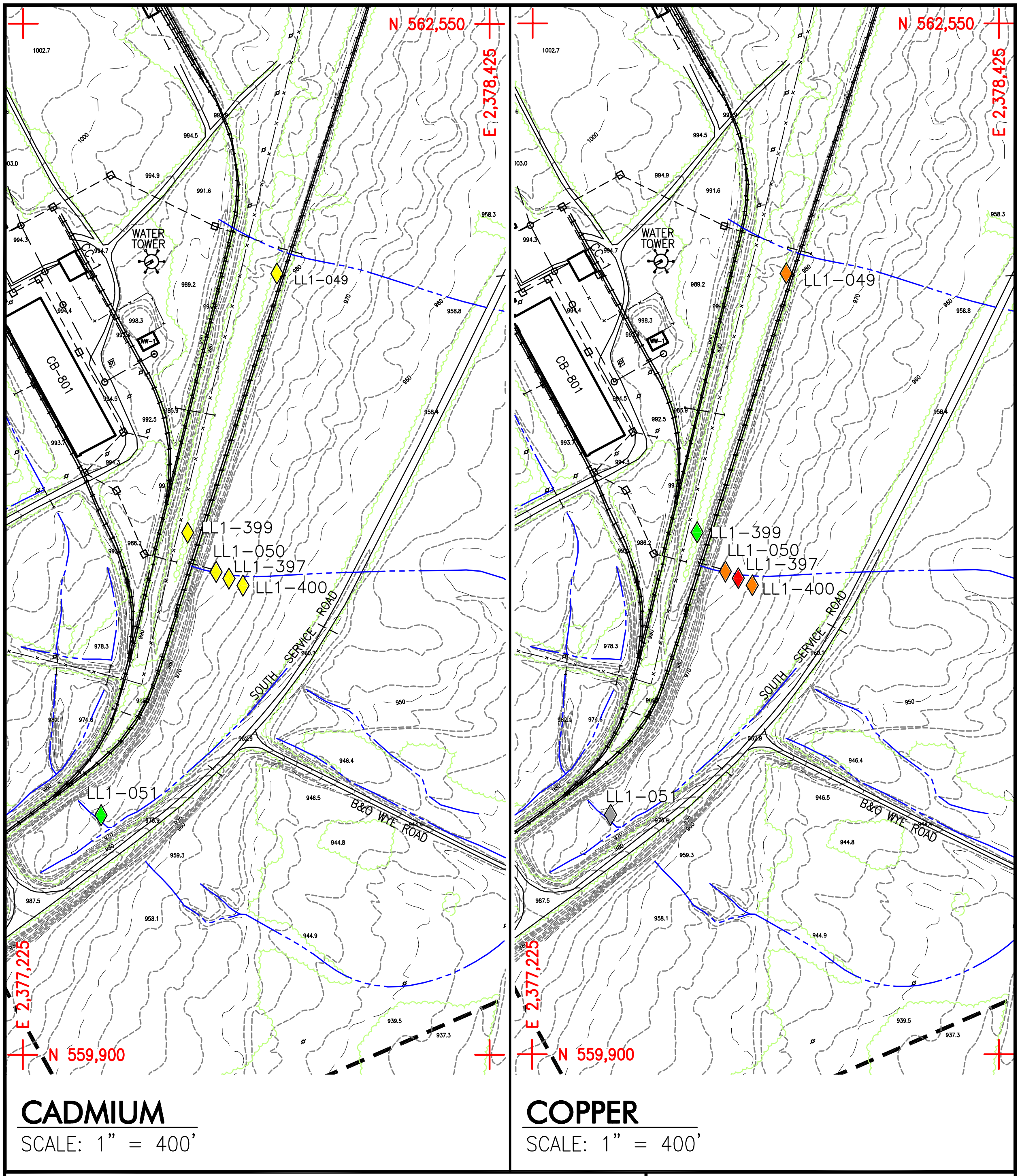


Figure 4-31. Distribution of Mercury and Lead in Sediment at Outlet C and Charlie's Pond



CADMIUM CONCENTRATION:

- ◆ .... NON-DETECT
- ◆ .... ≦ 1 mg/kg
- ◆ .... > 1 mg/kg TO 10 mg/kg
- ◆ .... > 10 mg/kg TO 20 mg/kg
- ◆ .... > 20 mg/kg TO 30 mg/kg

CADMIUM WAS NOT DETECTED IN BACKGROUND DATA SET

COPPER CONCENTRATION:

- ◆ .... NON-DETECT OR ≦ BACKGROUND
- ◆ .... > 1 TO 2 TIMES BACKGROUND
- ◆ .... > 2 TO 5 TIMES BACKGROUND
- ◆ .... > 5 TO 20 TIMES BACKGROUND
- ◆ .... > 20 TIMES BACKGROUND

COPPER BACKGROUND VALUE = 27.6 mg/kg

OHIO STATE PLANE
NAD 83 NORTH

0 200 400
SCALE: 1" = 400'

US Army Corps
of Engineers
Louisville District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

LOAD LINE 1
RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R.B. / S.D.	A / 12-20-02	/99035/DWGS/Q77MTL10

Figure 4-32. Distribution of Cadmium and Copper in Sediment at Outlets D, E, and F and Criggy's Pond

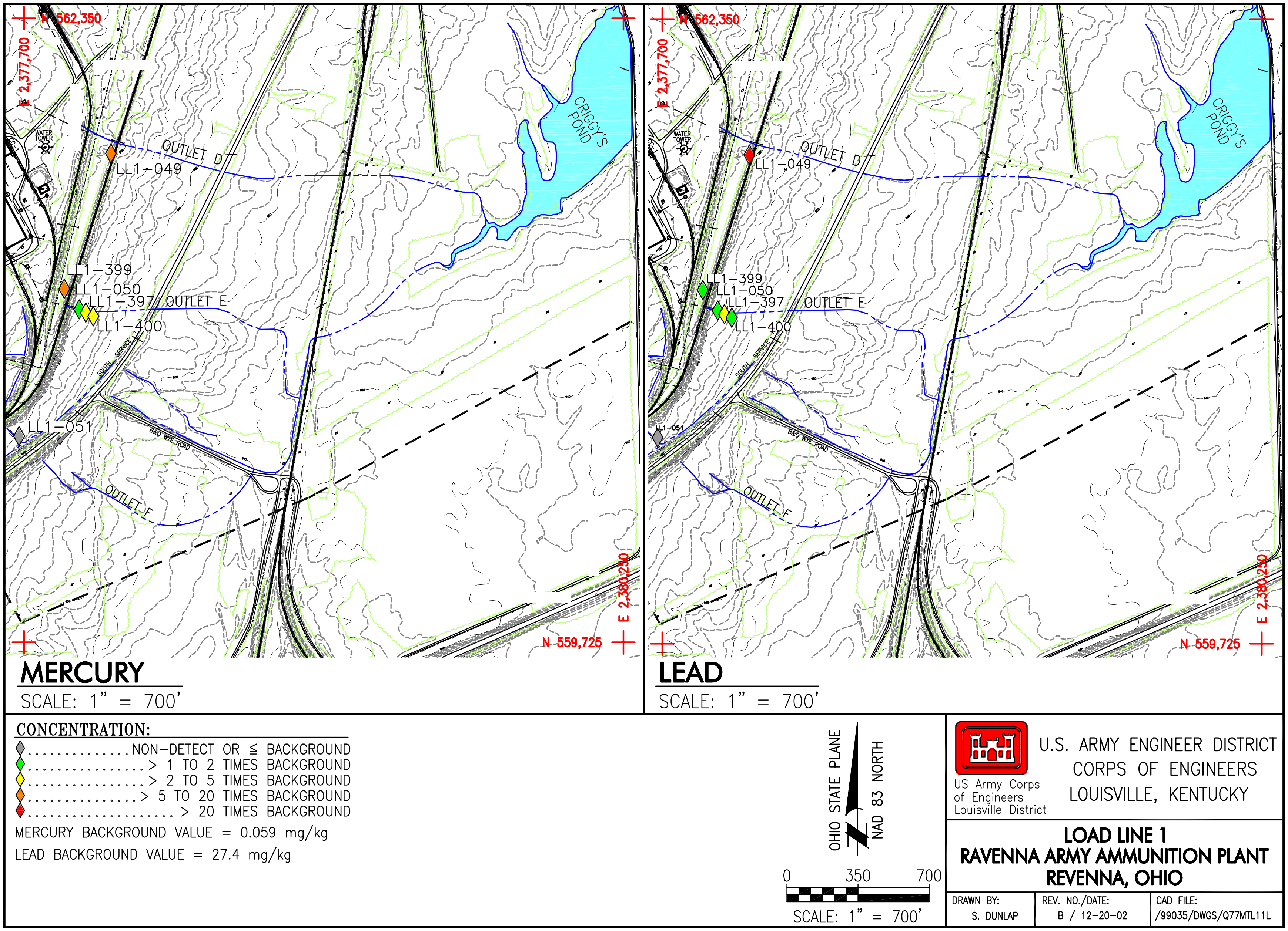


Figure 4-33. Distribution of Mercury and Lead in Sediment at Outlets D, E, and F and Criggy's Pond

The highest concentrations of barium (LL1-399), copper (LL1-397), and manganese (LL1-399) in any LL 1 sediment sample occurred within Outlets D, E, and F and Criggy's Pond.

4.4.3.4 North Area

One sample was collected from sediments at station LL1-046 in the North Area and analyzed for inorganic constituents. Seven TAL metals were detected at this station above their background criteria: barium, beryllium, cadmium, cobalt, lead, mercury, and nickel (Table 4-39).

4.4.3.5 Off-area of concern

Nine TAL metals were detected above background criteria at least once in the off-AOC area. Cadmium was detected above background at every station where it was analyzed. The other eight detected TAL metals were arsenic, beryllium, chromium, cobalt, copper, mercury, nickel, and selenium. Maximum detections for these metals occurred at two stations: LL1-318 for beryllium, cobalt, and mercury; LL1-320 for arsenic, cadmium, chromium, copper, nickel, and selenium (see Table 4-39). Cadmium, cobalt, and nickel were most likely transported to off-AOC stations, except LL1-318, in process-related effluents through Outlet C.

4.4.4 Semivolatile Organic Compounds, Volatile Organic Compounds, and Polychlorinated Biphenyls

Ten SVOCs, five VOCs, and three PCBs/pesticides were detected in five sediment samples collected and analyzed for these constituents. The most commonly detected SVOCs were benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and fluoranthene, each with three detections. The most commonly detected VOC was acetone, with three detections, and the most commonly detected PCB was PCB-1254, with two detections.

4.4.4.1 Outlets A and B

A total of 18 SVOCs were detected at LL1-398 and LL1-304, the only stations in Outlet A/B analyzed for organic compounds: (see Table 4-40). Three VOCs were detected at these stations: 1,2-DCE, toluene, and TCE (see Table 4-41). Three PCBs/pesticides were detected at these stations: endrin, PCB-1254 and gamma-chlordane (see Table 4-42).

4.4.4.2 Outlet C and Charlie's Pond

Ten PAHs were detected in sediment at two stations in the Outlet C and Charlie's Pond area: LL1-048 and LL1-077. Compounds with the highest detected concentrations were benzo(b)fluoranthene (0.18 mg/kg) and pyrene (0.15 mg/kg), both at station LL1-048. The remaining eight detected compounds [benzo(a)anthracene, benzo(a)pyrene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, and phenanthrene] were present at concentrations ranging from 0.054 mg/kg to 0.14 mg/kg. No other SVOCs were detected in sediment samples (Table 4-40).

Two VOCs, 1,2-DCE and acetone were detected in sediment at stations LL1-048 and LL1-077, respectively. No other VOCs were identified in sediment samples (Table 4-41).

Two PCBs/pesticides were detected in sediment at station LL1-048 (4,4'-DDE and PCB-1254); none were detected at LL1-077. No other PCBs/pesticides were identified in sediment samples (Table 4-42).