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<th>Description</th>
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<td>AOC</td>
<td>Area of Concern</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>bgs</td>
<td>below ground surface</td>
</tr>
<tr>
<td>Cal-EPA</td>
<td>California Environmental Protection Agency</td>
</tr>
<tr>
<td>CFOU</td>
<td>Chatsworth Formation Operable Unit</td>
</tr>
<tr>
<td>cm</td>
<td>centimeter</td>
</tr>
<tr>
<td>CSM</td>
<td>conceptual site model</td>
</tr>
<tr>
<td>CTL</td>
<td>Component Test Laboratory</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Energy</td>
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<tr>
<td>DTSC</td>
<td>Department of Toxic Substances Control</td>
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<tr>
<td>EPC</td>
<td>exposure point concentration</td>
</tr>
<tr>
<td>FSDF</td>
<td>Former Sodium Disposal Facility</td>
</tr>
<tr>
<td>H&amp;A</td>
<td>Haley &amp; Aldrich</td>
</tr>
<tr>
<td>IEL</td>
<td>Instrument and Equipment Laboratories</td>
</tr>
<tr>
<td>lpm</td>
<td>liters per minute</td>
</tr>
<tr>
<td>LOX</td>
<td>Liquid Oxygen</td>
</tr>
<tr>
<td>MW</td>
<td>Montgomery Watson</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<tr>
<td>RCRA</td>
<td>Resource Conservation and Recovery Act</td>
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<tr>
<td>RFI</td>
<td>RCRA Facility Investigation</td>
</tr>
<tr>
<td>RME</td>
<td>reasonable maximum exposure</td>
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<tr>
<td>SIM</td>
<td>Selective Ion Monitoring</td>
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<td>SRAM</td>
<td>Standardized Risk Assessment Methodology</td>
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<td>SSFL</td>
<td>Santa Susana Field Laboratory</td>
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<td>SWMU</td>
<td>Solid Waste Management Unit</td>
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<td>Surficial OU</td>
<td>Surficial Media Operable Unit</td>
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<tr>
<td>TCE</td>
<td>trichloroethene</td>
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<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
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<tr>
<td>VOC</td>
<td>volatile organic compound</td>
</tr>
<tr>
<td>UW</td>
<td>University of Waterloo</td>
</tr>
<tr>
<td>µg/L</td>
<td>micrograms per liter</td>
</tr>
<tr>
<td>µg/Lv</td>
<td>micrograms per liter vapor</td>
</tr>
<tr>
<td>µg/kg</td>
<td>micrograms per kilogram</td>
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1.0 INTRODUCTION

This work plan describes the collection, analysis, and evaluation of field data to validate the vapor migration modeling that is part of the human health and ecological risk assessment approach for impacted environmental media at the Santa Susana Field Laboratory (SSFL). The modeling is described in the Standardized Risk Assessment Methodology (SRAM) Work Plan, Revision 2 Final (MWH 2005a). This work plan has been prepared for The Boeing Company (Boeing), the National Aeronautics and Space Administration (NASA), and the U.S. Department of Energy (DOE) as part of the Resource Conservation and Recovery Act (RCRA) Corrective Action Program at the SSFL.

Environmental investigation and cleanup at the SSFL is conducted as part of the RCRA Corrective Action Program, under the jurisdiction of the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC). The SSFL RCRA program is entering the data evaluation, risk assessment, and reporting phase of the RCRA Facility Investigation (RFI) where site data will be evaluated and recommendations made for the Corrective Measures Study (CMS). This work plan provides the data for validating the vapor migration models to be used in the risk assessment as described in the SRAM. Cleanup decisions for individual Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) will be based on the risk assessment results.

1.1 Objectives of the Work Plan

The objectives of this work plan are:

1. Collect data necessary to validate model-predicted surface vapor flux for the range of SSFL site conditions;
2. Quantitatively identify sensitive parameters for vapor migration model inputs; and,
3. Identify any required vapor migration model modifications based on this field validation study.
1.2 Scope of the Work Plan

Volatile organic compound (VOC) transport through the vadose zone is a critical component of the vapor migration model (both for vapor migration to indoor air and outdoor air). The site data collected according to this work plan will be used to evaluate the vadose zone transport phenomena. The VOC flux at the ground surface is measured in this work plan to characterize the vadose zone VOC transport. These measured fluxes are compared to the ground surface flux calculated using the flux model component of the vapor migration model with input of site data (e.g., soil, soil gas and groundwater concentrations). Data collection to validate the ambient air dispersion model and transport associated with building properties is outside the scope of this work plan; however, these exposure pathways are considered in the quantitative sensitivity analysis described herein. Additionally, data to validate the air dispersion model will be collected under a separate work plan.

The scope of this work plan is limited to the collection of data for the evaluation of the vapor migration model. The use of data collected according to this work plan to provide a refined assessment of the nature and extent of the subsurface impacts at the facility or to evaluate site risks is outside the scope of this document and are described elsewhere. For example, the SRAM contains the methodology of how site characterization (e.g., groundwater, soil vapor, and soil matrix) data will be used for evaluation of site risks.

1.3 Vapor Migration Model Background

The SRAM vapor migration modeling methodology is intended to provide a consistent approach across the entire site to estimate exposure point concentrations (EPCs) in indoor and outdoor air to assess human health and ecological risks associated with migration of VOCs from soil, bedrock, and groundwater. Although each investigational unit (e.g., RFI site) is unique, many have similar contaminants, exposure pathways, and receptors. In addition, many of the investigational units share similar physical characteristics such as geology and groundwater depth.

The evaluation of VOC migration to outdoor air is based on modeled soil vapor flux at the ground surface from subsurface sources, and considers a vadose zone diffusive transport model coupled with an atmospheric dispersion model to predict outdoor air concentrations. Partitioning from soil, bedrock, or groundwater sources and/or soil gas may be included in the model. A separate model is used to predict indoor air
concentrations from subsurface sources; although the methods used to model diffusion and partitioning (when applicable) in the vadose zone are the same as those in the vadose zone transport model.

The validated model will be used to predict subsurface vapor migration at SSFL investigational units where soil vapor data cannot be collected or where future conditions are being evaluated in the risk assessment to make CMS recommendations. Although these vapor migration models are derived from fundamental, technically founded equations that predict subsurface chemical diffusive and advective transport, there is some uncertainty associated with model input values and the application of these models to specific conditions at the SSFL. Uncertainty can be reduced with field validation of the applicability of the vapor migration models. This work plan describes a field validation study to evaluate the performance of the vapor migration models when applied to site-specific conditions encountered at the SSFL.

1.4 Site Background

The SSFL is approximately 29 miles northwest of downtown Los Angeles, California, in the southeast corner of Ventura County (Figure 1-1). The SSFL occupies approximately 2,850 acres of hilly terrain, with approximately 1,100 feet of topographic relief near the crest of the Simi Hills. The Simi Hills are bordered to the southeast by the San Fernando Valley and to the north by the Simi Valley. Most of the land adjacent to the SSFL is undeveloped and mountainous. About 73 percent of the area within a 5-mile radius of the SSFL is undeveloped. Figure 1-2 shows the SSFL, including RFI site locations.

Ongoing investigation of environmental media at the SSFL is being conducted in accordance with the DTSC-approved work plans listed below. The program includes analysis of soil, bedrock, soil vapor, surface water, near-surface groundwater, and Chatsworth Formation groundwater samples. The following is a list of major RFI work plans and reports that guide this characterization work:

- RFI Work Plan Addendum (Ogden 1996);
- RFI Work Plan Addendum Amendment (Ogden 2000a);
- Shallow Zone Groundwater Investigation Work Plan (Ogden 2000b);
- Technical Memorandum, Conceptual Site Model, Movement of TCE in the Chatsworth Formation (Montgomery Watson [MW], 2000a);
• Work Plan for Additional Field Investigations, Chatsworth Formation Operable Unit (MW 2000b).
• Standardized Risk Assessment Methodology (SRAM) Work Plan, Revision 2 (MWH 2005a);
• RFI Work Plan Addendum Amendment, Surface Flux and Ambient Air Monitoring, Former Liquid Oxygen (LOX) Plant Site (SWMUs 4.5 and 4.6). (MWH 2005b);

This work plan for performing a vapor migration model validation study describes only new sampling methodologies, laboratory analyses, or data evaluations not included in the above-referenced documents. The work proposed in this plan will follow specifications described in this document or methodologies previously approved by DTSC. As applicable, sections of the above work plans governing field and laboratory procedures are referenced in the text.

1.5 Related Work

The SRAM (MWH 2005a) includes a description of how risks from indoor and outdoor concentrations of VOCs will be estimated. The SRAM contains a description of vapor migration evaluation for use in the cumulative multi-media, multi-exposure pathway risk assessment for potential SSFL receptors. Appendix G of the SRAM includes methodology for predicting outdoor and indoor air concentrations from soil, sediment, and bedrock (collectively termed as bulk soil media), groundwater, and soil vapor concentrations. Appendix G of the SRAM addresses SSFL-specific conditions in this modeling. As noted above, there are uncertainties associated with application of these vapor migration models to specific conditions at SSFL, particularly with respect to estimating chemical diffusion through fractured bedrock and the variability of water content as a function of depth and geologic conditions.

A work plan to perform vapor flux and airborne dispersion measurements of VOCs was prepared for the Former Liquid Oxygen Plant (LOX) site (MWH 2005b). The LOX work plan has been conditionally approved by DTSC (DTSC 2005a), and the LOX field work is planned to be conducted concurrently with field work described in this work plan to ensure consistency of data collection and optimize the costs and efforts for field mobilization and sampling. This work plan describes a portion of the scope of work included in the work plan for the LOX site.
1.6 Work Plan Organization

This work plan is organized as follows:

- Section 1 introduces the vapor migration modeling validation study and provides the background, scope and purpose for the proposed work;
- Section 2 describes site conditions where vapor migration modeling may or will be used and sampling that will be performed for each type of condition as part of this validation study;
- Section 3 describes the selection of locations for validation sampling and how sample locations are representative of various SSFL investigational units;
- Section 4 describes the field and laboratory procedures for each type of sampling to be performed in the validation study;
- Section 5 describes model evaluation and quantitative sensitivity analysis;
- Section 6 provides a summary validation data reporting and project schedule; and
- Section 7 provides the references cited in this work plan.
2.0 SITE CONDITIONS FOR VAPOR MIGRATION MODEL VALIDATION FIELD SAMPLING

An understanding of the physical setting at the SSFL is fundamental to characterizing the nature and extent of potential contamination in subsurface media. This section describes site characteristics, including topography, geologic setting, and soil and groundwater conditions. Also presented are three scenarios where data are needed to validate modeled vapor flux. Additional information on SSFL site conditions and investigation approaches are provided in the RFI Program Report (MWH 2004), the Near-Surface Groundwater Characterization Report (MWH 2003a) and various Groundwater Characterization Technical Memoranda.

2.1 Site Conditions

The SSFL is underlain mostly by exposed bedrock of the late Cretaceous Chatsworth formation, which consists of interbedded sandstone and shale deposited by marine turbidites (Dibblee 1992). Quaternary alluvium overlies the Chatsworth formation in places throughout the SSFL. Alluvial soils are generally thin at the SSFL, typically ranging from 5 to 15 feet thick. These soils usually occur in topographic lows and along stream drainages, although a thin (5 to 10 feet thick) alluvial veneer covers a broad expanse in the northwest referred to as the Burro Flats area. The highest surface elevations at the SSFL occur along two general ridges that trend northeast-southwest. Disturbed soils have been used as fill materials in some developed portions of the site. Native and fill soils are generally comprised of the weathered Chatsworth formation materials and are typically fine-grained silty sands and sandy silts.

A regional geologic map is presented on Figure 2-1. The current geologic map of the Chatsworth formation at the SSFL is presented on Figure 2-2a, and a stratigraphic column on Figure 2-2b. The general occurrence of alluvium across the SSFL is shown on Figure 2-3. As indicated by this figure, the thickest deposits of alluvium or fill soils occur in the northeastern (up to 40 feet) and north-central (up to 30 feet) portions of the SSFL.

The SSFL has been divided into two RFI Operable Units (OUs): the Surficial Media OU (Surficial OU) and Chatsworth formation OU (CFOU). The Surficial OU includes saturated and unsaturated soil, sediment, surface water, near-surface groundwater, air, biota, and weathered bedrock. Near-surface groundwater is groundwater that occurs within the alluvium or weathered bedrock. The unit termed “weathered bedrock” is
comprised of oxidized, and typically more highly fractured, Chatsworth formation sandstone, with interbeds of shale and siltstone. The weathered bedrock is also less cemented and generally more friable than the deeper unweathered, competent Chatsworth formation bedrock. Based on well drilling information, the thickness of weathered bedrock at the SSFL typically ranges from about 20 to 50 feet. The CFOU includes both saturated and unsaturated unweathered (competent) bedrock.

### 2.2 VOC Characterization

The Surficial OU and CFOU have been locally impacted by chlorinated solvents from historical operations resulting in surficial spills and subsequent infiltration. The location, contaminant concentrations and extent have been defined by the RFI characterization sampling completed to-date. These contaminants may then migrate to areas away from the source. Trichloroethene (TCE) has been the VOC most commonly detected in samples of subsurface media (MW 2000a). Figure 2-4 shows TCE concentration ranges in soil vapor and groundwater sampling locations across the site. This figure is also provided at a smaller scale as Plate 2-1.

VOC impacts to both near-surface and CFOU groundwater have been characterized by sampling over 400 monitoring wells, springs/seeps, and piezometers at the site since 1984. The lateral extent of TCE impacts to near-surface and Chatsworth formation groundwater is shown on Figure 2-4. Impacts to soil are characterized by both soil vapor and soil matrix sampling results. For previous site characterization, the characterization method for VOCs was by soil vapor, with soil matrix sampling generally performed in shallow soils (typically less than 2 feet thick). Because most soil matrix data are colocated in areas of soil vapor data, only soil vapor sampling results are shown in Figure 2-4.

### 2.3 Vapor Migration Modeling Conditions

As chlorinated solvents infiltrate through the subsurface, they can be transported by groundwater to areas downgradient (i.e., distal) from the source. VOCs in the subsurface may volatilize from various media to outdoor and indoor air, resulting in complete exposure pathways. Figure 2-5 depicts a generalized conceptual site model (CSM) for human and ecological receptors, and identifies exposure pathways related to vapor migration at the SSFL. Appendix G of the SRAM describes methods for estimating
outdoor and indoor air VOC concentrations from subsurface vapor migration. The following subsurface media are potential sources of VOCs to the surface:

- CFOU groundwater,
- CFOU unweathered bedrock,
- Surficial OU weathered bedrock,
- Surficial OU soil, and
- Surficial OU near-surface groundwater.

Investigational units at the SSFL may have one or more of these contaminated media. For the purposes of collecting data for this model validation study, the SSFL has been categorized according to the following conditions:

1. "VOC Source Areas" - Investigational units where VOC sources are present in Surficial OU soils, and VOCs are also present in underlying media (i.e., Surficial OU groundwater, Surficial OU weathered bedrock, CFOU groundwater and/or CFOU unweathered bedrock) – Soil vapor concentrations represent vapor impacts from all sources below the sample point and will be used as a vapor migration model input. In addition, separate vapor migration calculations will be made to evaluate the contribution of each media (soil vapor, groundwater, bulk soil, and/or bulk bedrock) to outdoor and indoor air quality for the risk assessment.

The use of soil vapor data for vapor migration model input is preferred and will be used when obtainable. If soil vapor data cannot be obtained due to technical or feasibility limitations (e.g., low permeability soils, distance to known sources, insufficient soil thickness), bulk soil data or bulk bedrock data will be used to conduct the risk assessment for vadose zone impacts. The use of bulk media measurements for vapor migration modeling where soil vapor cannot be obtained is consistent with DTSC guidance (2005b).

For cases where Surficial OU groundwater is present above the CFOU, modeling will be conducted using the Surficial OU groundwater concentrations. VOC measurements beneath a shallow groundwater zone are not appropriate inputs to predict the vapor migration to the surface. Any flux to the surface will need to diffuse through the shallow groundwater zone (with diffusion coefficients up to five

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1 This would not apply if the Surficial OU groundwater is not continuous over the CFOU impacts or if the presence of Surficial OU groundwater is transient.
orders of magnitude lower than those for unsaturated soils) and would be evident in
the shallow groundwater analytical data. Modeling that considers CFOU
groundwater and/or CFOU bedrock concentrations will not be conducted, because
vapor flux through shallow groundwater is not considered significant. If there is no
Surficial OU groundwater present above the CFOU media, vapor migration
calculations will be made to evaluate the contribution of CFOU groundwater using
groundwater concentrations as the model input.

2. “Distal Areas” - Investigational units where no VOC sources are present in Surficial
OU soils, but where VOCs are present in underlying media (i.e., Surficial OU or
CFOU groundwater and/or bedrock) – In these cases, no soil VOC sources or
impacts are expected. If soil vapor samples have not been collected and field
validation and site conditions clearly indicate that soil vapor sampling would not
contribute meaningfully to remedial decisions, groundwater concentrations will be
used as inputs to the field-validated vapor migration model. For example, this
approach will be acceptable if field validation studies demonstrate that using
groundwater concentrations will provide an acceptable estimation of surface flux. If
soil vapor samples are also available, then separate vapor migration calculations using
concentrations from both media will be conducted. The risk assessment will describe
the choice of exposure point concentration and the modeling results used to determine
that concentration.

For cases where Surficial OU groundwater is present above the CFOU, modeling will
be conducted using the Surficial OU groundwater concentrations. Modeling using
CFOU groundwater and/or CFOU bedrock concentrations will not be conducted,
because vapor flux through shallow groundwater is not considered significant. If there
is no Surficial OU groundwater present above the CFOU media, vapor migration
model calculations will be made to evaluate the contribution of CFOU groundwater
using groundwater concentrations as the model input.

3. “Control Areas” - Areas far from surficial VOC sources where soil matrix and soil
vapor VOC concentrations are expected to be non-detect, and where groundwater
VOC concentrations are non-detect – VOC data collected from these areas will be
used to establish baseline comparison (“background”) concentrations for soil vapor,
vapor flux, soil matrix and groundwater data collected at known VOC source areas.
Vapor modeling is used to estimate VOC flux at the ground surface from measured soil vapor inputs. In certain situations bulk soil media concentrations and groundwater concentrations will be used as inputs into the field-validated vapor migration model. This validation study focuses on vapor migration transport for SSFL investigational units that will use groundwater concentrations. This study will compare measured data to predicted modeling results, and validate the modeling methodologies and input parameters described in Appendix G of the SRAM (MWH 2005a). Evaluation of the validation study results and application for future modeling is described in Sections 5 and 6.

SSFL investigational units represent a range of geologic and hydrogeologic conditions that can affect the subsurface migration of VOCs. In addition to varying VOC concentrations described above (Source versus Distal Areas), other site characteristics, such as soil thickness, surface conditions (asphalt cover), and presence of near-surface groundwater define how vapors migrate in the subsurface. The selection of validation sampling locations focused on locations with the highest predicted vapor flux amongst the range of site conditions, as described in Section 3.
3.0 VALIDATION SAMPLING

This section presents the specific vapor migration model validation sampling scope for various SSFL site conditions. The field validation sampling plan focuses on collecting data in areas where vapor modeling will be performed using input values from VOCs measured in near-surface media and Chatsworth formation groundwater.

As described above, the preferred input values for the vapor migration models are measured soil vapor data. Field validation of the vapor migration model using soil vapor as the input source will be performed at selected locations across SSFL, including at the LOX site in accordance with the approved LOX work plan (MWH 2005b). Data collected during implementation of the LOX work plan, along with data collected according to this work plan, will be evaluated as described in Section 5 to determine how the vapor migration model is performing. Therefore, for completeness, the DTSC-approved surface flux sampling locations at the LOX site are shown on figures prepared for this work plan (see Section 3.2.2).

This work plan focuses on validation sampling locations above areas where there are VOC sources in near-surface or Chatsworth formation groundwater. While this work plan does have an emphasis on areas with a groundwater VOC source, sampling for various site conditions including soil matrix and soil vapor source inputs are included. The work plan considers areas with and without soil contamination, with and without groundwater contamination, and with and without soil cover. Vapor modeling based on source concentrations from either near-surface or Chatsworth formation groundwater concentrations will be performed (1) when it is technically infeasible to collect soil vapor data, or (2) to discern risk contribution from other media when soil vapor data are used. Further information regarding the modeling inputs and approach is provided in Appendix G of the SRAM (MWH 2005a).

Table 3-1 and Figure 3-1 present a summary of proposed sampling locations for this vapor modeling validation study. Figure 3-1 is also provided at a smaller scale as Plate 3-1. Site conditions for validation were grouped as: (1) VOC Source Areas, (2) Distal Areas, or (3) Control Areas. VOC Source Area and Distal Area site conditions have been further categorized to indicate whether near-surface groundwater is present. Since near-surface groundwater does not occur at the Control Areas, this distinction was not necessary. Ten validation sampling locations were selected for this study, four each at the Source and Distal Areas, and two at Control Areas.
Also shown in Table 3-1 are soil and groundwater conditions at each of the validation sampling locations, including recent TCE concentrations in groundwater and maximum concentrations in soil vapor. TCE is the chemical most widely detected and typically occurs at the highest concentrations in soil and groundwater at the SSFL. As such, this work plan has targeted sampling locations based on TCE impacts. Chemical and physical properties of TCE for vapor transport are similar enough to other VOCs to make this a representative compound for the vapor model validation study.

The overall approach for validation sampling is to measure TCE vapor flux at the ground surface and TCE concentrations in subsurface media near the flux measurement. Where soil thickness is greater than 3 feet, colocated soil vapor and soil matrix samples will be collected to obtain subsurface soil data to evaluate input parameter use. Surface flux, soil vapor, and soil matrix data will be collected within about 20 feet of the corresponding groundwater well. Surface flux and proximal soil vapor / soil matrix data will be collected within a few days of each other. Groundwater samples will be collected from the targeted well during the quarterly monitoring event closest to the flux sampling date. Details regarding sampling protocols and laboratory analyses are described in Section 4. One surface flux point, one soil vapor point, and one well will be sampled at each location as part of this study. Specific sampling for wells and existing soil vapor probes included in this sampling plan are detailed in Table 3-1.

Screening vapor model fluxes were calculated for a range of groundwater concentrations and depths to groundwater to aid in the selection of appropriate sampling locations (Appendix A). For cases with depths to groundwater of 20 feet below ground surface (bgs), these model calculations indicated that measurable (i.e., greater than laboratory reporting limits) surface vapor fluxes are expected only for groundwater TCE concentrations greater than about 50 micrograms per liter (µg/L). For cases where depth to groundwater is greater than 100 feet bgs, groundwater concentrations exceeding 1,000 µg/L would be needed to achieve measurable surface vapor flux. Locations with higher TCE concentrations and shallower groundwater depths were preferentially selected. Sample locations were selected where soil or bedrock are uncovered (i.e., no asphalt, gunite, or concrete). The following sections describe the locations selected for sampling.
3.1 VOC Source Areas

Sampling at VOC source areas include locations with high TCE concentrations in near-surface and Chatsworth formation groundwater, with and without known or measurable soil impacts. Sampling locations were selected to maximize the likelihood that the TCE flux would be detectable for each of the site scenarios. Sampling locations, analyses, and rationale are described below and summarized in Table 3-1.

3.1.1 Locations with Near-Surface Groundwater

As shown on Figure 2-4, near-surface groundwater is present only in limited areas of the SSFL and is typically associated with alluvial drainages and in the broad alluvial valley in the western part of the SSFL. Two validation sampling locations are proposed in VOC source areas with near-surface groundwater; one at the Compound A RFI site in the central portion of the SSFL and the other at the Former Sodium Disposal Facility (FSDF) RFI site in the western SSFL (Figure 3-1). Sampling locations, soil conditions, and recent TCE sampling results are shown for the Compound A and FSDF sites on Figures 3-2 and 3-3, respectively.

These two locations were selected because they represent a range in soil and groundwater conditions and concentrations. TCE concentrations in near-surface groundwater at the two sites in 2005 were 6,900 µg/L in ES-24 at Compound A (Figure 3-2) and 1,700 µg/L in RS-54 at FSDF (Figure 3-3). Depths to water at each site are similar, about 15 feet bgs during 2005 (Haley and Aldrich [H&A] 2005b and 2005c). At the FSDF, near-surface groundwater is perched above Chatsworth formation groundwater. At Compound A, the groundwater units are vertically continuous (MWH 2003a). The sites have variable soil conditions that range from less than 1 foot thick at Compound A, to about 15 feet at FSDF. VOCs were less than 50 µg/Lv in soil vapor collected in the vicinity of ES-24 at Compound A; but soil vapor has not been sampled at FSDF during the RFI.

It is worth noting that the FSDF was the site of an interim removal action that resulted in excavation of all soil and the upper portion of weathered bedrock. The excavated area was backfilled with clean soil. The validation sampling location near RS-54 is near the center of the excavated area (Figure 3-3). The validation sampling near ES-24 at the Compound A site is also near a former pond (currently dry).
3.1.2 Locations without Near-Surface Groundwater

Sampling locations to evaluate VOC source areas above TCE impacted Chatsworth formation groundwater were chosen in areas without near-surface groundwater. Two locations have been selected that exhibit these conditions: the Delta RFI site (southwestern SSFL), and the Component Test Laboratory III (CTL-III) RFI site (southeastern SSFL) (Figure 3-1). Detailed maps for each sampling location are provided on Figures 3-4 and 3-5, respectively. These locations were selected because they represent a range of TCE concentrations and depths to Chatsworth formation groundwater.

The first sampling location for this condition is located at the Delta RFI site (Figure 3-4). The validation sampling location is near Chatsworth formation well HAR-7, adjacent to the test stand spillway. The maximum TCE concentration in HAR-7 during 2005 was 3,800 µg/L. Depth to groundwater at this location is typically about 75 feet bgs but recently has been about 45 feet bgs (H&A 2005a and 2005c). Near-surface groundwater exists in the northern portion of the Delta site but not in the validation sampling area (Figure 3-4). Soil is thin in the validation sampling area. Soil vapor collected approximately 10 feet south of HAR-7 at a depth of 2 feet bgs contained 4.5 µg/L TCE.

The second sampling location for this condition is located at the southern portion of the CTL-III RFI site (Figure 3-5). The validation sampling location is near Chatsworth formation well RD-46A, adjacent to a former pond (currently dry). The maximum TCE concentration in RD-46A during 2005 was 3,800 µg/L. Depth to groundwater at this location is typically about 75 feet bgs (H&A 2005a). Near-surface groundwater is not present at this validation location (MWH 2003a; Figure 3-5). Soil approximately 17 feet thick is present in the sampling area. TCE up to 2,000 µg/L has been measured in soil vapor nearby at depth of 13 feet bgs.

3.2 Distal Areas

Sampling at Distal Areas includes locations above near-surface and Chatsworth formation groundwater TCE plumes, and away from the VOC Source Areas. At these locations, there are no suspected surficial VOC releases, and the subsurface VOCs would be only those dissolved in groundwater. Sampling locations, analyses, and rationale are described below and summarized in Table 3-1.
3.2.1 Locations with Near-Surface Groundwater

Two sampling locations were selected for this condition; at the northern end of the CTL-III RFI site in the southeastern SSFL, and at the RD-9 area in the northern SSFL (Figure 3-1). The distal sampling locations and recent TCE sampling results are shown for these sites in Figures 3-5 and 3-6, respectively.

The CTL-III site location for this condition is adjacent to near-surface groundwater well ES-3 (Figure 3-5). The maximum TCE concentration in ES-3 during 2003 was 130 µg/L. Depth to groundwater at this location has been measured at about 10 feet bgs (H&A 2005a). Near-surface groundwater is reportedly continuous with Chatsworth formation groundwater in this portion of the CTL-III site (MWH 2003a). Soil is less than 3 feet thick in the proposed sampling. Soil vapor could not be measured in proximity to this location, but to the southwest was non-detect for TCE (< 1 µg/Lv).

The RD-9 area sampling location for this condition is east of the Building 515 RFI site adjacent to near-surface groundwater well ES-21 (Figure 3-6). The maximum TCE concentration in ES-21 during 2002 was 650 µg/L. Depth to groundwater at this location is generally about 15 feet bgs but has recently been measured at 3 feet bgs (H&A 2005a and 2005c). Near-surface groundwater is reportedly continuous with Chatsworth formation groundwater in the RD-9 area (MWH 2003a). Soil is up to about 20 feet thick in the proposed sampling area. Soil vapor has been measured in several locations in the area, and TCE ranges from non-detect (< 1 µg/Lv) to 17 µg/Lv at 12 feet bgs.

3.2.2 Locations without Near-Surface Groundwater

Sampling locations to evaluate distal VOC areas above TCE-impacted Chatsworth formation groundwater were chosen in areas without near-surface groundwater. Two locations were selected for these conditions; the B-1 RFI site in the northeastern SSFL, and the LOX RFI site in the northern portion of the SSFL (Figure 3-1). Detailed validation sampling maps for each location are provided in Figures 3-7 and 3-8, respectively. These locations were selected because they represent a range of TCE concentrations and depths to Chatsworth formation groundwater.

The B-1 RFI site sampling location for this condition is located in the southernmost portion of the site, north of the Instrument and Equipment Laboratories (IEL) RFI site (Figure 3-7). The location, while within the B-1 site boundary, is located in a down-
gradient portion of a Chatsworth formation groundwater plume with VOC sources at the IEL RFI site (Figure 2-4). The validation sampling location is near the Chatsworth formation well RD-72. The maximum TCE concentration in RD-72 during 2001 was 6,000 μg/L. Depth to groundwater at this location is typically about 80 feet bgs (H&A 2005a). Near-surface groundwater does not exist in this portion of the SSFL (MWH 2003c) (Figure 3-7). Although much of this area is covered with asphalt, the validation sampling location will be within an uncovered area of very thin soil present east of RD-72. The exposed soil area contains only thin soils, generally less than 1 foot thick. No soil vapor samples have been collected near this location; the nearest soil vapor sample was collected about 200 feet away from this location, with 1.1 μg/Lv TCE detected.

The LOX RFI site sampling location for this condition is in the western portion of the site, adjacent to Chatsworth formation well RD-52A (Figure 3-8) and about 350 feet away from the VOC soil source area. The most recent (2005) TCE concentration in RD-52A was 110 μg/L. Depth to groundwater at this location is typically about 100 to 110 feet bgs (H&A 2005a and 2005c). Near-surface groundwater does not typically exist at this site (MWH 2003a), although it was present near the VOC soil source for a two-month period after record rainfall in May and June 2005 (H&A 2005c). A thin veneer of soil about 1 foot thick is present at the sampling location. Soil vapor sampling results nearest to the validation location were non detect (< 1 μg/Lv) for TCE. For reference, the vapor migration model validation sampling locations described in the LOX work plan for the VOC soil source area are also shown on Figure 3-8.

3.3 Control Areas

Control areas are locations where no subsurface sources of VOCs have been identified and surface flux measurements will be representative of ambient or background conditions. Two control areas were selected; one in the northern and one in the southern undeveloped portions of the SSFL (where no solvent use occurred or is suspected), adjacent to Chatsworth formation wells with a sampling history of non-detected TCE (Figure 3-1). The northern sampling location is adjacent to well RD-92, and the southern sampling location is adjacent to well RD-5A. Detailed sampling location maps for each are provided in Figures 3-9 and 3-10, respectively. Depths to water at these locations are similar to those at the other Chatsworth formation groundwater sampling areas, ranging from about 65 to 80 feet bgs (Table 3-1). Soil is estimated to be about 14 feet thick at the
southern location, and is about 3.5 feet thick at the northern location. TCE has never
been detected in groundwater in the northern location (RD-92). TCE has been non detect
in well RD-5A since 1998.
4.0 SAMPLING AND ANALYSIS PROCEDURES

This section provides details of how surface vapor flux, soil vapor, soil matrix, and groundwater samples will be collected and analyzed for the validation study. For the purposes of this study, TCE will be analyzed to represent VOC concentrations in soil, soil vapor, bedrock, and groundwater. All sampling and analysis will be performed following DTSC-approved protocols described in previous RFI work plans. New sampling or analysis protocols unique to this validation study (or that will be used to implement the LOX vapor work plan effort) are described in this section.

Samples collected during the field validation program will be analyzed by a qualified, California-certified laboratory, and data will be validated following approved RFI protocols (Ogden 2000a).

4.1 Surface Vapor Flux

Surface vapor flux sampling will follow the procedures described in Measurement of Gaseous Emission Rates from Land Surfaces Using an Emission Isolation Flux Chamber - User’s Guide (USEPA 1986). Measurement of surface flux will be conducted from an area with a likely measurable mass emission rate (see Section 3 and Appendix A). These measurements will be conducted on the soil or bedrock surfaces at locations near the targeted well location.

Quality control procedures will be implemented, including the collection of one blank, one duplicate, and one laboratory confirmation (split) sample for each ten flux samples collected. The field blank sample will be collected at the onset of testing by placing the flux chamber on a clean, impervious surface (i.e., Teflon sheet). Duplicate and confirmation samples will be collected immediately after the corresponding primary sample is collected, without moving the flux chamber.

For each surface flux sample, the following procedure will be followed:

- Measurement of surface flux at all locations will take place at the same time each day, at approximately mid-day. This will allow comparison of the results between the different SSFL site conditions.
- The chamber will be placed on the ground surface and worked into the soil to a depth of 2 to 3 centimeters (cm) to provide a good seal. For surface flux sampling locations with exposed bedrock the chamber will be sealed using bentonite to the bedrock.

- The flux chamber will initially be purged using ultrapure compressed air at a sweep gas flow rate of 5.0 liters per minute (lpm) for 30 minutes. This represents approximately five residence times (6 minutes each), providing a steady-state equilibrium condition within the chamber. Ambient air and chamber temperature, as well as flow rate will be recorded every 6 minutes, corresponding to each residence time.

- Once steady-state conditions have been achieved, the sampling line will be purged using a hand pump (approximately 10 plunges) and an evacuated 6liter SUMMA canister will be attached.

- The SUMMA canister valve will be opened and the sampling rate adjusted to maintain a sampling rate less than 2.5 lpm over the sampling period (approximately 2 to 3 minutes). When the canister is full, the canister valve will be closed and the sample collection data documented on the field data sheet.

- The flux chamber will be decontaminated by wiping the seal surface with a clean paper towel and water, if needed, and purging the chamber and sample line with sweep gas at 5 lpm for a minimum of 2 minutes.

- The SUMMA canister will be sent to the analytical laboratory following standard RFI chain-of-custody protocols. TCE will be analyzed using USEPA Method TO-15 SIM (selective ion monitoring) to achieve the low-level detection limits requested by DTSC. The anticipated laboratory reporting limit for TCE using this method is 0.0011 μg/L (MWH 2005a). This reporting limit combined with the canister flow rates will yield low flux detection limits.

4.2 Soil Vapor

Soil vapor sampling is proposed at all surface flux sampling locations where soil thickness is 3 feet or greater. Since soil vapor samples cannot be collected at locations with less than 3 feet of soil, other model source concentrations will be used. The purpose
of these samples is to document existing subsurface VOC site conditions at the time of flux sampling. These samples will be collected from sampling probes installed using standard RFI active soil vapor sampling field protocols. The following describes the protocol for soil vapor sampling.

- The soil vapor sampling probes will be installed within 3 to 5 feet of the soil vapor flux chamber locations, and samples will be collected at 5-foot depth intervals to bedrock where sufficient soil thickness is available. If soil thickness is between 3 and 5 feet, one soil vapor sample will be collected at the greatest depth possible.

- Soil vapor samples will be collected from currently existing probes or newly installed probes if needed. Installation of new soil vapor probes will be conducted at least 1 week prior to flux chamber sampling.

- Soil vapor probes will be capped prior to vapor flux sampling.

- Sampling of soil vapor will be conducted 1 day following flux chamber measurements.

- Quality control procedures will be implemented, including the collection of 1 blank and one duplicate sample for each 10 soil vapor samples collected.

- To ensure comparability with the flux chamber measurements, soil vapor samples will be collected using SUMMA canisters. SUMMA canisters will be sent to the analytical laboratory following standard RFI chain-of-custody protocols. TCE will be analyzed using USEPA Method TO-15 SIM (selective ion monitoring) to achieve the low-level detection limits requested by DTSC.

4.3 Soil Matrix

Soil matrix sampling is also proposed at all surface flux sampling locations where the soil thickness is 3 feet or greater. The purpose of these samples is to obtain VOC and geotechnical data from shallow soils at the flux chamber locations. The following describes how soil matrix samples will be collected.

- Soil matrix samples will be collected at 5-foot intervals to bedrock adjacent to (within 3 to 5 feet) each surface flux location where sufficient soil is present. For
locations with less than 5 feet of soil present, one soil matrix sample will be collected at the greatest depth available.

- TCE analysis will be performed on proposed samples using EPA Method 8260B following RFI protocols.
- The suite of geotechnical parameters to be measured include moisture content, bulk density, specific gravity, total porosity, degree of saturation, and hydraulic conductivity using American Society for Testing and Materials (ASTM) methods.

- Soil matrix samples will be collected following standard RFI field protocols (including methanol preservation as specified by DTSC guidance, DTSC 2004) within a few days following the completion of surface flux measurements and subsequent soil vapor sampling.

4.4 Groundwater

Groundwater samples collected from the targeted validation wells (Table 3-1) during the regularly scheduled quarterly monitoring event closest to the flux sampling period will be used for this field validation study. Sampling procedures and analyses will follow the DTSC-approved groundwater sampling protocols specified in the Sampling and Analysis Plan (Groundwater Resources Consultants 1995).
5.0 MODEL EVALUATION

Data collected during the validation field sampling will be evaluated to assess applicability of the vapor migration models to SSFL site conditions, considering the colocated surface flux measurements, source concentrations, and soil properties.

This field validation study focuses on the vapor migration model component used to estimate surface flux from subsurface VOC concentrations. Each subsurface sample will be used as input to the vapor flux modeling equations provided in Appendix G of the SRAM to provide an estimated surface flux that can be compared to the colocated, measured surface flux measurement. Data collected in accordance with this work plan and the LOX work plan will be evaluated to determine model performance.

5.1 Evaluation of Model Performance

The field validation study is designed to compare measured vapor flux from a variety of site conditions to modeled vapor flux. The evaluation will include:

- Comparison of source media concentrations (groundwater or bulk media) to colocated soil vapor data;
- Comparison of measured and modeled soil vapor profiles; and
- Comparison of measured and modeled vapor fluxes from bulk soil, soil vapor, or groundwater.

The multiple evaluations of these data sets will provide understanding of model applicability for the range of SSFL site conditions and source media.

5.2 Model Sensitivity/Uncertainty Analysis

The objective of the sensitivity/uncertainty analysis is to identify critical vapor migration model inputs. This analysis will include evaluation of the surface flux model as well as the Indoor Air model to evaluate sensitivity of subsurface migration input parameters relative to the additional default indoor air modeling parameter values presented in Appendix G of the SRAM. The sensitivity analyses will be conducted for specific SSFL site conditions and specific subsurface media data used as modeling input. The sensitivity analysis will be conducted by sequentially varying each input by +/- 50

MWH
percent and evaluating resulting changes in model output. The sensitivity/uncertainty of each parameter will be evaluated and reported for the range of SSFL site conditions and source data. Several input parameters are interrelated. For instance soil moisture is related to water infiltration rate, and soil porosity, air content, and moisture content are interrelated. The sensitivity analysis will account for these interdependent relationships.

Sensitivity/uncertainty analysis results will be used to establish appropriate model input parameters representative of average and reasonable maximum exposure (RME) risk assessment scenarios for use at the range of SSFL investigational units.

5.3 Proposed Changes to Vapor Models

Since the proposed SSFL vapor migration models are based on accepted fate and transport models, it is anticipated that there will be good agreement between measured and modeled vapor flux. ‘Good agreement’ means that modeled vapor flux is equivalent or up to five-times greater than measured flux. If there is not ‘good agreement’ between modeled and measured vapor flux (i.e., modeled flux is less than measured or greater than five-times measured) then adjustments to the proposed SSFL vapor migration models will be made. Possible input adjustments to the proposed models include:

- Model calculation parameters
- Soil parameters
- Selection of soil types
- Diffusion coefficients

Adjusted model output will be compared to measured results using the same procedure described above for the proposed models. If good agreement is achieved, then adjusted models will be used to predict vapor flux and exposure point concentrations in the risk assessment as described in the SRAM.
6.0 PROJECT REPORTING AND SCHEDULE

The following sections describe the validation study report and schedule.

6.1 Reporting

The Vapor Migration Modeling Validation Study Report will include discussion of work performed, resultant data, evaluation/validation analyses of the vapor models, and model applicability to SSFL conditions. Field procedures will be documented, including observed site conditions and sampling details. Laboratory reports, chain-of-custody forms, and data validation findings will be provided, including a discussion of any potential effects on the data quality and its use for model validation.

The study report will describe the model evaluation and sensitivity/uncertainty analyses. Any recommended model modifications will be described. Finally, the Vapor Migration Modeling Validation Study Report will recommend applicability of the validated model for use at the SSFL.

6.2 Validation Study Project Schedule

The schedule for the vapor migration model field validation program extends from the submittal of this work plan to the submittal of the report. The estimated total duration of the overall study is 6 months, and includes previously approved field work at the LOX RFI site (MWH 2005b). To perform sampling before the rainy season, field work is planned to begin in November 2005.

Field work will be completed within 30 to 45 days. Sampling will only be performed within a dry-weather window, and not occur unless a 2 week period has elapsed from any significant rainfall (greater than or equal to about 2 inches). Details regarding the sampling schedule will be discussed with DTSC prior to implementation of this work plan. The final 5 months of this project consists of laboratory analysis of samples, data validation and review of reported laboratory data, vapor model evaluation, and report writing. Changes in the schedule due to difficulties encountered in the field will be communicated to DTSC and the schedule amended if necessary.
7.0 REFERENCES


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### Table 3-1

**Summary of Site Conditions at Validation Sampling Locations**

<table>
<thead>
<tr>
<th>Types of Sampling Areas</th>
<th>Investigational Unit Location</th>
<th>Targeted Well(s)</th>
<th>Screened Interval</th>
<th>Total Depth (feet)</th>
<th>Near-Surface Groundwater Present?</th>
<th>Delta to Water (feet)</th>
<th>TCE in Groundwater (µg/L)</th>
<th>Maximum TCE in Soil Vapor (µg/L)</th>
<th>Maximum TCE in Soil Matrix (µg/kg)</th>
<th>Soil Thickness (feet)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. VOC Source Areas</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near-surface groundwater present:</td>
<td>Compound A</td>
<td>ES-04</td>
<td>18-30/30</td>
<td>yes</td>
<td>17</td>
<td>6900 (505)</td>
<td>40 @ 2 bgs</td>
<td>63 @ 7 bgs</td>
<td>&lt;1</td>
<td>Shallow depth to water, high TCE, very thin soil</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RS-04</td>
<td>7-35/35</td>
<td></td>
<td>13</td>
<td>1703 (203)</td>
<td>NA</td>
<td>15</td>
<td>Shallower depth to water, high TCE in groundwater, thick soil</td>
<td>X</td>
<td>X (new)</td>
</tr>
<tr>
<td>No near-surface groundwater present:</td>
<td>Delta</td>
<td>HA-07</td>
<td>35-100/100</td>
<td>no</td>
<td>44</td>
<td>3500 (405)</td>
<td>4.6 @ 4 bgs</td>
<td>NO</td>
<td>&gt;1</td>
<td>Moderate depth to water, high TCE, very thin soil</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RD-46A</td>
<td>30-140/140</td>
<td></td>
<td>73</td>
<td>3500 (505)</td>
<td>2.000 @ 13 bgs</td>
<td>220 @ 12 bgs</td>
<td>17</td>
<td>Moderate depth to water, high TCE, thick soil</td>
<td>X</td>
</tr>
<tr>
<td><strong>2. Distal Areas</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near-surface groundwater present:</td>
<td>CTL-11 (South)</td>
<td>ES-03</td>
<td>17-37/37</td>
<td>yes</td>
<td>15</td>
<td>1300 (203)</td>
<td>NO</td>
<td>NS</td>
<td>&lt;3</td>
<td>Shallow depth to water, moderate TCE, thin soil</td>
<td>X</td>
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<tr>
<td></td>
<td></td>
<td>RD-21</td>
<td>16-35/35</td>
<td></td>
<td>165</td>
<td>660 (203)</td>
<td>17 @ 12 bgs</td>
<td>NS</td>
<td>26</td>
<td>Shallow depth to water, moderate TCE, thick soil</td>
<td>X</td>
</tr>
<tr>
<td>No near-surface groundwater present:</td>
<td>B-1 South (EL GW Plume)</td>
<td>RD-72</td>
<td>37-102/102</td>
<td>no</td>
<td>68</td>
<td>6000 (101)</td>
<td>NO</td>
<td>NS</td>
<td>1</td>
<td>Moderate depth to water, high TCE, thin soil</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RD-63A</td>
<td>20-107/107</td>
<td></td>
<td>109</td>
<td>115 (203)</td>
<td>NO</td>
<td>NS</td>
<td>&gt;1</td>
<td>Moderate depth to water, moderate TCE, thick soil</td>
<td>X</td>
</tr>
<tr>
<td><strong>3. Control Areas</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>No near-surface groundwater present:</td>
<td>Undeveloped Land North</td>
<td>RD-03</td>
<td>20-100/100</td>
<td>no</td>
<td>64</td>
<td>NO &lt; 0.24 (144)</td>
<td>NO</td>
<td>NS</td>
<td>3.5</td>
<td>Moderate depth to water, no TCE, thick soil</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RD-65A</td>
<td>20-100/100</td>
<td></td>
<td>81</td>
<td>NO &lt; 0.24 (144)</td>
<td>NO</td>
<td>NS</td>
<td>14</td>
<td>Moderate depth to water, no TCE, thick soil</td>
<td>X</td>
</tr>
</tbody>
</table>

### Notes:

1. VOC Source Areas are areas with high TCE concentrations in soil or groundwater, near operations which had a surface release. Distal Areas are down-gradient to the VOC Source Areas, with no suspected release of TCE to the surface. Control Areas are in undeveloped land where TCE is not present in surficial media or deep groundwater.

2. Selected parameters will be collected at all soil vapor locations where sufficient soil is present. Soil vapor samples will be collected at 5 foot intervals to top of bedrock.

3. Sampling locations shown on Figures 3-1 through 3-6.

4. Vapor migration model test validation sampling will also be conducted at the soil vapor area at the DCM site in accordance with a UTGDO-approved work plan (NMAR-20015). These sampling locations are shown on Figures 3-1 and 3-6.

### Table 3-2

**Summary of Vapor Migration Model Validation Sampling Locations**

| Types of Sampling Areas | Investigational Unit Location | Targeted Well(s) | Screened Interval | Total Depth (feet) | Near-Surface Groundwater Present? | Delta to Water (feet) | TCE in Groundwater (µg/L) | Maximum TCE in Soil Vapor (µg/L) | Maximum TCE in Soil Matrix (µg/kg) | Soil Thickness (feet) |
|-------------------------|--------------------------------|------------------|------------------|--------------------|-------------------------------|---------------------|--------------------------|-------------------------------|---------------------------------|----------------|-------|
| **1. VOC Source Areas**  |                                |                  |                  |                    |                               |                     |                          |                               |                                 |                 |       |
| Near-surface groundwater present: | Compound A | ES-04 | 18-30/30 | yes | 17 | 6900 (505) | 40 @ 2 bgs | 63 @ 7 bgs | <1 | Shallow depth to water, high TCE, very thin soil | X | no | no | ES-04 |
| | | RS-04 | 7-35/35 | | 13 | 1703 (203) | NA | 15 | Shallower depth to water, high TCE in groundwater, thick soil | X | X (new) | X | RS-04 |
| No near-surface groundwater present: | Delta | HA-07 | 35-100/100 | no | 44 | 3500 (405) | 4.6 @ 4 bgs | NO | >1 | Moderate depth to water, high TCE, very thin soil | X | no | no | HA-07 |
| | | RD-46A | 30-140/140 | | 73 | 3500 (505) | 2.000 @ 13 bgs | 220 @ 12 bgs | 17 | Moderate depth to water, high TCE, thick soil | X | CLSP01 | X | RD-46A |
| **2. Distal Areas** |                                |                  |                  |                    |                               |                     |                          |                               |                                 |                 |       |
| Near-surface groundwater present: | CTL-11 (South) | ES-03 | 17-37/37 | yes | 15 | 1300 (203) | NO | NS | <3 | Shallow depth to water, moderate TCE, thin soil | X | no | no | ES-2 |
| | | RD-21 | 16-35/35 | | 165 | 660 (203) | 17 @ 12 bgs | NS | 26 | Shallow depth to water, moderate TCE, thick soil | X | B3SP03 | X | ES-21 |
| No near-surface groundwater present: | B-1 South (EL GW Plume) | RD-72 | 37-102/102 | no | 68 | 6000 (101) | NO | NS | 1 | Moderate depth to water, high TCE, thin soil | X | no | no | RD-72 |
| | | RD-63A | 20-107/107 | | 109 | 115 (203) | NO | NS | >1 | Moderate depth to water, moderate TCE, thick soil | X | no | no | RD-62A |
| **3. Control Areas** |                                |                  |                  |                    |                               |                     |                          |                               |                                 |                 |       |
| No near-surface groundwater present: | Undeveloped Land North | RD-03 | 20-100/100 | no | 64 | NO < 0.24 (144) | NO | NS | 3.5 | Moderate depth to water, no TCE, thick soil | X | no | no | RD-03 |
| | | RD-65A | 20-100/100 | | 81 | NO < 0.24 (144) | NO | NS | 14 | Moderate depth to water, no TCE, thick soil | X | X (new) | X | RD-65A |

### Notes:

1. VOC Source Areas are areas with high TCE concentrations in soil or groundwater, near operations which had a surface release. Distal Areas are down-gradient to the VOC Source Areas, with no suspected release of TCE to the surface. Control Areas are in undeveloped land where TCE is not present in surficial media or deep groundwater.

2. Selected parameters will be collected at all soil vapor locations where sufficient soil is present. Soil vapor samples will be collected at 5 foot intervals to top of bedrock.

3. Sampling locations shown on Figures 3-1 through 3-6.

4. Vapor migration model test validation sampling will also be conducted at the soil vapor area at the DCM site in accordance with a UTGDO-approved work plan (NMAR-20015). These sampling locations are shown on Figures 3-1 and 3-6.
APPENDIX A

VAPOR FLUX SCREENING CALCULATIONS
APPENDIX A

VAPOUR FLUX SCREENING CALCULATIONS

This appendix presents the calculations of trichloroethylene (TCE) surface flux estimates for a range of TCE groundwater concentrations and depths to groundwater. The results of the flux estimates presented here are intended to aid the selection of potential locations for TCE surface flux measurements that would have the greatest likelihood of resulting in a measurable flux, i.e. above the flux analytical detection limit. The surface flux measurements are being conducted to validate the vapor migration modeling that is part of the human health and ecological risk assessment approach for impacted environmental media at the Santa Susana Field Laboratory (SSFL). The modeling is described in the Standardized Risk Assessment Methodology (SRAM) Work Plan, Revision 2 - Final.

Screening Equations

The vapor migration model presented in the SRAM was used to estimate surface flux for a range of groundwater concentrations and depths to groundwater. The equations used are:

\[
 F = \frac{C_{\text{source}} R / H'}{\exp \left( \frac{R \times L_T}{D_T^{\text{eff}} \times H'} \right) - 1}
\]

where

\[
 F = \text{total mass flux (} \mu \text{g/m}^2 \text{-s)} \\
 C_{\text{source}} = \text{sub-surface source vapor concentration (} \mu \text{g/m}^3 \text{-vapor)} \\
 R = \text{average steady recharge rate (m/s)} \\
 D_T^{\text{eff}} = \text{overall effective diffusion coefficient through all layers (m}^2 \text{/s);} \\
 L_T = \text{the total combined thickness of all layers (m);} \\
 H' = \text{Dimensionless Henry's Law coefficient (m}^3 \text{-water/m}^3 \text{-vapor)}
\]

The total effective diffusion coefficient is the harmonic average of the diffusion coefficients through each layer and is described by:

\[
 D_T^{\text{eff}} = \frac{L_T}{\sum \frac{L_i}{D_{\text{eff},i}}}
\]
where

\[ D_{\text{eff,i}} = \text{effective diffusion coefficient through layer } i \text{ (m}^2/\text{s}); \text{ and} \]
\[ L_i = \text{the thickness of layer, } i. \]

The equation to calculate the effective diffusion \((D_{\text{eff}})\) coefficient is described by:

\[
D_{\text{eff}} = \left[ \phi_f \left( \frac{\theta_w^{7/3}}{n^2} \right) \times D_w \right] + \left[ \phi_f + \phi_m \left( \frac{\theta_v^{7/3}}{n^2} \right) \times D_a \right]
\]

\[
\phi_f = \text{fracture porosity (m}^3\text{-fractures/m}^3\text{-soil)}
\]
\[ n = \text{matrix porosity (m}^3\text{-void space/m}^3\text{-soil)}
\]
\[ \theta_v = \text{volumetric air content of the matrix (m}^3\text{-vapor/m}^3\text{-soil)}
\]
\[ D_a = \text{molecular diffusion coefficient in air (m}^2/\text{s)}
\]
\[ \theta_v = \text{volumetric water content of the matrix (m}^3\text{-water/m}^3\text{-soil)}
\]
\[ D_w = \text{molecular diffusion coefficient in water (m}^2/\text{s)}
\]

For this screening evaluation, the sub-surface source vapor concentration is calculated from the groundwater concentration using Henry’s Law:

\[
C_{\text{source}} = C_{GW} \times H' \times 1000 \text{ L/m}^3
\]

where

\[ C_{GW} = \text{groundwater concentration (ug/L-water).} \]

**Screening Scenarios**

The site conditions assumed for the analyses are a location with the upper most 15 feet of the subsurface being comprised of soil matrix. The soil layer was assumed to be underlain by a 15 foot thick layer of weathered bedrock. The weathered bedrock layer was assumed to be underlain by an unweathered bedrock layer that extended down to a groundwater source. Screening vapor model calculations were performed for a range of groundwater concentrations and depths to groundwater. Although groundwater sources are assumed, the reduction in the overall diffusion coefficient due to the capillary fringe is not considered in this screening evaluation. The depths to groundwater source evaluated were 10, 20, 50, 100, and 200 feet below ground surface (bgs). Note that the scenarios assuming a 10-foot depth to groundwater consider only diffusion through the soil matrix and the scenarios assuming a 20-foot depth to groundwater consider diffusion through the soil matrix and weathered bedrock. The range of ground water source TCE
concentrations evaluated ranged from 0.5 to 100,000 µg/L. The TCE chemical properties used in the evaluation are shown in Table A-1. The subsurface physical properties of soil, weathered bedrock, and unweathered bedrock are also listed in Table A-1.

**Screening Results**

The resulting estimated TCE surface fluxes from each of the scenarios are presented in Table A-2. The results are also plotted in Figure A-1. Also plotted in the figure is the expected TCE surface flux detection limit of 0.1 µg/m²-min. Figure A-1 indicates that for groundwater 20 feet bgs, a groundwater TCE concentration of approximately 50 µg/L would be necessary to result in a measurable surface flux. For groundwater depths greater than 100 feet bgs, TCE groundwater concentrations greater than 1,000 µg/L are necessary.