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Environmental Services

Via email and certified mail
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March 4, 2014

Mr. Jacinto Soto
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Berkeley, CA 94710-2737

Subject: Lawrence Berkeley National Laboratory (LBNL) Workplan for Conducting Supplemental Soil Vapor Sampling at the Former Bevatron Site

Dear Mr. Soto,

Attached for your review and approval is the *Workplan for Conducting Supplemental Soil Vapor Sampling at the Former Bevatron Site*. This workplan supplements LBNL's 2010 *Preliminary Subsurface Investigation Workplan for the Building 51 and Bevatron Demolition Project* (*2010 Workplan*).

The rationale for the proposed work was discussed at the December 3, 2013 meeting held at your office. The need for additional sampling is based on soil vapor sampling results conducted in accordance with requirements specified in the *2010 Workplan* that indicate a potential threat to the health of future indoor workers through the vapor intrusion pathway should this area eventually be developed. The proposed soil vapor sampling would serve the following purposes:

- further delineate the magnitude and extent of the soil vapor contamination previously detected in the former Bevatron area
- better evaluate the potential threat to the health of future indoor workers
- help select and design mitigation measures and/or corrective measures that might be required to protect the health of potential future indoor workers

The attached supplemental workplan also provides a conceptual site model (CSM) and a discussion of data quality objectives (DQOs), which are required for compliance with DTSC's 2012 *Advisory Active Soil Gas Investigations.*

Please contact David Baskin (dabaskin@lbl.gov) at 510-486-5684 or me (ropauer@lbl.gov) at 510-486-7614 if you have any questions or require additional information.

Sincerely,

Ron Pauer

Ron Pauer
Environmental Manager

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Workplan for Conducting Supplemental Soil Vapor Sampling at the Former Bevatron Site

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WORKPLAN FOR CONDUCTING SUPPLEMENTAL SOIL VAPOR SAMPLING AT THE FORMER BEVATRON SITE

(Supplement to the Preliminary Subsurface Investigation Workplan for the Building 51 and Bevatron Demolition Project)

Lawrence Berkeley National Laboratory
Environmental Services Group
Environmental Restoration Program

March 2014

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WORKPLAN FOR CONDUCTING SUPPLEMENTAL SOIL VAPOR SAMPLING AT THE FORMER BEVATRON SITE

(Supplement to the Preliminary Subsurface Investigation Workplan for the Building 51 and Bevatron Demolition Project)

Lawrence Berkeley National Laboratory
Environmental Services Group
Environmental Restoration Program

March 2014

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APPENDIX A: PROCEDURE FOR COLLECTING SOIL VAPOR SAMPLES

LIST OF ABBREVIATIONS

amsl	above mean sea level
α	Attenuation Factor (for vapor intrusion)
bgs	below ground surface
Cal/EPA	California Environmental Protection Agency
CSM	Conceptual Site Model
DQOs	Data Quality Objectives
DTSC	Cal-EPA Department of Toxic Substances Control
ERP	Environmental Restoration Program
FY	Fiscal Year
HI	Hazard Index
HQ	Hazard Quotient
HSPP	Health and Safety Program Plan
ICM	Interim Corrective Measure
ILCR	Incremental Lifetime Cancer Risk
LARWQCB	Los Angeles Regional Water Quality Control Board
LBNL	Lawrence Berkeley National Laboratory
MIP	Membrane Interface Probe
mg/kg	milligrams per kilogram
QAPP	Quality Assurance Program Plan
QL	Quantitation Limit
µg/L	micrograms per liter (10^{-6} grams per liter)
$\mu g/m^3$	micrograms per cubic meter
PCE	Tetrachloroethylene (Perchloroethene)
ppbv	parts per million by volume air
RSL	Remedial Screening Level
SOP	Standard Operating Procedure
SWRCB	State Water resources Control Board
TCE	Trichloroethylene
VOCs	Volatile Organic Compounds
WSP	Worksite Safety Plan

1.0 INTRODUCTION

1.1 BACKGROUND

Between September 2010 and February 2012, Lawrence Berkeley National Laboratory (LBNL) investigated potential subsurface contamination beneath the Bevatron Demolition Project area. On August 6, 2012, LBNL submitted the *Report of Environmental Investigations in the Former Building 51 Vacuum Pump Room and Former Building 51A Areas* (*2012 Investigation Report*) (LBNL, 2012) to the California Environmental Protection Agency (Cal/EPA) Department of Toxic Substances Control (DTSC). As described in the *2012 Investigation Report*, volatile organic compound- (VOC) contaminated soil, soil vapor, and groundwater were present in a previously identified area of contamination in the vicinity of former Building 51L and in two newly identified areas: 1) beneath the former location of Building 51A and 2) under the former Building 51 Vacuum Pump Room and adjacent Cooling Tower areas. The former location of the Bevatron and the locations of the areas of contamination are shown on Figure 1 and Figure 2.

1.2 PURPOSE AND SCOPE

The former Bevatron site is a large flat area that is currently paved and used for vehicle parking. Since flat undeveloped areas are a scarce resource at LBNL, the Bevatron site is a potential site for future facility development. Contamination at the Bevatron site poses no unacceptable risks to current site workers, but soil vapor sampling results indicate the potential for health risks to future indoor workers through the vapor intrusion pathway (soil vapor migrating into indoor air). LBNL plans to conduct supplemental soil vapor sampling to further evaluate the magnitude and extent of the soil vapor contamination. The soil vapor sampling results will be used to help select and design mitigation measures and/or corrective measures that might be required to protect the health of future indoor workers should this site be developed.

Soil vapor sampling results in the former Building 51A area, the former Vacuum Pump Room/Cooling Tower area, and the former Building 51L area were reported to DTSC in the

2012 Investigation Report. Those results were based on analysis of soil vapor samples primarily collected in 2011 as part of the Bevatron Demolition Project investigation. The 2011 samples were collected in accordance with the scope of work described in the *Preliminary Subsurface Investigation Workplan for the Building 51 and Bevatron Demolition Project* (*2010 Workplan*) (LBNL, 2010).

The current workplan is a supplement to the *2010 Workplan*, and proposes additional soil vapor sampling to further delineate the magnitude and extent of the soil vapor contamination previously detected in the former Bevatron area. The current workplan also provides a conceptual site model (CSM) and a discussion of data quality objectives (DQOs), both of which are required for compliance with the most recent soil vapor sampling guidance published by Cal/EPA (Cal/EPA, 2012a).

The following sections include a summary of sampling results previously reported to DTSC (LBNL, 2007; LBNL, 2008; LBNL, 2012a; and LBNL, 2013a), and a description of the scope of the proposed supplemental sampling.

2.0 POTENTIAL RISK TO HUMAN HEALTH AND THE ENVIRONMENT

2.1 EXPOSURE PATHWAYS OF POTENTIAL CONCERN

Based on comparison of contaminant concentration data with EPA Regional Screening Levels (RSLs) (http://www.epa.gov/region9/superfund/prg/) and DTSC-modified RSLs (DTSC, 2013a), the potential human health risk pathways of primary concern for the three Bevatron contamination areas described above (Vacuum Pump Room/Cooling Tower, Building 51A, and Building 51L) are:

- Inhalation by future indoor workers of VOCs volatilizing from soil to soil vapor and subsequent migration into indoor air
- Inhalation by future indoor workers of VOCs volatilizing from groundwater to soil vapor and subsequent migration to indoor air

In addition, direct exposure to soil is a potential concern for outdoor workers in the Vacuum Pump Room/Cooling Tower area due to the presence of VOCs at concentrations exceeding RSLs at shallow depth in two limited areas.

It is important to note that the indoor air inhalation exposure pathways are incomplete for current site workers because there are no buildings in the vicinity of the contamination. The direct contact pathway is also incomplete because the areas of shallow soil contamination are protected by institutional controls (signage and a permit process for digging).

In addition to potential human health risks, contamination in all three areas has the potential to impact beneficial uses of groundwater (i.e. domestic use) in areas where groundwater meets State Water Resources Control Board (SWRCB) criteria for potential drinking water sources (SWRCB Resolution No. 88-63), and/or to result in violation of the SWRCB antidegradation policy (SWRCB Resolution No. 68-16) if contaminated groundwater migrates to areas of clean groundwater. The groundwater at LBNL is not used for any purpose including domestic, irrigation, or industrial supply. Migration of contaminated groundwater in the Building

51L and Building 51A areas is controlled by the groundwater remediation system operating at Building 51L (LBNL, 2007) and migration in the Vacuum Pump Room/Cooling Tower area is controlled by the DTSC-approved Interim Corrective Measure (ICM) that was recently implemented by LBNL (LBNL, 2014).

2.2 PROCESS FOR ESTIMATING POTENTIAL INDOOR AIR RISK FOR FUTURE BUILDING OCCUPANTS

As noted above, the primary threat to human health associated with Bevatron area contamination is through the vapor intrusion pathway (i.e. VOC-contaminated soil vapor migrating into indoor air). The potential risk to human health from this pathway was determined in accordance with DTSC guidance (DTSC, 2013b) as follows:

1) The following equation was used to estimate the indoor air concentration that would result from migration of soil vapor contaminants into indoor air.

$$C_{indoor}=(\alpha)x(C_{soil\ vapor})$$

Where:
α=Attenuation factor, the ratio of the concentration of the VOC in indoor air to the concentration of the VOC in soil vapor
$C_{soil\ vapor}$ =Measured soil vapor concentration in $\mu g/m^3$
C_{indoor}=Calculated indoor air concentration in $\mu g/m^3$

An attenuation factor (α) of 0.0005 was used for the calculation. This attenuation factor was obtained from Table 2-Attenuation Factors for Preliminary Screening Evaluations (for future commercial buildings) in DTSC guidance (DTSC, 2011).

2) For carcinogens, the indoor air concentration was divided by the DTSC-recommended industrial indoor air screening level (DTSC, 2013a) and multiplied by 10^{-6} to calculate the theoretical incremental lifetime cancer risk (ILCR) for that chemical. For non-carcinogens, the Hazard Quotient (HQ) was estimated by dividing the indoor air concentration by its screening level. The total ILCR at each soil vapor sampling location was determined by summing the individual cancer risks for each chemical. The total non-cancer risk – that is, the Hazard Index (HI) – at each soil vapor sampling location was determined by summing the HQs of each chemical.

In general, an HI greater than 1.0 or a theoretical ILCR greater than 10^{-6} indicates the presence of contamination that may pose a "significant" threat to human health (DTSC, 2013b).

3.0 CONCEPTUAL SITE MODEL

Several primary components of the CSM for the Building 51 Vacuum Pump Room/Cooling Tower area and the Building 51A area are provided in the *2012 Investigation Report*, including detailed descriptions of the geology; hydrogeology; possible release sources; and the distribution of the soil, groundwater and soil vapor contamination. For the Building 51L area, those CSM components (with the exception of soil vapor contamination) are presented in the LBNL *Corrective Measures Study Report* (LBNL, 2005). Soil vapor sampling results for the Building 51L area are presented in the LBNL fourth quarter fiscal year (FY) 2008 *Quarterly Progress Report and Annual Summary* (LBNL, 2008) and summarized in the *2012 Investigation Report*. The reports referenced above are incorporated herein by reference and brief summaries of the CSM components provided in those reports are presented in the following site-specific subsections. The CSM components are compiled below in order to comply with Cal/EPA's most recent soil vapor sampling guidance that recommends that a CSM should be included as a component of a soil gas sampling workplan (Cal/EPA, 2012a).

3.1 BUILDING 51 VACUUM PUMP ROOM AND COOLING TOWER AREA

As described in the *2012 Investigation Report*, soil contamination in the Vacuum Pump Room/Cooling Tower areas consists primarily of trichloroethylene (TCE) and is generally limited to the artificial fill at the east edge of the air duct shafts and near the retaining wall separating the Vacuum Pump Room area from the Cooling Tower area. Except at the former location of temporary groundwater sampling point SB51-11-9, where soil contamination extends to a depth of about 25 feet, soil contamination is relatively shallow (Figure 3, Figure 4, and Figure 5). The maximum detected contamination (230 mg/kg of TCE) was detected at a depth of 12 feet in SB51-11-9. The limited vertical extent of soil contamination in this area is due to the relatively low permeability of the Orinda Formation siltstone that underlies the fill. SB51-11-9 was properly destroyed in 2013 and groundwater extraction well EW51-13-1 was installed at the same location as an ICM.

The primary source of the contamination in the Cooling Tower Area is suspected to have been a sump that was located adjacent to the retaining wall forming the northern boundary of the area. The source of contamination in the Vacuum Pump Room area may have been migration beneath the retaining wall from that sump, or could possibly have been from a secondary source within the Vacuum Pump Room.

Concentrations of VOCs detected in groundwater during the fourth quarter of FY13 are shown on Figure 6. Prior to recent implementation of the DTSC-approved ICM (LBNL, 2013b), contaminated groundwater was migrating westward from the Vacuum Pump Room area into the clean backfill that had been placed in the air duct shafts following demolition of the Bevatron. The ICM consisted of installation of a groundwater extraction well (EW51-13-1) in the Vacuum Pump Room at the location shown on Figure 6. As described in the *Interim Corrective Measures Report for Controlling the Migration of Contaminated Groundwater at the Former Building 51 Bevatron Site* (LBNL, 2014), water level drawdowns measured in wells in the Vacuum Pump Room area indicate that the ICM has been effective in controlling the westward flow of contaminated groundwater.

Soil vapor sampling results in the Vacuum Pump Room and Cooling Tower areas are shown on Figure 7. One soil vapor sample in the Vacuum Pump Room area (SG51-10-34) and two in the Cooling Tower area (SG51-11-10 and SG51-11-11) contained significant soil vapor concentrations (VOCs at levels that could pose a threat to the health of future indoor workers through the vapor intrusion pathway). SG51-10-34 was located where SB51-11-9 was later installed and then replaced by EW51-13-1. This location is where the maximum TCE concentration was detected in Vacuum Pump Room area soil.

3.2 BUILDING 51A AREA

As described in the *2012 Investigation Report*, soil contamination in the former Building 51A area consists primarily of TCE and carbon tetrachloride and is present in a relatively narrow band extending from the Building 51A active catch basin towards the Building 51A abandoned catch basin (Figure 8). The top of the contamination is relatively shallow (approximately 6 to 10 feet below ground surface [bgs]) in the area of the Building 51A active catch basin and deepens

northwards to approximately 20 feet near the Building 51A abandoned catch basin (Figure 9). The base of the contamination drops fairly rapidly from about 10 feet bgs near the active catch basin to approximately 30 feet bgs toward the north. The contamination is restricted to the clayey silty artificial fill, which is underlain at a depth of about 30 feet bgs by fractured shale bedrock of the Great Valley Group. As shown on Figure 9, membrane interface probe (MIP) survey results support these conclusions.

The data suggests two possible explanations for the source of the release: 1) The relatively shallow contamination to the north and east of the Building 51A active catch basin suggests that the source was a possible surface spill in that area and/or 2) The configuration of the contamination, which extends in a relatively narrow band along and beneath the abandoned storm drain line between the active and abandoned catch basins, indicates a release from the storm drain line was the source.

Groundwater monitoring data indicate that the migration of contaminated groundwater is currently controlled. Contaminated groundwater flows northward from the Building 51A area and is captured by two groundwater extraction wells: EW51A-06-1, which was installed in the Building 51A abandoned catch basin, and EW51L-06-1, which was installed in the Building 51L remedial excavation. Concentrations of VOCs detected in groundwater during the fourth quarter of FY13 and the locations of the two extraction wells are shown on Figure 10.

Soil vapor sampling results in the Building 51A and Building 51L areas are shown on Figure 11. The maximum soil vapor concentrations detected in the Building 51A area were north of the Building 51A active catch basin where soil vapor VOC concentrations significantly exceeded levels that could pose a threat to human health through the vapor intrusion pathway. Soil vapor concentrations are relatively low further northwards towards the Building 51A abandoned catch basin. The northward decrease in concentrations likely occurs because soil contaminants are relatively shallow (primarily within the vadose zone) close to the Building 51A active catch basin but relatively deep (primarily beneath the water table) north of this area. Figure 12 shows the potential theoretical ILCR to future indoor workers in the Building 51A area via the vapor intrusion pathway based on soil vapor sampling results. (See Section 2.2 for a discussion of the methodology used to estimate the ILCR.) The area impacted by an HI greater

than 1.0 is much smaller than, and completely overlapped by, the area exceeding an ILCR of 10^{-6}, so is not shown.

3.3 BUILDING 51L AREA

Prior to implementing the DTSC-approved corrective measure for the Building 51L area, relatively high levels of VOCs (up to 45 mg/kg total TCE and tetrachloroethylene [PCE]) were present in the soil extending from near the surface to approximately 15 to 20 feet bgs. The source of the contamination appears to have been surface spills but the exact source is not known. A machine/maintenance shop was located in the area prior to the 1970s. Solvent drum racks were reportedly located at various locations in the area. Building 51L was constructed in the early 1980s as a computer support facility and demolished in 2004. An indoor air sample collected inside Building 51L in 1999 indicated no impact to indoor air quality from the potential migration of soil vapor into indoor air.

The corrective measure for Building 51L area groundwater contamination consisted of excavating contaminated soil to a maximum depth of approximately 20 feet within the area shown on Figure 8. Approximately 6 inches of gravel was placed at the base of the excavation and groundwater extraction well EW51L-06-1 was installed in the deepest (northwest) corner of the excavation. The main excavation was backfilled with clean soil. The small excavation extensions on the north and east sides of the main excavation were backfilled with lean concrete. The DTSC-required Media Cleanup Standards (MCSs) were achieved for the corrective measure; however, relatively low concentrations of VOCs (primarily TCE) remain in the former Building 51L area at relatively shallow depths (less than 10 feet bgs). The extent of this residual contamination is shown on Figure 8 and Figure 9.

In 2008, soil vapor samples were collected from the area surrounding the Building 51L remedial excavation area. The purpose of this sampling was to assess residual vapor concentrations following removal of contaminated soil from the excavation area in 2006. Soil vapor sampling results for this area are included on Figure 11. Soil vapor VOC concentrations significantly exceeded levels that could pose a threat to future human health through the vapor

intrusion pathway around much of the periphery of the Building 51L remedial excavation. Likely reasons for the presence of elevated soil vapor concentrations in this area include:

1) The detected soil vapor may be a residual “halo” around the remedial excavation that had not yet dissipated following removal of the primary source of contamination. These samples were collected only two years following excavation of contaminated soil and capping of the area with concrete.
2) The residual shallow soil contamination in this area may contribute to the soil vapor VOC concentrations detected.
3) Soil vapor may be conveyed through abandoned storm drains or storm drain backfill from the Building 51A area to the Building 51L area.

4.0 SAMPLING AND ANALYSIS PLAN

The following sections describe both the site-specific rationale and sampling locations for the proposed soil vapor sampling in each of the three areas (Vacuum Pump Room/Cooling Tower, Building 51A, and Building 51L) and the methodology for collecting the proposed samples. Vapor samples will be collected from shallow soil vapor probes installed to a depth of approximately 5 feet, except for two locations described below where clustered probes will be installed at depths of 5 and 12 feet to assess vertical variations in soil vapor concentrations.

4.1 RATIONALE AND SAMPLING LOCATIONS

Building 51 Vacuum Pump Room/Cooling Tower Areas

As noted in Section 3.1, only a single soil vapor sample was previously collected in the contaminated portion of the Vacuum Pump Room. This sample indicated that soil vapor VOC concentrations posed a potential indoor air threat at the soil contamination "hot spot" beneath the former Vacuum Pump Room; however, since it is a single sample it provides no information on the extent of the area of elevated soil vapor concentrations. Also, the result might not be representative of current site conditions since the sample was collected prior to demolition of the Bevatron and implementation of the ICM in this area. To assess the current magnitude and extent of the soil vapor contamination, LBNL proposes to install and sample additional soil vapor probes at the six locations shown in Figure 7. If soil vapor concentrations in the most westward sample(s) indicate potential indoor air risk, additional vapor probes will be installed at an approximately 20-foot spacing until the extent of elevated soil vapor VOC concentrations has been delineated. No samples are proposed to the east of the "hot spot" area because significant soil or groundwater contamination has not been detected more than a few feet east of the "hot spot". Also, the "hot spot", which is where a vapor probe is proposed, is located only about 12 feet from the retaining wall to the east.

Soil vapor samples could not be collected from five of the seven soil vapor probes previously installed in the Cooling Tower area (as shown on Figure 7) due to the presence of very shallow (3 feet bgs) perched groundwater. For this reason, and because it is unlikely that

this area will be developed in the near future, no additional soil vapor sampling is currently proposed for this area.

Building 51A Area

The magnitude and extent of elevated soil vapor concentrations in the Building 51A area have not been sufficiently delineated to determine building design requirements since previously collected soil vapor samples were located over a relatively widely-spaced irregular grid pattern. Therefore, LBNL proposes to install and sample soil vapor probes at the seven locations shown on Figure 13 (SG51A-x locations). Three of these probes will be installed at prior soil vapor sampling locations to assess any changes in concentrations that have occurred. Two probes (one at approximately 5 feet depth and one at approximately 12 feet depth) will be installed at one of the locations as shown on Figure 13.

Building 51L Area

Seven years have elapsed since the removal of the primary contaminant source in the Building 51L area and five years have elapsed since soil vapor sampling was conducted in this area in 2008. More recent activity in this general area includes the completion of the Bevatron Demolition Project, which involved the excavation and backfilling of a large area east of the Building 51L excavation. In addition, the abandoned storm drain line running through the Building 51A area was removed during the Bevatron Demolition Project and is therefore no longer a potential migration pathway for soil vapor contaminants to the Building 51L area. For these reasons, the Building 51L soil vapor plume may have dissipated significantly since it was last sampled in 2008. LBNL therefore proposes to install and sample soil vapor probes at the eight locations shown on Figure 13 (SG51L-x locations) in order to assess the current magnitude and extent of soil vapor VOC concentrations in this area. Two probes (one at approximately 5 feet depth and one at approximately 12 feet depth) will be installed at one of the locations as shown on Figure 13.

4.2 SAMPLING METHODOLOGY

The *2010 Workplan* (LBNL, 2010) specified soil vapor sampling methods and soil vapor probe construction that were compliant with guidance issued by Cal/EPA (Cal/EPA, 2003, 2004) and the Los Angeles Regional Water Quality Control Board (LARWQCB, 1997), including methods to minimize sampling apparatus volume, seal sampling apparatus and probes to avoid leaks, and employ leak testing methods to ensure the integrity of the samples. Since preparation of the *2010 Workplan* the applicable guidance documents have been updated with the issuance of the 2012 *Advisory - Active Soil Gas Investigations* (Cal/EPA, 2012a). This advisory includes only relatively minor modifications to the previously recommended procedures regarding vapor probe equilibration times, purging and sampling rates, sample containers, sample tubing, holding times, probe drive methods, and leak check compounds, as noted in Cal/EPA's *Summary of Changes, Advisory - Active Soil Gas Investigations* document (Cal/EPA, 2012b). Generally, the procedures specified for the soil vapor sampling proposed in the *2010 Workplan* comply with the 2012 Advisory, so the previous data are still valid.

All soil vapor samples proposed in this workplan will be collected in accordance with the methods specified in the 2012 Advisory. Appendix A provides the general procedure that will be followed for collecting soil vapor samples. Any deviation from the requirements specified in this procedure will be checked for compliance with Cal/EPA guidance (Cal/EPA, 2012a) prior to implementation and the deviation will be documented. All samples will be analyzed for VOCs using either EPA Method TO-15 or EPA Method 8260.

4.3 HEALTH AND SAFETY

The LBNL ES&H Manual (PUB 3000) describes the facility's general health and safety policies and responsibilities, and details the facility-specific procedures to implement these policies. In addition, all work will be conducted in accordance with the LBNL Environmental Restoration Program (ERP) Health and Safety Program Plan (HSPP) (LBNL, 2009b). In accordance with HSPP requirements, a Worksite Safety Plan (WSP) will be completed prior to the initiation of any subsurface work associated with the soil vapor sampling specified in this workplan. The WSP will describe potential contaminants and site hazards as well as specify the required personnel protective

equipment and any monitoring requirements. In addition, a Penetration Permit will be obtained from the LBNL Facilities Division prior to the start of any intrusive work.

5.0 DATA QUALITY

Sampling will be conducted in accordance with requirements of ERP's Quality Assurance Program Plan (QAPP) (LBNL, 2009a) and the Environmental Services Group's Standard Operating Procedures (SOPs). Since the QAPP does not include up-to-date data quality requirements for soil vapor sampling, the DQO process and data quality requirements for the soil vapor sampling proposed in this workplan are provided in the following subsections, and are considered to be supplemental to the QAPP.

5.1 Data Quality Objectives (DQOs)

Following is the DQO process that was followed for the activities proposed in this workplan.

Step 1 - State the Problem

Sampling at the Bevatron Site has indicated that soil vapor contaminated with VOCs poses a potential threat to human health, primarily by vapor intrusion into future buildings that may be built during redevelopment activities. The magnitude and extent of the contamination has not been sufficiently determined to be able to design mitigation measures that might be required for future site buildings and/or define the scope of corrective measures that may be required to protect future building occupants.

Step 2 - Identification of the Decision

The principal questions that will be addressed:

- What is the magnitude and extent of soil vapor VOC concentrations?
- What is the potential risk to human health from soil vapor contamination at the Bevatron site?
- Is cleanup required to reduce the potential health risks to acceptable levels or will mitigation measures for future buildings be sufficient?
- What are the appropriate screening and/or cleanup levels for contaminants in soil vapor?

Step 3 - Identify the Inputs to the Decision

The required decision inputs are magnitude and extent of elevated soil vapor VOC concentrations obtained from soil vapor samples and the planned locations of new buildings relative to areas of contaminated soil vapor.

Step 4 - Define the Boundaries of the Site

The boundaries of the site are the areas of the Vacuum Pump Room and Building 51A/Building 51L shown in the boxes on Figure 2.

Step 5 - Develop a Decision Rule

The process specified in Section 2.2 will be followed to estimate indoor air concentrations from soil vapor data. The DTSC has published DTSC-modified RSLs for VOC concentrations in industrial indoor air (DTSC, 2013) that represent a theoretical ILCR of 10^{-6} or a non-cancer HI of 1.0 for indoor workers. Concentrations below these RSLs are considered to not represent a significant health threat and therefore could support a decision not to pursue further investigation, mitigation, or remediation. Concentrations higher than the RSLs indicate that further investigation, mitigation, or remediation may be needed if the vapor intrusion pathway is potentially complete.

Step 6 and 7 - Specify Tolerable Limits on Decision Errors

When evaluating the magnitude and extent of soil vapor contamination, two types of decision errors are possible: a decision that no action is necessary because an area has soil vapor concentrations lower than the equivalent indoor air RSLs when they actually exceed the RSLs (Type I error); or, alternatively, a decision that further investigation, mitigation or remediation is necessary when soil vapor concentrations do not actually exceed the equivalent indoor air RSLs (Type II error).

The potential consequence (threat to human health or the environment) of making a Type I error is minimized by comparing the estimated indoor air concentrations to RSLs based on theoretical ILCRs that are at the lowest level within the EPA target range for risk managers (for carcinogens), and HIs less than 1.0 (for non-carcinogens). Although a cancer risk

anywhere within the target range (between 10^{-4} and 10^{-6}) is considered by the EPA to be safe and protective of public health, the most conservative level within the target range (10^{-6}) is used to generate the RSLs. In addition, DTSC vapor intrusion guidance (DTSC, 2011) specifies that a default buffer zone that extends 100 feet beyond areas of contamination be used to determine when vapor intrusion mitigation should be required. Both of these factors limit the potential threat to human health resulting from a Type I error.

Due to the potential impact on human health from vapor intrusion to indoor air and the somewhat unreliable method used to estimate indoor air concentrations from measured soil vapor concentrations, Type II errors are considered to be tolerable.

5.2 Quality Assurance/Quality Control

Sampling Process Design

Soil vapor samples will be collected to evaluate whether temporal changes in soil vapor concentrations have occurred in areas previously sampled, and to define the lateral extent where soil vapor concentrations exceed levels that could pose a significant threat to human health through the vapor intrusion pathway. To evaluate temporal changes, at least one sample in each of the three areas will be collected at the same location as, or as close as practicable to, previously sampled locations where significant soil vapor concentrations were detected. To reduce the potential for the Type I decision errors, soil vapor samples will be collected at a maximum spacing of 20 feet. Based on the prior sampling described in Section 2, this spacing is adequate to characterize the vapor plumes previously detected in this area, and also provides redundant data within the 100-foot default buffer zone that DTSC recommends. Note that since the data proposed in this workplan is in part being used to supplement previously collected data, the maximum spacing of 20 feet includes the previously collected soil vapor samples.

Maximum Allowable Quantitation Limits (QLs)

The maximum allowable Quantitation Limits (QLs) for the chemicals of potential concern (COPCs) are provided in the following table. The COPCs are the soil vapor contaminants that were

detected in soil vapor samples collected during the investigations conducted in 2008 and 2010/2011 (LBNL, 2012). The QLs were set at the lowest estimated soil vapor concentration that would result in an increased lifetime cancer risk of 10^{-6} for carcinogens or HQ of 1.0 for non-carcinogens through the indoor air pathway. To obtain the QL, the indoor air RSL for each chemical was divided by the DTSC-recommended attenuation factor (α) of 0.0005 for the migration of soil vapor into future commercial buildings (DTSC, 2011).

Maximum Quantitation Limits for Soil Vapor Contaminants of Potential Concern

Chemical of Potential Concern	Indoor Air RSL(µg/m^3)	Maximum Allowable Quantitation Limit (µg/m^3)
Benzene	0.42	840
Carbon tetrachloride	0.29	580
Chloroform	0.53	1060
1,1-Dichloroethane (DCA)	7.7	15400
1,1-Dichloroethene (DCE)	310	620,000
Cis-1,2-dichloroethene (DCE)	31	62,000
Trans-1,2-dichloroethene (DCE)	260	520,000
Tetrachloroethylene (PCE)	2.08	4160
toluene	22,000	44,000,000
1,1,1-Trichloroethane (TCA)	4400	8,800,000
Trichloroethylene (TCE)	3.0	6000
Vinyl chloride	0.16	320

Comparability

Since RSLs are presented in units of micrograms per cubic meter of air (µg/m^3), all soil vapor samples will be reported in these units.

Accuracy

Accuracy will be ensured by utilizing a laboratory for analysis certified by the California Department of Public Health, Environmental Laboratory Accreditation Program (ELAP) or National Environmental Laboratory Accreditation Program (NELAP) and by adhering to standard methods of analysis (EPA Method TO-15 or 8260B).

Precision

To evaluate the precision of the soil vapor sampling method in producing repeatable results, one replicate sample will be collected per 20 samples, with at least one replicate sample collected for each sampling event. Replicates will be collected by sequentially collecting two samples from the same sampling manifold. No additional purging will be conducted between each replicate sample.

6.0 SCHEDULE AND REPORTING

6.1 SCHEDULE

Sampling will commence following receipt of DTSC approval of this workplan. Specific schedule dates will be determined based on site constraints and weather. Fieldwork is anticipated to be completed within approximately six months of DTSC's approval to proceed.

6.2 REPORTING

LBNL will submit a report to DTSC within 60 days of the receipt of all results. The results of sampling will also be provided in the ERP semiannual progress reports that are submitted to DTSC.

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LBNL, 2014. *Interim Corrective Measures Report for Controlling the Migration of Contaminated Groundwater at the Former Building 51 Bevatron Site*, Lawrence Berkeley National Laboratory Environment / Health / Safety Division, Lawrence Berkeley National Laboratory, Berkeley, California, January 2014.

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■	Excavation confirmation wall soil sample
⊙	Groundwater monitoring well
⊗	Properly destroyed monitoring well
T ⊙	Temporary groundwater sampling point
T ⊗	Properly destroyed sampling point
◎	Observation well
	Groundwater extraction well
⊕	Soil boring
⊛	Soil vapor sampling point
A A'	Cross section location
CB SD CB	Active storm drain and catchbasins
CB SD CB	Abandoned storm drain and catchbasins
	Building 51L remedial excavation
51L	Former building location

NOTES:
All other symbols used are explained on the figures.

Key to Symbols Used on Figures.

symbols.ai
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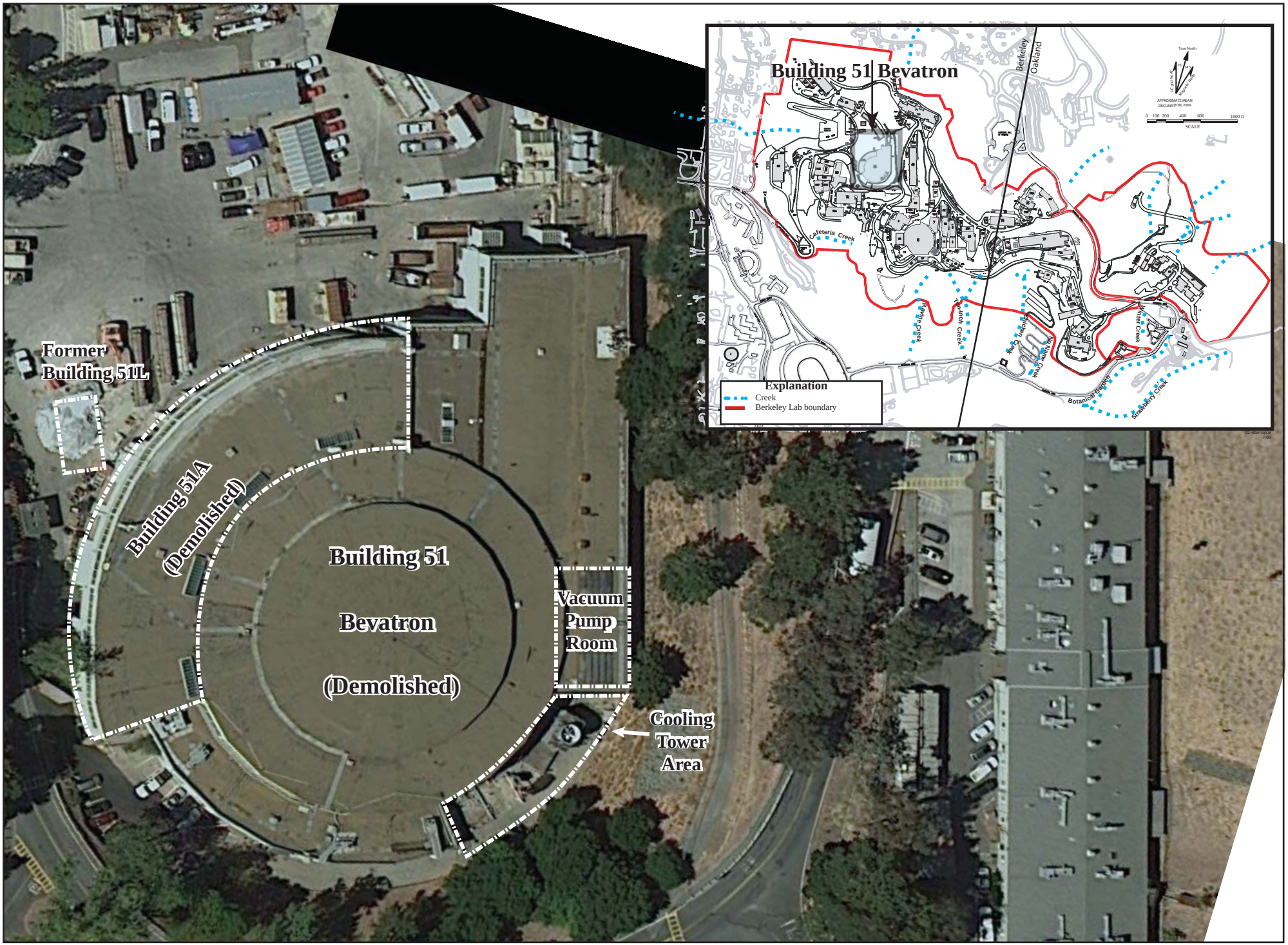

Figure 1. Location of Former Building 51 and the Bevatron, Lawrence Berkeley National Laboratory.

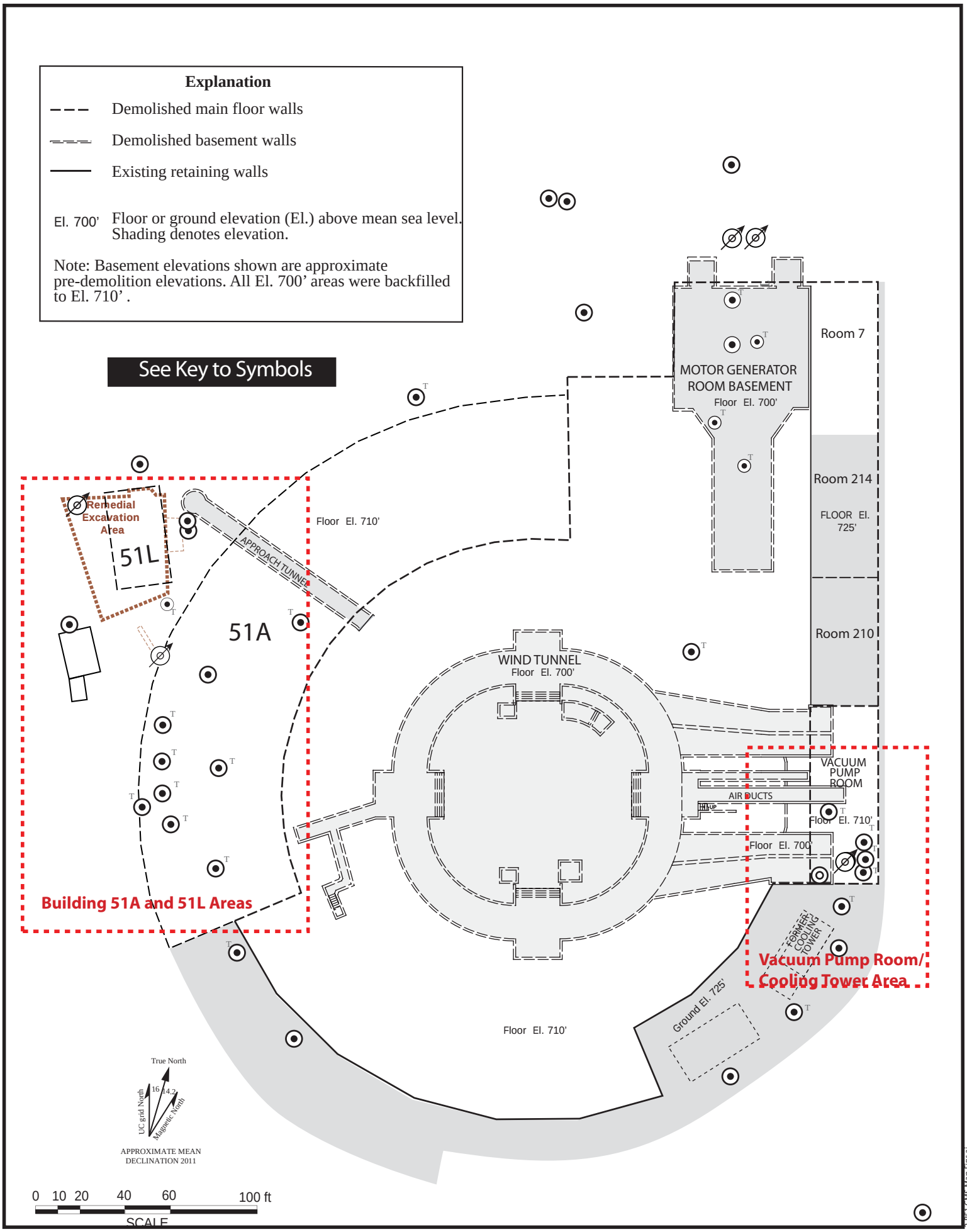

Figure 2. Location of Vacuum Pump Room/Cooling Tower Area, Building 51A Area, and Building 51L Area, Former Bevatron Site.

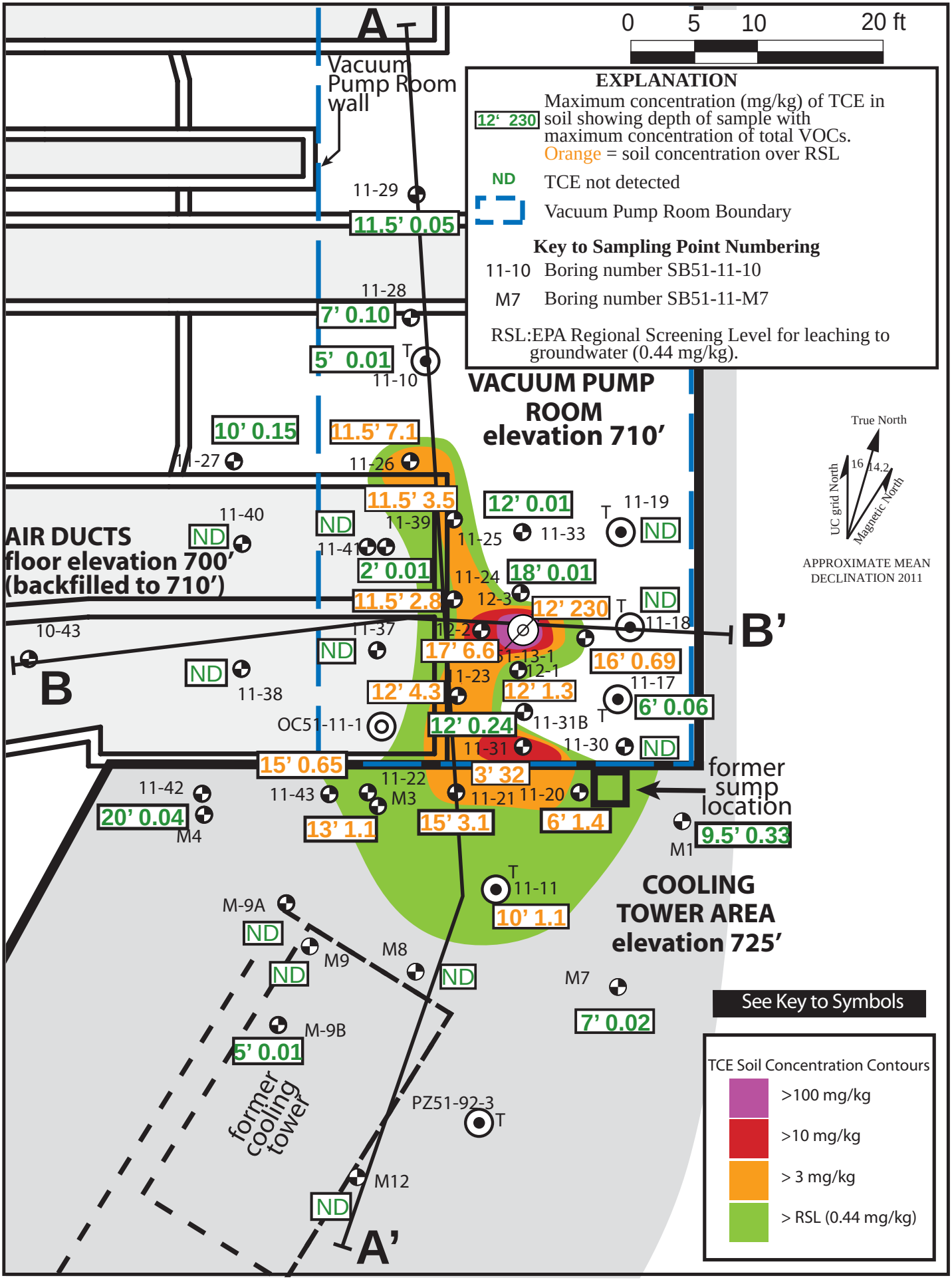

Figure 3. Maximum Concentrations of TCE Detected in Soil, Vacuum Pump Room/ Cooling Tower Area.

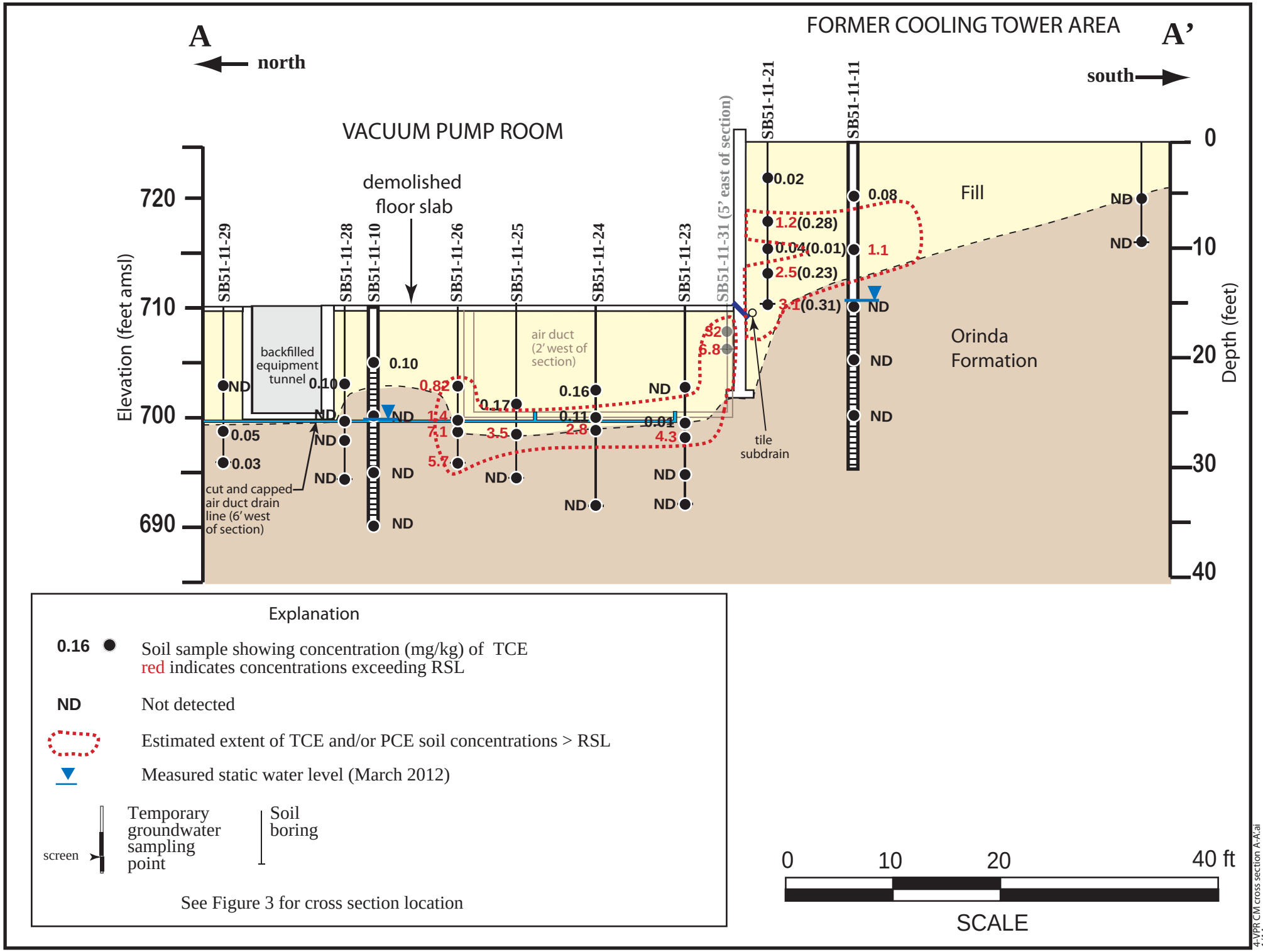

Figure 4. Geologic Cross Section A-A' Through Former Vacuum Pump Room/Cooling Tower Area.

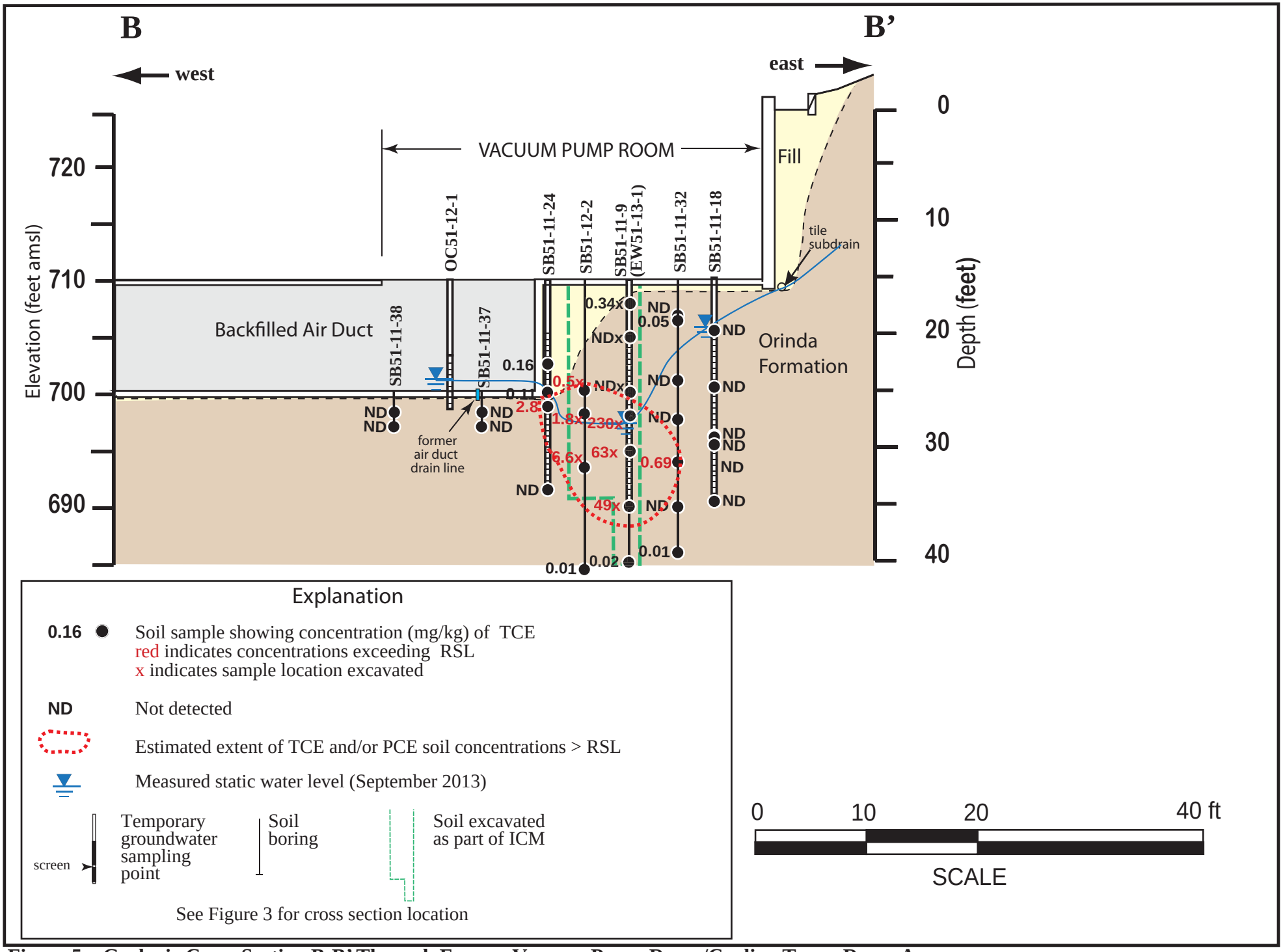

Figure 5. Geologic Cross Section B-B' Through Former Vacuum Pump Room/Cooling Tower Room Area.

5-VPR CM cross section B-B'.ai
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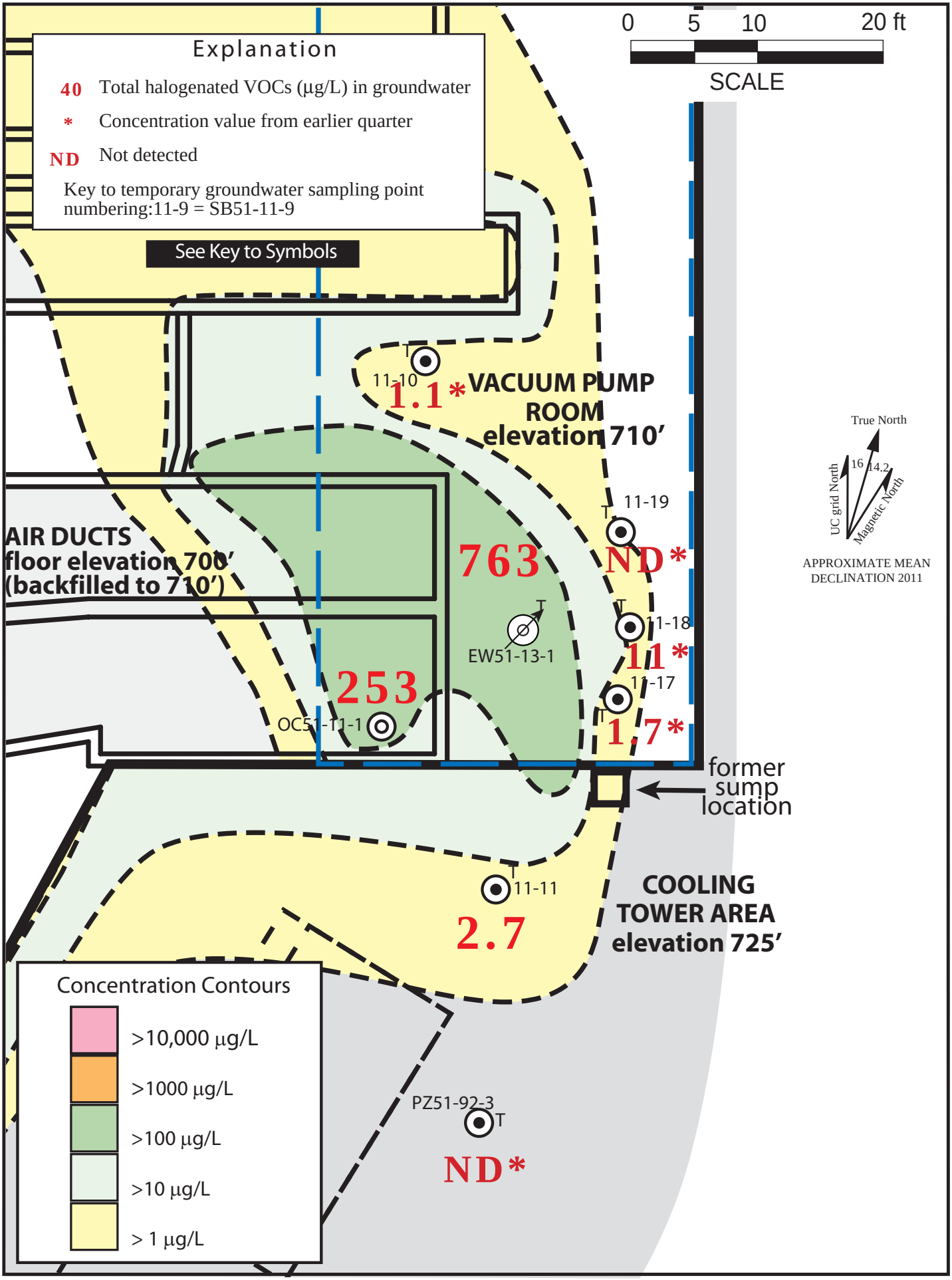

Figure 6. Concentrations of Total Halogenated VOCs Detected in Groundwater, Fourth Quarter FY13, Vacuum Pump Room/Cooling Tower Area.

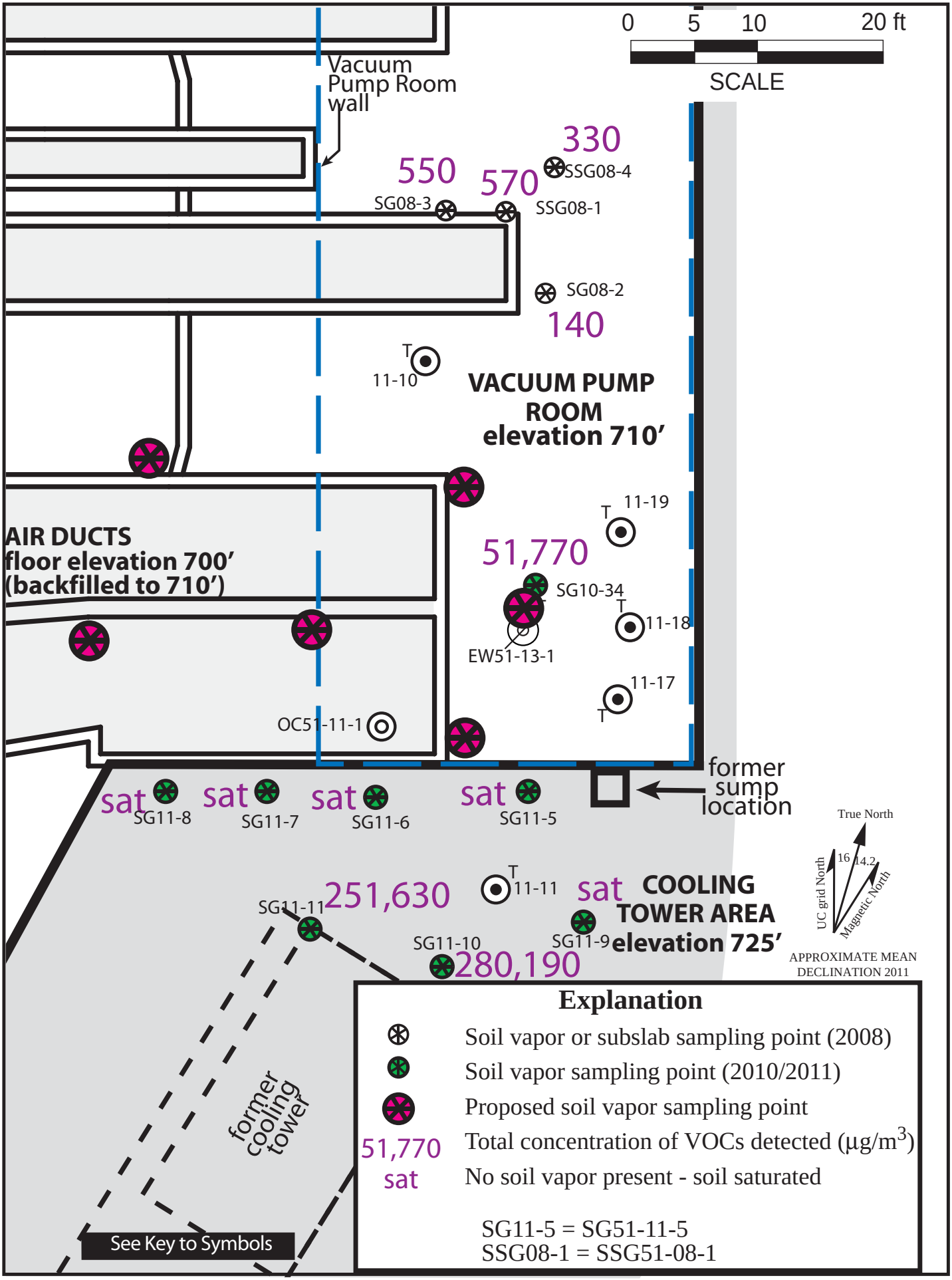

Figure 7. Total Volatile Organic Compounds in Soil Vapor and Subslab Vapor Showing Proposed Sampling Locations, Vacuum Pump Room/Cooling Tower Area.

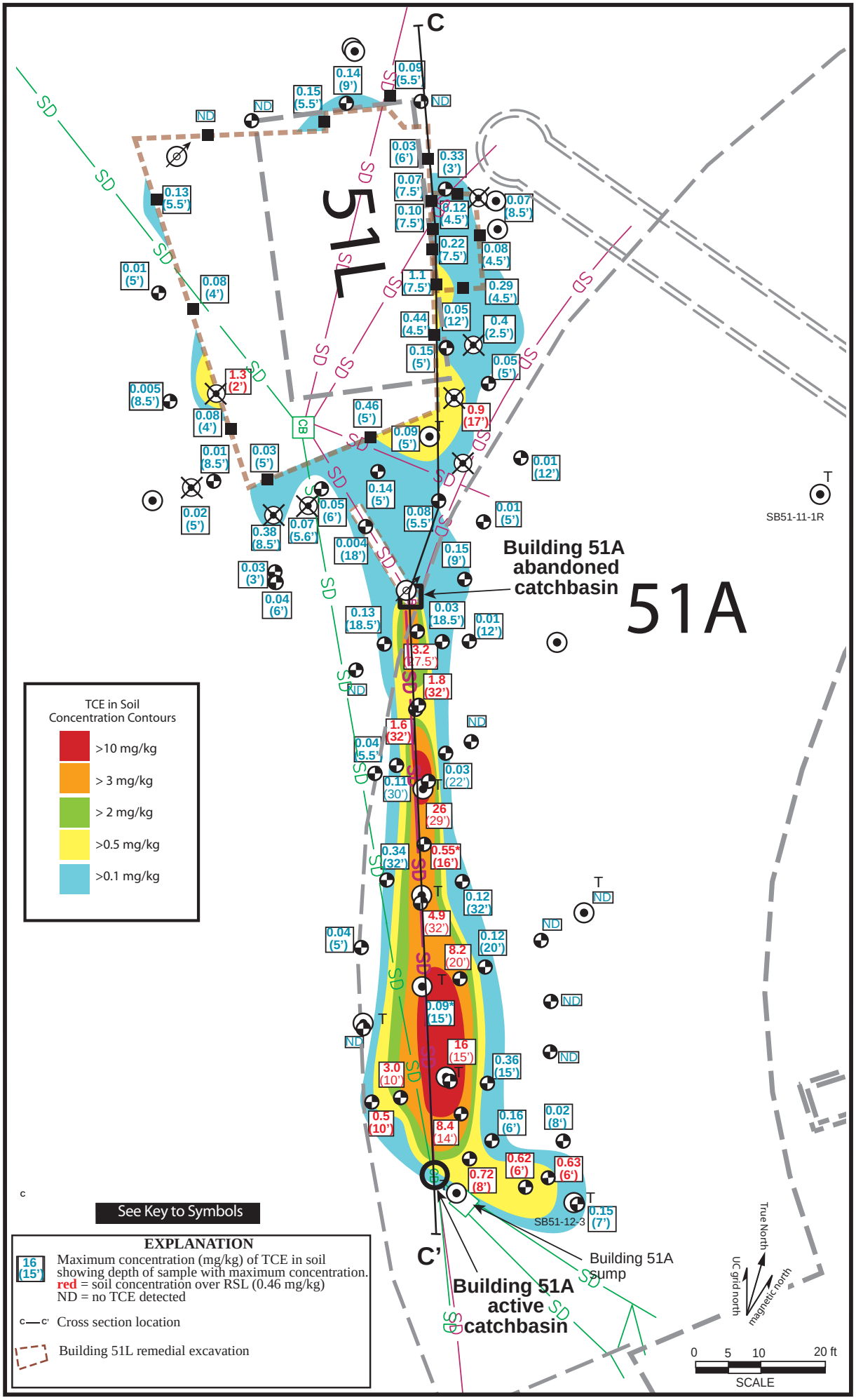

Figure 8. Maximum Concentrations of TCE Detected in Soil, Former Building 51A Area.

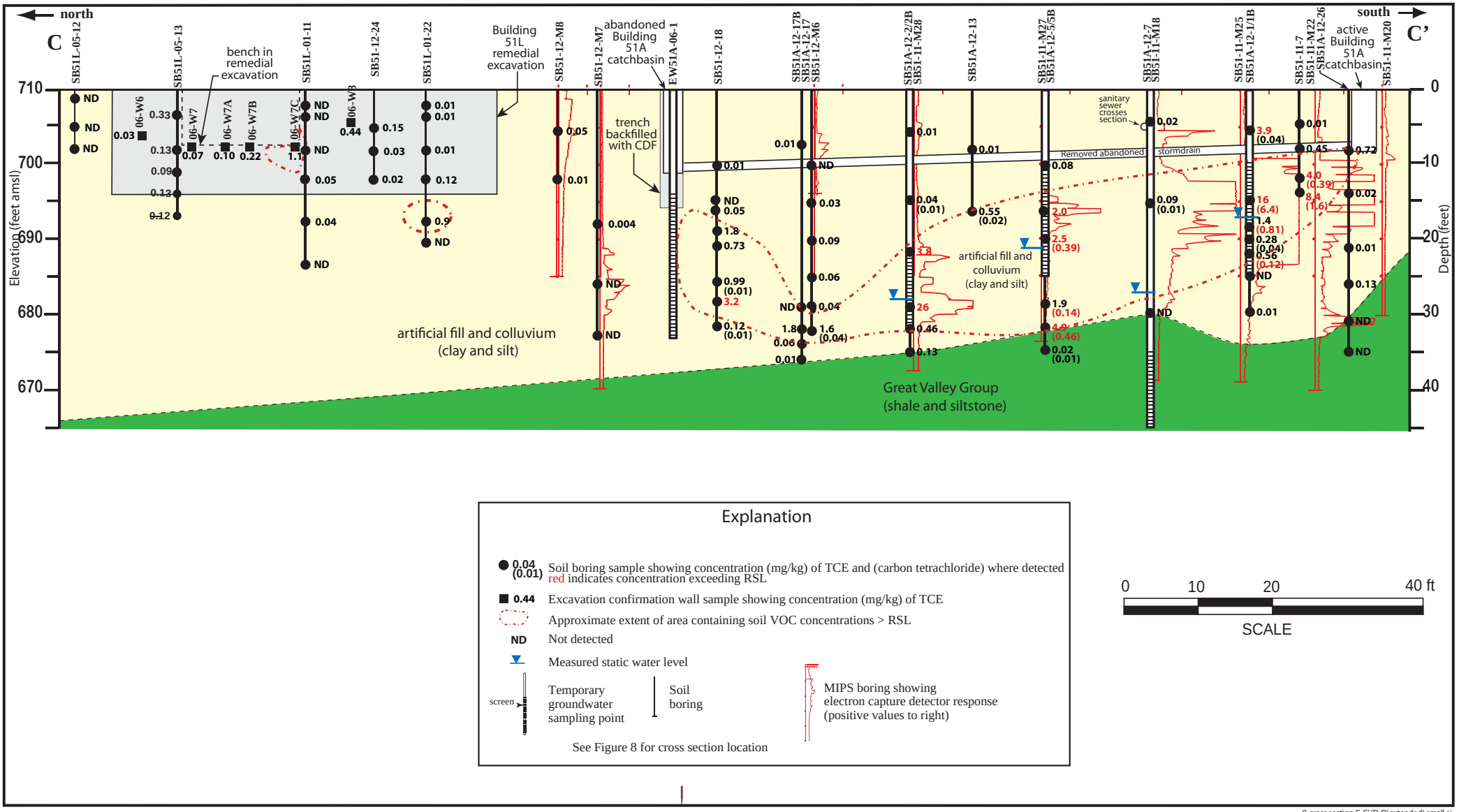

Figure 9. Geologic Cross Section C-C' Through Former Building 51A and 51L Areas.

9-cross section C-C' (D-D' extended) small.ai
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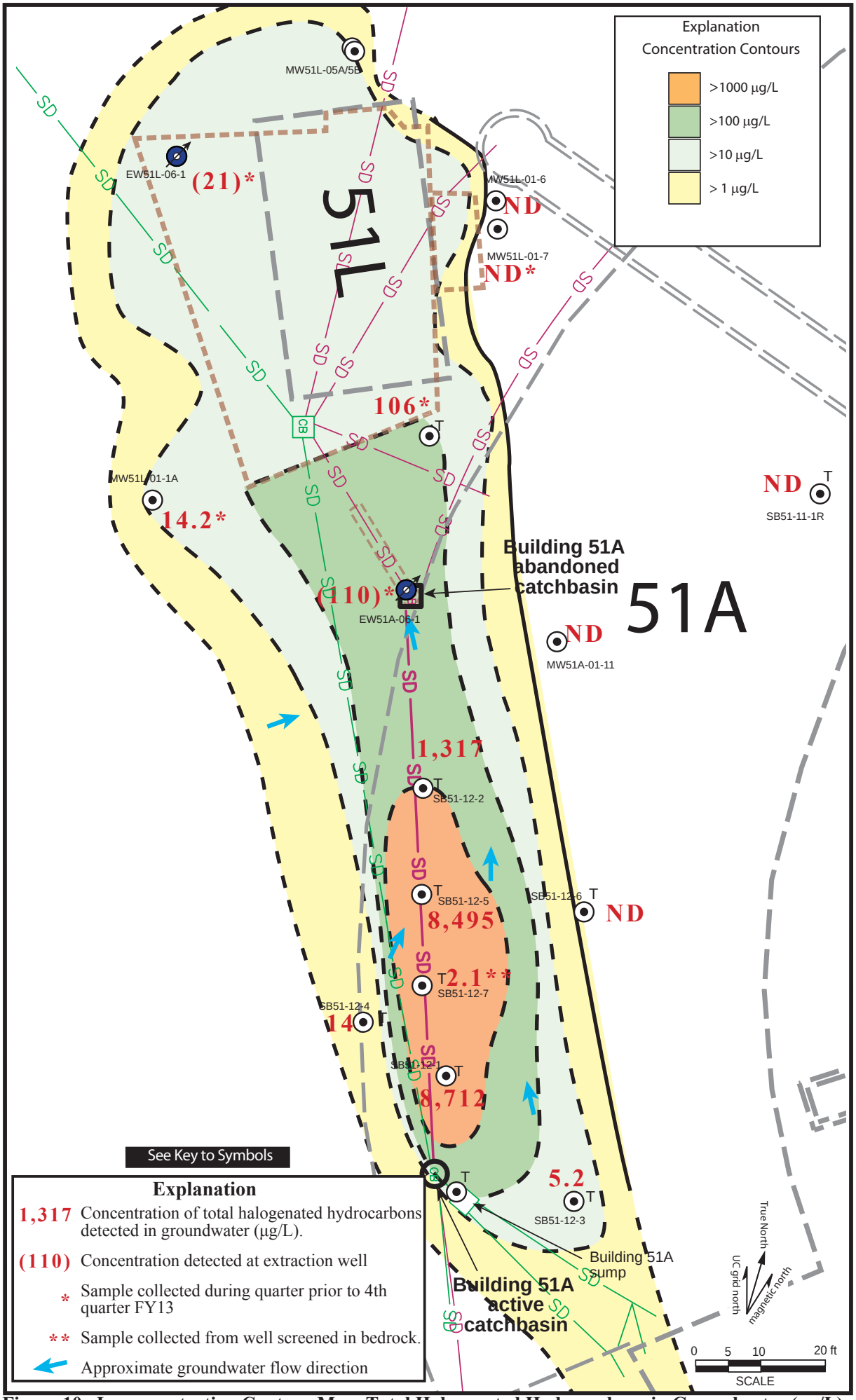

Figure 10. Isoconcentration Contour Map, Total Halogenated Hydrocarbons in Groundwater (µg/L), Fourth Quarter FY13, Building 51A and 51L Areas.

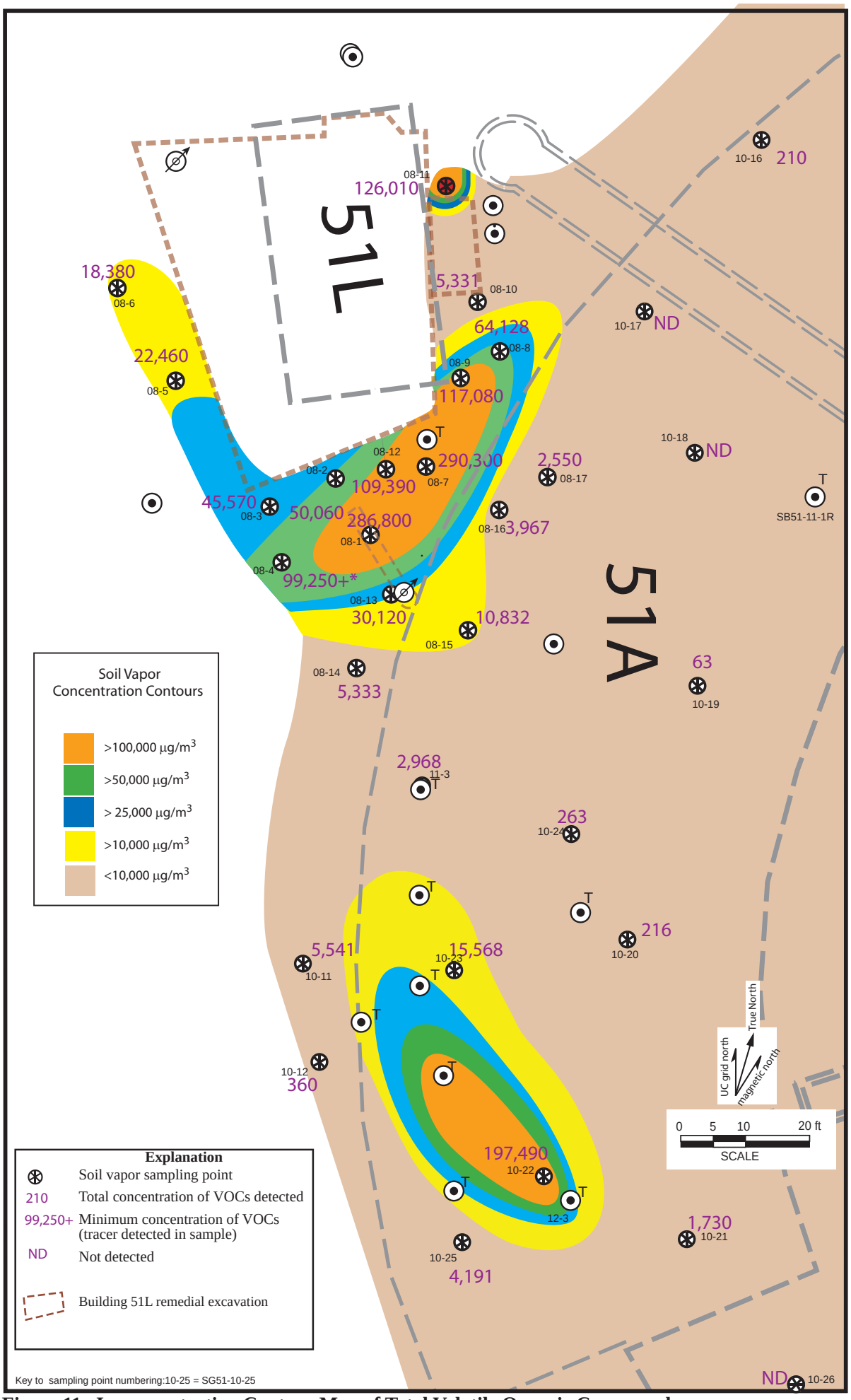

Figure 11. Isoconcentration Contour Map of Total Volatile Organic Compounds Detected in Soil Vapor, Building 51A and 51L Areas.

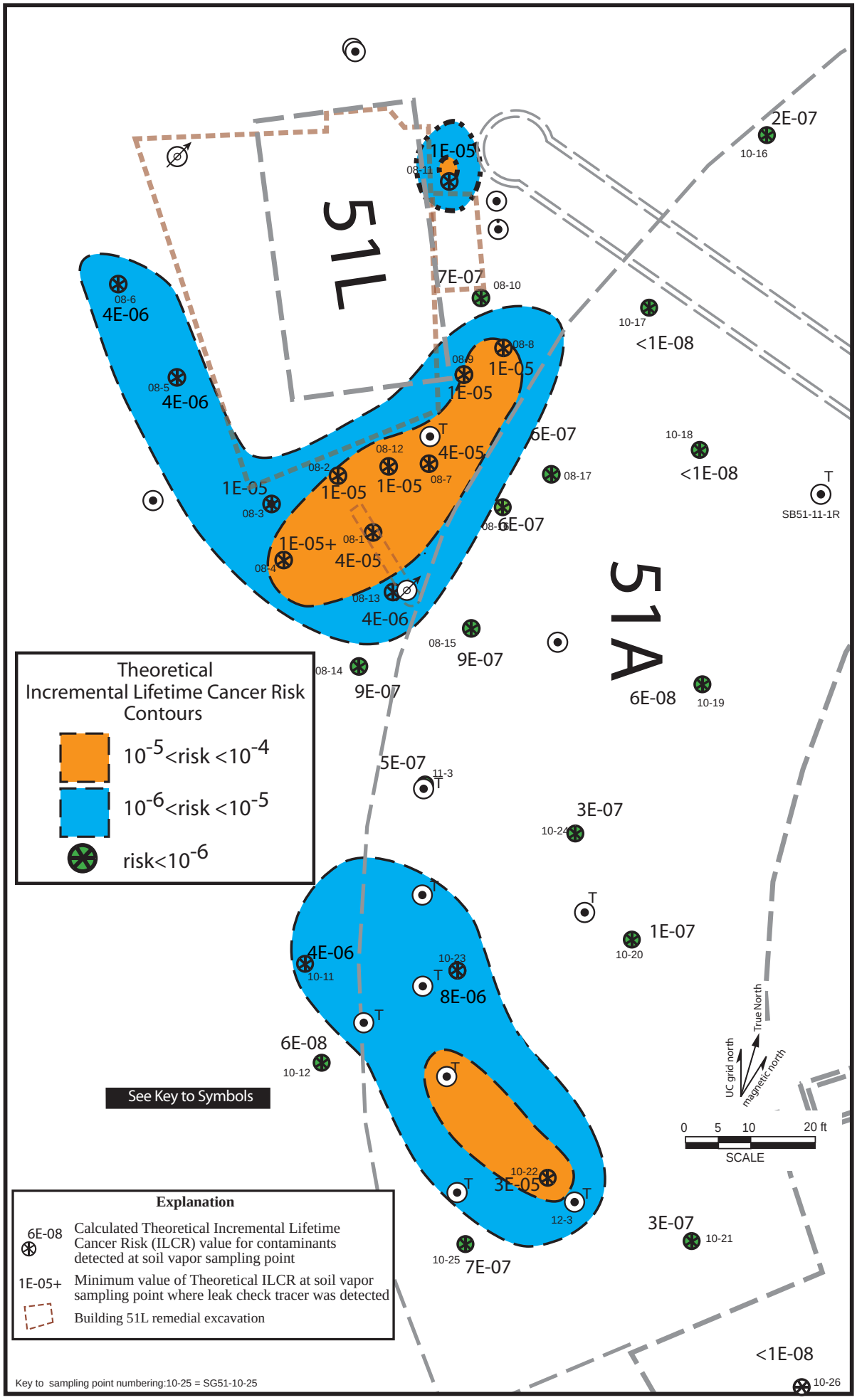

Figure 12. Theoretical Incremental Lifetime Cancer Risk Contour Map for Migration Pathway from Soil Vapor to Indoor Air, Building 51A and Building 51L Areas.

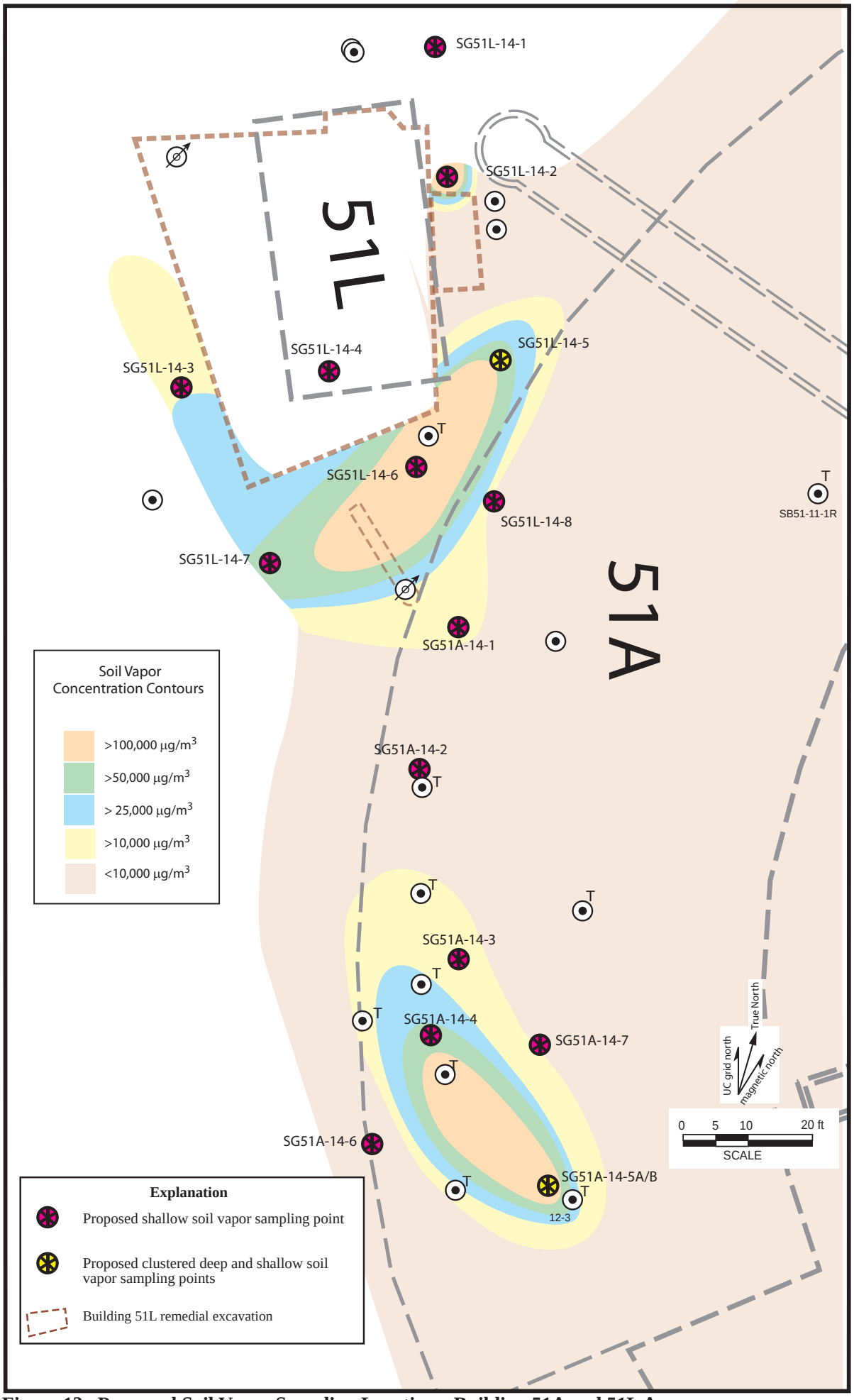

Figure 13. Proposed Soil Vapor Sampling Locations, Building 51A and 51L Areas.

APPENDIX A:

PROCEDURE FOR COLLECTING SOIL VAPOR SAMPLES

1.0 PURPOSE

This procedure provides the requirements for collecting soil vapor samples at Lawrence Berkeley National Laboratory (LBNL). The requirements are based on guidance published by the California Environmental Protection Agency for collecting and analyzing soil gas samples (Cal/EPA 2012). Alternative approaches and methods to those specified in this procedure may be employed (for example, glass syringes or bulbs may be used for sample transfer if an on-site laboratory is used) but must be equivalent to those provided in the Cal/EPA guidance document. All such deviations will be reported with the results.

2.0 EQUIPMENT CHECKLIST

- Hammer drill, slide hammer, or direct-push rig with fittings for installing and removing direct-push vapor probes
- Vapor probes with retractable or dedicated drop-off tips (e.g. AMS SGVP) and Teflon, Nylaflow or polyetheretherketone (PEEK) tubing with Swagelok or similar threaded compression fittings and vapor-tight caps for direct push vapor probes
- Hand auger (optional)
- PVC or metal casing and screens (optional)
- Filter-pack sand (for dedicated tips)
- Powdered or granular bentonite
- Vials or similar measurement device for pouring sand
- 6-Liter Summa canister (evacuated with approximately 30” Hg vacuum) with vacuum gauge for purging and leak testing
- 1-Liter Summa canister with vacuum gauge for each sample
- Stainless-steel sampling manifold (e.g. Figure 1) with flow restrictor calibrated to 100 to 200 mL/minute flow rate
- Leak-check compound (e.g. isopropyl alcohol)
- Dispensing equipment for leak-check compound (e.g. sampling jar and absorbent material for isopropyl)
- Calibrated photoionization detector (PID)
- Leak-check enclosure(s) (large plastic tub with flexible weather stripping and openings for sampling enclosure atmosphere)
- Record-keeping materials
- Latex or nitrile gloves

3.0 SOIL VAPOR PROBE INSTALLATION

3.1 Boring Clearance

Prior to installing soil vapor probes, ensure that a Penetration Permit has been obtained from the LBNL Facilities Division. Core any paved surfaces using a rotary hammer-drill or concrete-coring equipment. Use new, clean, dry tubing for each sample location. Use new tubing at each vapor sampling probe. Use new tubing for each sample location.

3.2 Semi-permanent Vapor Probe Installation

1. Drive a solid drive rod to a depth of approximately 5 feet, unless otherwise specified in the sampling plan, and then remove.
2. Attach a disposable drop-off tip to sampling tube with a fitting such as a barbed fitting or a screw adapter with an O-ring to prevent leakage. If a screw adapter with O-ring is used, inspect the O-ring to ensure that it is not flawed and use rigid tubing that can be tightened from the surface. The volume of the sampling apparatus should be minimized. Cal/EPA guidance requires that tubing should be no greater than ¼" nominal diameter.
3. Place 3" of sand in the hole then drive a hollow drive rod with the drop-off tip attached to flexible tubing extending to the surface to the top of the sand. Remove the drive rod leaving the disposable drop-off tip in the hole. Sometimes caving of the hole does not allow reinsertion of a hollow drive rod. In this case, omit insertion of a solid drive rod and only use the hollow drive rod with a tip. Note in this case, it is not possible to put sand at the bottom of the hole.
4. Cover the probe tip with at least 6" of sand, followed by at least 6" of dry granular bentonite. Fill the remainder of the boring with hydrated bentonite. EPA volatile organic analysis (VOA) vials are useful for measuring and placing these materials since they have the same approximate diameter as the hole.
5. After probe installation, tightly cap the tubing, record probe installation time/date and depth, and wait at least **2 hours** before conducting purge volume tests, leak tests, or soil gas sampling.

3.4 Semi-permanent Vapor Well Installation

1. Auger to a depth sufficient to allow a minimum of 6 feet between the surface and the top of the screened section of tubing (see below for details).
2. Install small diameter tubing with a short (<6" long) screened section close to the bottom of the hole.
3. Cover the screened section with at least 6" of sand, followed by at least 6" of dry granular bentonite. Ensure that the screened section is near the center of the sand pack. Fill the remainder of the boring with hydrated bentonite. The bentonite should be hydrated at the surface and poured into the borehole. For probes deeper than 10 feet, use a rigid rod to support flexible sample tubing.
4. After probe installation, tightly cap the tubing, record probe installation time/date, and wait at least **48 hours** before conducting purge volume tests, leak tests, or soil gas sampling:

3.4 Temporary Vapor Probe Installation Using Post Run Tubing Method

This method should only be used for qualitative assessments due to the possibility of vapor leaks along the drive rods. Do not use this method when sampling in coarse granular materials due to potential leakage along the probe.

1. Drive the drive rod to the predetermined depth (generally 6 feet minimum) and then pull back to expose the inlets of the soil gas probe by exposing a short-screened section.
2. Attach the sampling tube to the probe tip with a fitting such as a barbed fitting or a screw adapter with an O-ring to prevent leakage. If a screw adapter with O-ring is used, inspect the O-ring to ensure that it is not flawed and use rigid tubing with a minimum ¼" outside diameter that can be tightened from the surface. The volume of the sampling apparatus should be minimized. Cal/EPA guidance requires that tubing should be no greater than ¼" nominal diameter.
3. Seal around the drive rod using hydrated bentonite at the ground surface to prevent ambient air intrusion. VOA vials are useful for measuring and placing these materials because they have approximately the same inside diameter as the AMS drive rod outer diameter.

4. After probe installation, tightly cap the tubing, record probe installation time/date, wait at least **2 hours** before conducting purge volume tests, leak tests, or soil gas sampling:

4.0 VAPOR SAMPLING

Record all valve open/close times and canister/manifold vacuum readings at each step. Use a decontaminated sampling manifold for each sample location. Soil vapor sampling should not be conducted in areas of bare soil or permeable pavement (e.g. highly degraded or cracked asphalt or concrete) within 5 days of a rain event that has ½ inch or greater rainfall during a 24-hour period. Wear latex or nitrile gloves while handling sampling equipment. Change gloves whenever a new sample is collected and after handling leak-check compound.

4.1 Setup

Calculate and record the vapor-filled volume of the sampling assembly, tubing, vapor probe, and any permeable annular space around the vapor probe tip.

Volume of tubing/manifold/borehole=3.14 x (1/2*ID) x (1/2*ID) *L

Where ID = tubing or manifold inside diameter and L = length of tubing/manifold/borehole segment. To convert volume in cubic feet to units of ml/ft. multiply the volume by 28,317 and divide by L

Volumes for standard tubing/boring diameters are:

1/8” ID tubing volume = 2.4 ml/ft.

3/16” ID tubing volume = 6 ml/ft.

1/4” ID tubing volume = 9.7 ml/ft.

1/4” OD (0.17” ID) tubing volume = 4.5 ml/ft.

2-1/8” auger boring volume = 697 ml/ft. * 0.4 = 278 ml/ft. (sand) minus tubing volume

2-1/8” auger boring volume = 697 ml/ft. * 0.5 = 349 ml/ft. (dry bentonite) minus tubing volume

3-1/4” auger boring volume = 1631 ml/ft. * 0.4 = 652 ml/ft. (sand) minus tubing volume

3-1/4” auger boring volume = 1631 ml/ft. * 0.5 = 652 ml/ft. (dry bentonite) minus tubing volume

Note: Porosity of 50% is used for dry bentonite and 40% for #3 sand pack to calculate boring linear volume of vapor-filled porosity.

4.2 Flow and Shut-In Check

1. Connect the sampling manifold to both the sample Summa canister and the purge Summa canister using Swagelok fittings. Shut in manifold by capping vapor probe port. Check all fittings for tightness (do not over tighten).
2. Close all valves. Record pre-test vacuum readings on both canisters.
3. Open manifold valves and valve on purge Summa canister. Do *not* open valve on sample port. Allow manifold/tubing vacuum to stabilize at approximately 30” Hg.
4. Close purge canister valve and conduct a shut-in test by waiting at least 2 minutes. Monitor manifold vacuum gauge to test for leaks. If the vacuum decreases, repair the leak before proceeding.

5. If vacuum is stable, connect manifold to vapor probe. Open purge canister valve and vapor probe valve for approximately 5 seconds. Note the vacuum on the probe-side vacuum gauge. If the vacuum exceeds approximately 7” Hg, then insufficient flow is present to collect a representative sample and this condition should be noted. A sample may be collected for qualitative screening purposes only. For vacuums above 7” Hg, temporarily close the canister valve and estimate flow rate by recording the elapsed time after valve closure for manifold vacuum to drop to 5” vacuum, as indicated on the following chart (specific to K-Prime sampling manifold, but should provide rough estimates for other manifolds with similar flow restrictors). If no significant flow is attained, either the sampling line is plugged or the vapor probe is positioned in an impermeable or saturated layer. Determine the cause of the problem and correct the situation by unplugging the line, or repositioning or relocating the probe.

K PRIME, INC. SOIL GAS MANIFOLD FLOW RATE AND VACUUM LEVEL ESTIMATES

T (seconds)	PV	F (ml/minute)
5	0	135
10	5	115
15	10	90
30	15	60
120	20	40
480	25	20

Source: K Prime, Inc. – July 24, 2006

NOTES:
T = Time duration from full vacuum to less than 5" vacuum after closing purge canister.
PV = Approximate vapor probe vacuum level based on measured T
F = Approximate sampling flow rate based on measured T
Assumes probe side vacuum is zero

4.3 Purge, Sample, and Leak Check

1. Open purge-canister valve and vapor probe valve, if any, and measure purge volume based on the table above. Include the purging conducted during the flow-rate step above in the purge volume measurement. For vapor sampling in support of risk-assessments for regulatory review, a step-purge test should be conducted at a “worst case” sampling point, using 1, 3 and 7 purge volumes to determine the appropriate purge volume that yields the highest target compound concentration. However, when using Summa canisters and/or for collecting samples from depths of approximately 5 feet or less, use a default purge of approximately 3 purge volumes of the tubing and sampling assembly. Do *not* over-purge.
2. Close purge canister valve.
3. Dispense leak-check compound into leak-check enclosure. For example, when using isopropyl alcohol, place absorbent materials (e.g., gauze) moistened with alcohol in an open container (i.e.uncapped sampling jar) adjacent to the vapor probe. Do not allow liquid to come in direct contact with tubing or sampling assembly.
4. Place leak-check enclosure over vapor probe, floor/ground penetration, Summa canister/manifold assembly, and leak check container, and seal to floor using weather-stripping or duct tape or weight so that perimeter is sealed to ground surface.
5. Allow at least 5 minutes for leak check compound to permeate atmosphere of leak-check enclosure. Measure and record the observed PID reading for the leak-check vapor through a small hole in the leak-check enclosure. The typical leak check compound that has been used at LBNL is isopropyl alcohol. For isopropyl alcohol, reapply the leak-check compound if the PID reading is less than 2 ppm. Note that the isopropyl alcohol response factor is approximately 5.6 (i.e. a reading of 2 ppm on a PID calibrated with isobutylene indicates 5.6 x 2 = 11.2 ppm of isopropyl

alcohol). Note that other ionizable leak check compounds would have different response factors. Also there are other acceptable compounds for leak testing such as helium gas.

6. Once at least a 2 ppm PID reading has been reached, open sample canister valve. Sampling should take approximately 5 minutes for a 1-liter Summa canister and 30 minutes for a 6-liter canister.
7. Record PID reading in the leak-check enclosure approximately every 5 minutes during purging and sampling. Slowly reapply leak-check compound if PID reading drops more than 20% below initial readings.
8. Periodically check the integrated flow rate during sampling by closing the sample canister valve and checking the elapsed time versus the sampling volume. Sampling volume for 6-liter and 1-liter canisters can be estimated based on the following table.

Relationship between Final Canister Vacuum and Volume Sampled

Final Vacuum (“Hg)	0	2.5	5	7.5	10	12.5	15	17.5	20
Volume Sampled (L)	6	5.5	5	4.5	4	3.5	3	2.5	2

Source: Air Toxics, Inc.

9. Close sampling canister valve when vacuum decreases to between 1” and 5” mercury. Do *not* allow vacuum to fall below this range.
10. If quantitative leak information is desired, use a 1-liter Summa canister and sampling manifold to collect a sample from the leak-check enclosure during the same period that sampling is conducted. Submit canister for analysis of leak-check compound only.
11. Disassemble sampling assembly, and cap (or remove and restore) vapor sampling point.
12. Fill out chain-of-custody form, including analysis for chemicals of concern and leak-check compound. Include final vacuum reading and serial numbers of canister and flow restrictor.
13. For vapor sampling in support of risk-assessments for regulatory review, collect at least one duplicate sample per site per sampling event from the sampling point with the anticipated highest vapor concentrations. The duplicate sample should be collected by attaching a fresh sample canister following collection of the initial sample. If a new manifold is used, follow the same purging and sampling procedures used for the original sample. If the same manifold is used, collect a sample without further purging, using the same sampling procedures used for the original sample

4.4 Decontamination and Decommissioning

Decontaminate drive rods and other reusable components between sample locations by washing equipment with a non-phosphate detergent and rinsing with tap water and/or by steam-cleaning. Return sampling manifolds to laboratory for decontamination.

Backfill any open soil vapor probe holes with bentonite slurry.

5.0 REFERENCES

Cal/EPA, 2012, Advisory-Active Soil Gas Investigation, California Environmental Protection Agency, Department of Toxic Substances Control, Los Angeles Regional Water Quality Control Board, San Francisco Regional Water Quality Control Board, April.

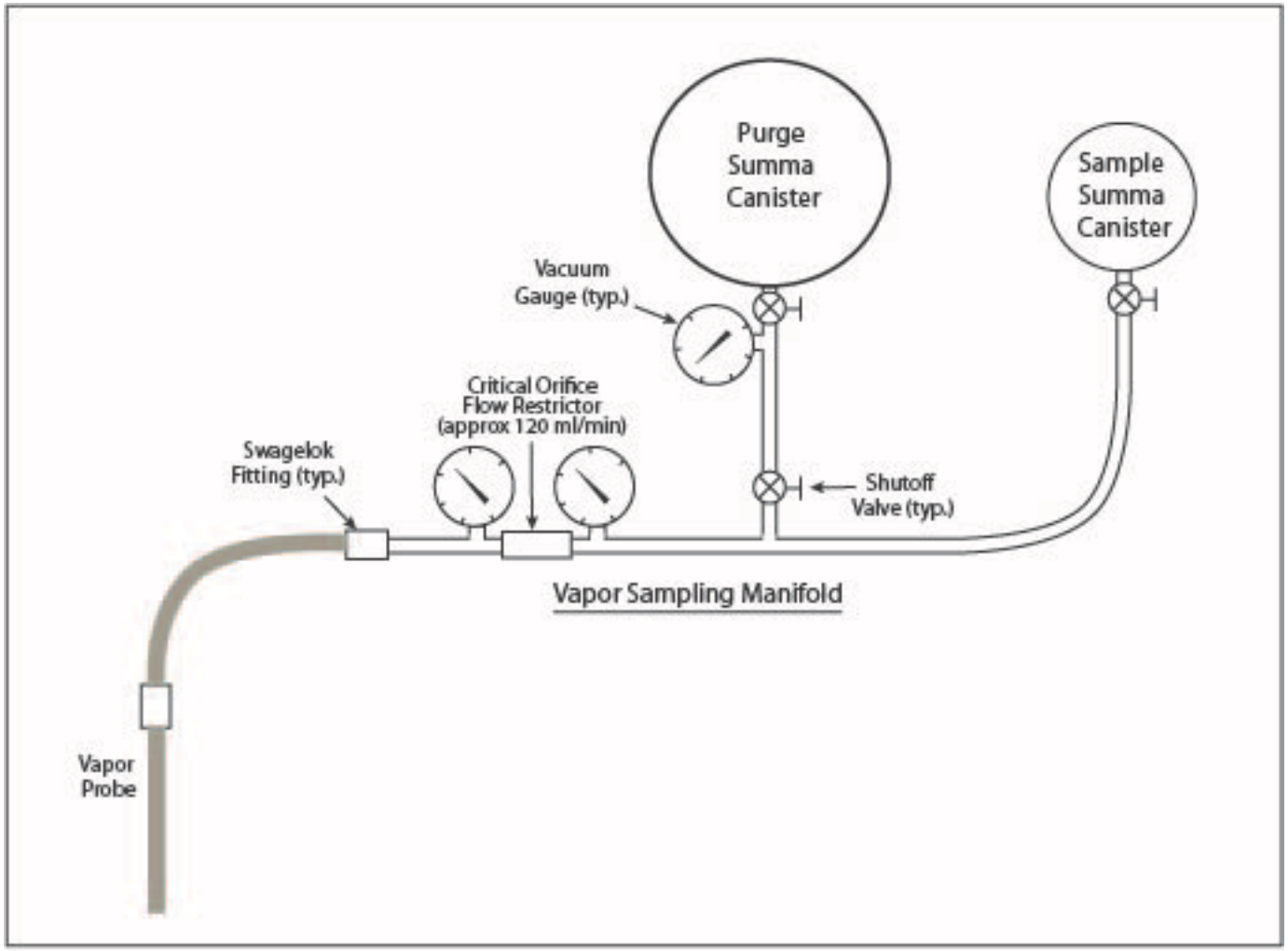

Figure 1. Soil Vapor Sampling Manifold Schematic