Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater

Volume 1: User's Guide

Pacific Basin Edition

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[Note: The Tier 1 ESLs were updated in October 2008 to incorporate updates to the USEPA Region Screening Levels (USEPA 2008). Refer to Appendix 9 and the ESL Surfer for details and most recent updates.]

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DISCLAIMER

This report, *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (Summer 2008), is a technical guidance document prepared for the Guam Environmental Protection Agency (Guam EPA). The guidance and associated models represent an update to a similar, 2005 guidance document prepared under the direction of the Commonwealth of the Northern Mariana Islands (CNMI). Similar guidance documents have been prepared for the State of California and State of Hawai‘i by the same author (Dr. Roger Brewer). This version of the guidance, referred to as the *Pacific Basin* edition, adheres most strictly to USEPA standards and publications and is considered to be the most widely applicable of the three.

The document provides guidance for identification and evaluation of environmental hazards associated with contaminated soil and groundwater. The Environmental Screening Levels (ESLs) presented in this document and the accompanying text are specifically *not* intended to serve as: 1) a stand-alone decision making tool, 2) guidance for the preparation of baseline environmental risk assessments, 3) a rule to determine if a waste is hazardous under the state or federal regulations, or 4) a rule to determine when the release of hazardous substances must be reported to the overseeing regulatory agency.

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B Shallow Soil (<3m bgs), Groundwater IS NOT a Current or Potential Source of Drinking Water

C Deep soil (>3m bgs), Groundwater IS a Current or Potential Source of Drinking Water

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- BATCH TEST SOIL LEACHING MODEL (EXCEL)

Executive Summary

This document presents guidance for the expedited identification of environmental hazards associated with contaminated soil and groundwater. Guidance is also provided for the preparation of *Environmental Hazard Evaluation* reports that assist in completion of site investigations and help guide appropriate remedial actions. An earlier edition of this guidance was prepared under the oversight of the Commonwealth of the Northern Mariana Islands Division of Environmental Quality (CNMI 2005). This document, sponsored by the Guam Protection Agency (Guam EPA), represents a significant update to the earlier guidance. The Summer 2008 edition also incorporates updates to toxicity factors and risk models in the May 2008 USEPA Regional Screening Levels guidance (not included in the original, April 2008 edition of this guidance). Although prepared specifically for Guam EPA, the use of well-accepted, US Environmental Agency (USEPA) standards, models and protocols should permit flexible use of the guidance throughout tropical and subtropical areas of the Pacific Basin region with little or no modification. Use of the guidance outside of this region is primarily limited by the need for a more detailed evaluation of subsurface, vapor intrusion hazards in areas where buildings are heated for much of the year (increased threat of vapor intrusion from contaminated soil or groundwater). [The Tier 1 EALs were updated in October 2008 to incorporate updates to the USEPA Region Screening Levels (USEPA 2008). Refer to Appendix 10 and the EAL Surfer for details.]

An *Environmental Hazard Evaluation* (EHE) should be carried out at all sites where contaminated soil or groundwater is identified. A brief but properly prepared EHE will in most cases replace what is traditionally known as an environmental "risk assessment." An important part of the EHE is the use of pre-approved, *Environmental Screening Levels* (ESLs) included in the lookup tables and *ESL Surfer* included in this guidance document. The ESLs are used to rapidly screen soil, soil gas and groundwater data collected for a site and identify potential environmental hazards. Under most circumstances, and within the limitations described, the presence of a chemical in soil, soil gas or groundwater at concentrations below the corresponding Tier 1 ESL can be assumed to not pose a significant threat to human health and the environment. This allows sites or portions of sites with minimal or no contamination to be quickly cleared for potential environmental concerns, a task which could easily take months or even years using a traditional, environmental risk assessment approach.

The ESLs incorporate an enormous amount of technical expertise across fields as diverse as toxicology, geology, chemistry, physics, ecology, engineering and even economics. Much like driving a car, however, it is not necessarily to understand the technical intricacies of the ESLs in order to use them. As potential problems are identified, internal or external expertise can be brought in to help evaluate and mitigate the problems as needed.

Exceeding the Tier 1 ESL for a specific chemical does not necessarily indicate that the contamination poses significant environmental concerns, only that additional evaluation is warranted. A detailed review of specific hazards can be carried out if time- and cost-beneficial, or contamination that exceeds the ESLs can simply be remediated. This can even include the preparation of site-specific, human health or ecological risk assessments, although this level of effort will rarely be required for typical sites.

An EHE serves as the link between site investigation activities and the selection of final response actions. As potential environmental hazards are identified, the site investigation can be modified to ensure that adequate types and amounts of data are collected to understand the extent and nature of potential hazards. Once the site investigation and EHE are completed, *Environmental Hazard Maps* can be prepared to summarize the findings of the investigations and serve as a tool to help guide and design subsequent remedial efforts. The type of remedial actions required at the site will vary, depending on the nature of the environmental hazards identified (e.g., soil removal or capping to address direct exposure or leaching hazards versus soil vapor extraction to address vapor intrusion hazards).

The following information should be included in an EHE (or included in a report that contains the EHE):

1. **Site History:** Brief summary of the site history and operations that lead to the release of hazardous chemicals;
2. **Past Investigations and Remedial Actions:** Overview of past investigations and remedial actions;
3. **Extent and Magnitude of Contamination:** Summary of the extent and magnitude of contamination in soil, soil gas and/or groundwater above Tier 1 ESLs, clearly depicted on to-scale maps of the site;
4. **Identification of Potential Environmental Hazards:** Identification of potential environmental hazards by comparison of site soil, soil gas and/or groundwater data to Tier 1 ESLs as well as screening levels specific hazards (latter especially important at sites where full cleanup to the Tier 1 ESLs will not take place or alternative screening levels will be considered);

5. **Detailed Evaluation of Specific Environmental Hazards (optional):** Detailed evaluation of specific environmental hazards using approaches described in this document or alternative approaches approved by the overseeing regulatory agency;
6. **Conclusions and Recommendations:** Provides a summary of EHE findings and recommendations for followup actions.

The level of detail needed in the EHE will vary depending on the nature of the contamination and anticipated cleanup actions. A basic EHE should be used to screen for potential environmental hazards, identify data gaps and complete the site investigation. The completed EHE should conclude with recommendations for followup actions, such as no further action, collection of additional data to better evaluate a specific environmental hazard or evaluation of remedial alternatives. At sites where full cleanup is not possible, an "as-built" EHE should be used to document the extent and magnitude of remaining contamination as well as potential environmental hazards posed by the contamination in the absence of institutional or engineered controls. This "as built" EHE serves as the basis for an *Environmental Hazard Management Plan* that describes ongoing measures to be taken to ensure that the contamination is properly managed in the future.

The Tier 1 ESLs presented in the lookup tables are NOT regulatory "cleanup standards". Site-specific screening levels and cleanup levels are, however, subject to the approval of Guam EPA (or other overseeing regulatory agency). ESLs presented for chemicals that are known to be highly biodegradable in the environment may be excessively conservative for use as final cleanup levels (e.g., many petroleum-related compounds). Stand alone use of the Tier 1 ESLs may be inadequate in some cases. Examples include sites with a high public profile that cannot be fully cleaned up and require a detailed discussion of potential risks to human health. Other examples include sites where physical conditions differ drastically from those assumed in development of the ESLs (e.g., mine sites, landfills, etc., with excessively high or low pH) and sites where impacts pose heightened threats to sensitive ecological habitats. Use of the ESLs as stand alone screening criteria or final cleanup levels should be evaluated in terms of overall site conditions and potential environmental hazards, the cost/benefit of developing site-specific cleanup levels as well as the pros and cons of full site cleanup versus long–term management.

The *Environmental Hazard Evaluation* approach described in this guidance is applicable to any site where contaminated soil and groundwater are identified, including sites that fall under the purview of the Comprehensive Environmental

Restoration and Reclamation Act (CERCLA). The guidance will be of particular benefit to small-business owners and property owners with limited financial resources, for whom the preparation of traditional, Superfund-type risk assessments is generally not feasible or even necessary. The guidance is particularly useful as a rapid and cost-effective tool for the evaluation of brownfield or potential brownfield properties. This guidance will be updated as needed, in order to incorporate changes in the referenced sources as well as lessons gained from site investigation and response actions. Comments and suggestions are welcome at any time and should be submitted to the contacts noted at the beginning of this document.

1

Introduction

1.1 Environmental Hazard Evaluation

Environmental Hazard Evaluation is the link between the discovery of contaminated soil or groundwater during the *site investigation* and *response actions* taken to address this contamination (Figure 1-1). During this step of the overall environmental response process, the presence or absence of potential environmental hazards associated with contaminated soil and groundwater is determined. This is carried out initially by comparison of site data to pre-approved, Environmental Screening Levels (ESLs) presented in Tables A through F at the end of this volume. If potential concerns are confirmed then the specific hazards posed by the contamination are identified, the need for additional data to complete the site investigation is determined and the preparation of appropriate remedial actions is recommended.

Once the site has been adequately characterized, the most appropriate remedial action is determined. For sites where the extent of contamination is minimal or time is of the essence, the most cost-beneficial response may be the immediate removal of the contaminated media. In other cases, the potential cost of remediation or difficulty in accessing the contamination could preclude a complete cleanup. An advanced evaluation of specific environmental hazards is usually warranted at such sites. This may involve the development of site-specific cleanup levels and remedial actions to address the most pressing hazards (e.g., discharges of free product into storm sewers or vapor intrusion into overlying buildings). The extent and magnitude of the remaining contamination and the specific environmental hazards posed by the contamination is then documented in final site investigation and environmental hazard evaluation report. This is then used to prepare an *Environmental Hazard Management Plan* that presents guidelines for long-term management of the contamination and associated institutional and engineered controls.

Environmental Hazard Evaluations are therefore an integral part of site investigations and remedial actions. Site investigations and remedial actions carried out in the absence of a basic understanding of the environmental hazards posed by contaminated soil or groundwater run the risk of being incomplete. This can result in later, unanticipated requirements for additional actions and unnecessary delays and costs needed to bring the property back into productive use. The guidance presented in this document is intended to help avoid such surprises and make the investigation, evaluation and remedial action process as effective and efficient as possible.

1.2 Targeted Environmental Hazards

A basic understanding of environmental hazards associated with contaminated soil and groundwater is critical in the overall environmental response process (see Figure 1-1). Common environmental hazards that should be initially screened for at all contaminated sites include:

Soil:

- Direct-exposure threats to human health;
- Intrusion of subsurface vapors into buildings;
- Leaching and subsequent threats to groundwater resources;
- Threats to terrestrial habitats;
- Gross contamination and general resource degradation concerns;

Groundwater:

- Threats to drinking water resources;
- Threats to aquatic habitats;
- Intrusion of subsurface vapors into buildings;
- Gross contamination and general resource degradation concerns.

For the purpose of this document, "soil" refers to any unlithified material in the vadose zone that is situated above the capillary fringe of the shallowest saturated unit. Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2). Tier 1 Environmental Screening Levels (ESLs) for soil presented in this guidance are *not* directly applicable to soil that is situated within the capillary fringe zone or below the water table (refer to following section and Chapter 2).

A brief description of each hazard is provided in Figure 1-2. Detailed discussions of each hazard are provided in Chapters 3 and 4 and in Appendix 1. Additional site-specific environmental hazards that may need to be reviewed on a site-specific basis include the uptake of contaminants in garden produce and the erosion and runoff of contaminated soil into nearby surface water bodies.

Note that several of the environmental hazards listed above are not necessarily "risk-based," at least in the traditional regulatory use of this term. For example, soil that is grossly contaminated with petroleum may not pose a toxicological risk to future residents, but it could pose significant odor and nuisance concerns and in some cases even result in explosive levels of vapors in soil gas. Although it may seem counterintuitive, it is quite possible (and unfortunately common) for traditional, human health risk assessments to conclude that soil is "nontoxic," even though the soil would ignite if a match was dropped on it. Nevertheless, the fact that the soil is flammable is clearly important to identify and discuss in the environmental hazard evaluation. Gross contamination can also complicate future construction or subsurface utility activities that require disturbance of heavily contaminated soil or groundwater. Leaching of contaminants from soil into groundwater is also important to consider, even though this is often neglected in traditional risk assessments. Discharges of contaminated groundwater or free product into surface water bodies, either naturally or via seepage into storm sewers or via discharge during construction-related dewatering activities, can likewise pose significant environmental hazards to aquatic habitats.

The environmental hazard that drives the potential need for remedial action at a contaminated site depends on the toxicity and mobility of the targeted contaminants (refer to Appendix 1). Soil contaminated with chemicals that are that are highly toxic to humans and relatively immobile (e.g., arsenic, lead, PCBs, etc.) will generally be flagged as posing potential direct exposure hazards. Soil contaminated with volatile chemicals that are potential carcinogens (e.g., benzene, PCE, TPH gasoline, methane, etc.) are typically identified as posing potential vapor intrusion hazards. Soil contaminated with petroleum, solvents or highly mobile pesticides (e.g., TPH gasoline or diesel, BTEX, PCE, atrazine, etc.) will often be identified as posing potential leaching hazards. Soil contaminated with pesticides or metals that are relatively non-toxic to humans (e.g., barium, copper, nickel, etc.) can pose significant toxicity hazards to terrestrial flora and fauna.

Drinking water toxicity hazards are almost always identified for aquifers contaminated with hazardous chemicals. As is the case for soil, vapor intrusion hazards will often be identified for groundwater contaminated with carcinogenic, volatile chemicals. A number of chemicals pose potential aquatic toxicity hazards at relatively low concentrations, if the groundwater were to discharge into a sensitive aquatic habitat. Free product on groundwater poses gross contamination hazards that could lead to sheens or odor in surface water if allowed to migrate offsite (as well as vapor hazards). Gross contamination hazards could also be identified for drinking water contaminated with chemicals that have a low taste and odor threshold (e.g., TPH, ethylbenzene, toluene, xylenes, MTBE).

1.3 Tier 1 Environmental Screening Levels

Tier 1 *Environmental Screening Levels* (Tier 1 ESLs) are concentrations of contaminants in soil, soil gas and groundwater above which the contaminants could pose a potential adverse threat to human health and the environmental. Figure 1-3 summarizes the use of the Tier 1 ESLs. Exceeding the Tier 1 ESL does not necessarily indicate that contamination at the site poses environmental hazards. It does, however, indicate that additional evaluation is warranted. This can include additional site investigation and a more detailed evaluation of the specific, tentatively identified hazards. The screening levels, or approved alternatives, can be used to delineate specific areas of the site that require remedial actions. These actions can vary, depending on the hazard present and site conditions. An overview of the development of the Tier 1 ESLs is provided in Chapter 2. A detailed discussion of the compilation and development of the ESLs is provided in Appendix 1.

1.3.1 ESL Surfer

The ESL Surfer, an Excel-based version of the lookup up tables, makes use of the ESLs and the identification of potential environmental hazards at contaminated sites especially easy. The Surfer is available for download from the Guam EPA web page (refer to contact information at beginning of guidance). A link to this guidance document and related material is also provided on the Hawai‘i DOH web page. Use of the Surfer in Environmental Hazard Evaluation reports is highly recommended. Guidance on use of the Surfer and example printouts are provided in Chapter 3.

1.3.2 Use of ESLs in Site Investigations

One of the most basic uses of the ESLs is to identify potential contaminant of concern (COPCs) and guide completion of the site investigation. The initial list of COPCs established during a review of past site operations can be quickly narrowed down by direct comparison of soil and groundwater data to the Tier 1 ESLs. Further consideration of contaminants that do not exceed Tier 1 ESLs is not necessary. This assumes of course that existing data are representative of overall site conditions.

The lateral and vertical extent of contamination should be determined for COPCs that exceed the Tier 1 ESLs (or approved, alternative screening levels). Delineation of the extent of contamination to laboratory reporting or detection limits is often impracticable and, from a hazard evaluation standpoint, unnecessary. The investigation can be considered complete once the extent of contamination in excess of Tier 1 ESLs (or approved alternatives) is accomplished. The use of field screening methods, mobile labs and quick turnarounds in laboratory analyses will help expedite the completion of site investigation activities.

The identification of potential environmental hazards should begin as soon as the first data are received. This will help identify the need for alternative types of data that will be required for more detailed evaluations of specific hazards and completion of the site investigation. For example, if arsenic is reported in soil at concentrations above 20 mg/kg then laboratory bioaccessibility tests should be run on the same sample (refer to Chapter 4). If the reported concentration of volatile contaminants exceed screening levels for vapor intrusion concerns then soil gas data should be collected. Incorporating these decisions rules in the sampling and analysis plan will help expedite completion of the site investigation as well identify potentially significant environmental hazards at the site that could require immediate action.

1.3.3 Use of ESLs in Environmental Hazard Evaluations

The most important use of the Tier 1 ESLs is the rapid identification of potential environmental hazards associated with contaminated soil and groundwater (refer to Section 3.1). With the exception of gross contamination, most of the environmental hazards noted earlier are not obvious in the field. An initial comparison of site data to the Tier 1 ESLs provided in Tables A through F will only indicate if a potential hazard is present (i.e., “yes” or “no”). If the Tier 1 ESL is exceeded, site data should be compared to the detailed screening levels used to develop the Tier 1 ESL. The specific, potential environmental hazard(s) associated with the contaminant can then be identified. This process is described in more detail in Chapter 3. As discussed above, use of the ESL Surfer will significantly expedite this process.

Potential environmental hazards identified in a Tier 1, screening level Environmental Hazard Evaluation can be evaluated on a more site-specific basis as needed (refer to Chapters 3 and 4). The information gained can be used to better define the need for additional site investigation as well as to help develop appropriate remedial options. The level of effort required for advanced evaluations can vary greatly. For example, only a minimal level of effort may needed to rule out potential hazards to terrestrial ecological habitats at a highly developed commercial or industrial site that does not contain significant natural habitat. Vapor intrusion is typically a potential hazard at VOC contaminated sites where occupied structures are present (or proposed). The collection of soil gas data at these sites can be highly useful and in some cases required. A detailed review of groundwater data can replace soil screening levels for leaching hazards at sites that have remained uncapped for a sufficiently long period of time for worst-case groundwater impacts to take place.

1.3.4 Use of ESLs in Remedial Actions

In cases where contamination is limited, easily accessible and time is of the essence, it can be more cost-effective to aggressively remediate the impacted soil or groundwater to the Tier 1 ESLs. The Tier 1 ESLs are not strict cleanup standards, however, and should not be used as such. In cases where cleanup costs could be significant or complete cleanup is not practicable, the choice is not so clear and a more advanced evaluation of specific environmental hazards is usually warranted (refer to Chapters 3 and 4). Use of the detailed ESLs presented in Appendix 1 of this guidance, and in particular use of the accompanying *ESL Surfer*, makes the identification of specific, potential environmental hazards relatively quick and easy. The information gained can then be used to evaluate specific environmental hazards in more detail and develop more efficient remedial actions.

Long-term management will be required for sites where contaminated soil and groundwater cannot be remediated in a relatively short time frame. In such cases, the detailed screening levels presented in this guidance (or acceptable alternatives) should be used to delineate areas of contaminated soil and groundwater that will require long-term management as well identify as the specific environmental hazards posed by the contamination under uncontrolled site conditions. Specific actions required to address these hazards should then be described in an *Environmental Hazard Management Plan* (EHMP). An overview of EHMPs is presented in Chapter 5.

1.4 Decision Unit and Multi-Increment Investigation Strategies

The use of *decision unit* and *multi-increment sampling* site investigation strategies is strongly encouraged (Ramsey and Hewitt 2005). A brief introduction to these approaches is provided similar guidance prepared for the Hawai'i Department of Health (HDOH 2008a) and in an HDOH technical memorandum entitled *Pesticides in former agricultural lands and related areas* (HDOH 2007a). A copy of the HDOH technical memorandum is provided in Appendix 8. Additional guidance will be provided in the upcoming revision of the Hawai'i Department of Health *Technical Guidance Manual* (HDOH 2008b).

1.4.1 Decision Units

A decision unit is an area where a decision is to be made regarding the extent and magnitude of contaminants with respect to the potential environmental hazards posed by the existing or anticipated future exposure to contaminants (Ramsey and Hewitt 2005). Strictly speaking, a decision unit is really a volume rather than area of soil (or water), since the thickness of the decision unit is often a key factor. Establishing decision units early in the site investigation design helps develop an effective sampling approach and ensure that adequate data are available to prepare an Environmental Hazard Evaluation (EHE, see Chapter 3).

The selection of decision units (DUs) is unique to each site and is dependent in part on the specific type of environmental hazard under investigation (refer to section). Decision units generally fall into two categories: 1) Exposure Areas and 2) Spill Areas. The appropriate type, size, shape and number of DUs for a given project is necessarily site-specific and must take into consideration the historical, current and future use of the site.

1.4.1.1 DUs Associated with Exposure Areas

The most appropriate decision unit for relatively immobile contaminants that primarily pose direct-exposure, toxicity-based hazards is the assumed exposure area (e.g., lead, arsenic, dioxins or PCBs or PAHs, etc.; refer to Section 1.2). "Exposure areas" are open, unpaved areas of a property frequented by residents or workers who may come in contact with contaminants in soil on a regular basis. Examples residential yards, schoolyard, playgrounds, gardens, open areas on commercial/industrial properties, etc. For these types of DUs, the primary question is "What is the representative concentration of target contaminants across the exposure area as a whole?" The DUs could be based on current property use (e.g., an open area of a commercial or industrial site) and/or or future use of the property (e.g., assumed hypothetical residential lots).

The size of exposure-area DUs for commercial or industrial sites should be based on the location of exposed areas of soil and use of the site by workers. DUs based on exposure areas for residential properties usually encompass the entire yard and/or open, unpaved common areas in high-density developments. For future redevelopment projects that involve single-family homes, the size of a hypothetical residential lot is generally assumed to be 5,000 ft^2 (refer to following section for investigation of former agricultural lands). When possible, it is generally best to investigate a site in a manner that allows unrestricted (e.g., residential) land use (refer to Section 2.7).

The concentration of contaminants in small spill areas or "hot spots" within the DU itself is not important, nor is the exact location of these areas. This is an important point. The objective of the DU investigation is to estimate an average contaminant concentration for the DU as a whole, not to identify maximum and minimum contaminant concentrations within the DU. It is essential, however, to incorporate any such areas in the sample data collected for the DU. As discussed in Section 4, this is best accomplished by the collection of a multi-increment (versus discrete) sample or samples across the DU. Examples of DUs based on exposure areas are included in later parts of this section.

Decision units based on exposure areas can also be established for ecological risk assessments. Detailed guidance for the preparation of ecological risk assessments is not included in this guidance at this time.

1.4.1.2 DUs Associated with Spill Areas

Spill areas are localized areas where the release of a contaminant is known or suspected to have occurred. Examples include areas with obviously contaminated and stained soils, unpaved areas used to store or mix hazardous chemicals, known waste disposal areas, areas immediately adjacent to transformer pads or other types of equipment that may have contained hazardous chemicals, releases from pipelines, etc.

The isolation and evaluation of individual spill areas is generally necessary to evaluate environmental hazards associated with soil leaching, vapor intrusion and gross contamination hazards (refer to Section 1.2). This applies to most releases of petroleum, solvents and highly mobile pesticides like atrazine and ametryn. In these cases, the appropriate question is "What is the representative concentration of the contaminant(s) within the spill area itself?"

If the target contaminant at the site poses one or more of these potential concerns, then the spill area itself should be established as a separate decision unit. For example, a spill area associated with a petroleum release around an aboveground storage tank should be identified as a separate DU and appropriate investigated. This is because petroleum contamination can pose a multiple of environmental hazards, included leaching of contamination of subsurface groundwater resources, intrusion of vapors into overlying buildings and nuisance or even explosion hazards associated with grossly contaminated soil. It is inappropriate to incorporate data outside of the spill area in the evaluation of these types of hazards.

Consideration of individual spill areas as separate DUs may also be important if the target contaminant poses potential direct exposure hazards and there is a chance that contaminated soil could be excavated and spread out during future construction activities. For example, PCB-contaminated soil in the immediate vicinity of a transformer pad may not in itself pose direct exposure hazards to workers given the current, assumed exposure area. Under a future redevelopment scenario, however, the soil could feasibly be excavated and spread out over a much larger area. This could result in a dramatic increase in the representative concentration of a contaminant across a DU. Other examples of DUs based on spill areas are described later in this section.

1.4.1.3 Evaluation of DU Data

Data collected from DUs are evaluated in an Environmental Hazard Evaluation report (refer to Chapter 2). When using a decision unit strategy, the entire area of a decision unit is acted upon as a single entity based on the data collected from that unit, regardless of internal variation. If the data indicate that remediation is required, then this applies to the entire decision unit. If the decision outcome is "contaminated", then the entire area of the DU is treated as being contaminated. If the outcome is "not contaminated", then the entire area of the DU is treated as being not contaminated. As discussed above, this makes it important during the selection of decision units to segregate areas of obvious, heavy contamination into DUs separate from areas presumed to be uncontaminated in order to reduce the volume of soil or groundwater that may be identified as "contaminated" and therefore require treatment.

Alternative approaches for the use of decision unit strategies at very large sites (e.g., >50 acres) are discussed in the HDOH guidance for pesticide-contaminated sites provided in Appendix 8 and the HDOH *Technical Guidance Manual* (HDOH 2008b). For example, testing of every lot in a very large residential development project on former industrial or agricultural land can be very expensive. To reduce sampling costs, initial screening of the area on the scale of large, neighborhood-scale decision units is recommended. More detailed investigation can then be carried out on randomly selected decision units the size of hypothetical residential lots. This approach can expedite the investigation and clearance of large tracts of land while also providing a relatively high degree of confidence in the data collected.

1.4.2 Multi-Increment Samples

Multi-increment samples should be collected from selected decision units whenever practicable. This sampling approach reduces the variability and improves the reliability of decision unit data in comparison to conventional, discrete sampling strategies. Thirty to fifty small *increments* of soil (typically 10 to 50 grams per increment) are collected from each specific decision unit of interest (see previous section). The increments are collected in a stratified-random manner (e.g., by collecting increments while walking up and down adjacent rows) and physically combined into one sample. The combined sample is analyzed to obtain a representative contaminant concentration for the entire decision unit. Multi-increment sampling data typically have low variability and high reproducibility, which results in a high level of confidence for decision-making. Three multi-increment samples, referred to as field replicate samples or *triplicates*, should be collected in 10% of the decision units being tested (minimum one set of triplicate samples per site). Data for the replicate samples can be statistically compared in order to evaluate the precision of the field sampling methodology used at the site.

Multi-increment sample mass is based on particle size and generally ranges from 500 to 2,000 grams. The laboratory dries the sample, and sieves it to <2mm particle size (this may also be done in the field). To obtain a representative subsample, the field sample must be processed so that the entire "population" of soil particles is accessible for collection. Sub-sampling can be accomplished with a sectorial splitter or by collecting a multi-increment sample using the same approach as used to collect the field sample but with smaller tools and increment masses. A minimum subsample mass of ten grams is recommended in order to reduce lab fundamental error due to the range of particle sizes being tested. Note that this is greater than typically called for in some USEPA laboratory methods, especially for metals. Handling and analysis of a larger subsample mass should be discussed ahead of time with the laboratory.

Multi-increment samples can be collected for both nonvolatile and volatile contaminant analyses. When collecting samples for volatile contaminants, increments must be placed into an extraction solution in the field (e.g. methanol) in order to prevent VOC loss. However, since issues related to field extraction solutions, methanol transportation in the field, appropriate sample containers, elevated laboratory method reporting limits, etc., are still unresolved, this approach is not yet widely used. In the meantime, consultants who would like to use the approach should provide sampling and analysis work plans to the overseeing regulatory agency for review and ensure close coordination with the receiving laboratory.

1.5 Guidance Organization

Volume 1 of this guidance document is kept intentionally brief and as non-technical as possible. The scope and use of the Tier 1 ESLs is summarized in Chapter 2. Chapter 3 discusses the preparation of basic *Environmental Hazard Evaluations.* Chapter 4 presents mode advanced approaches for the evaluation of specific environmental hazards. The final chapter provides guidance for the long-term management of contaminated sites that cannot be easily remediated, with a focus on petroleum-related contamination. Technical details regarding the compilation and development of the Tier 1 ESLs are discussed in a series of appendices presented in Volume 2. The ESL Surfer and advanced models that accompany this guidance document are available for download from the Guam EPA website (see contact information at front of document).

1.6 Limitations

The Tier 1 ESLs presented in the lookup tables are NOT required, regulatory "cleanup standards". Use of the ESLs as actual cleanup levels should be evaluated in view of the overall site investigation results and the cost/benefit of performing a more detailed environmental risk assessment. The ESLs are intended to be conservative for use at the vast majority of impacted sites in developed areas. As discussed in Chapter 4, however, stand-alone use of the EHE approach may not be appropriate for final assessment of all sites. Examples include:

- High profile sites that cannot be fully cleaned up and warrant a detailed, traditional human health or ecological risk assessment;
- Sites where more than three known or suspected carcinogens or more than five chemicals with similar noncarcinogenic health effects have been identified (generally not required at petroleum-contaminated sites, see section 2.4 for details);
- Sites with high rainfall (e.g., >250cm (100 inches) per year) and infiltration (e.g., >720mm (28 inches) per year) that overlie highly vulnerable and valuable groundwater resources (refer to overseeing regulatory agency for information on local groundwater resources);

- Sites where inorganic chemicals (e.g., metals) are potentially mobile in leachate due to soil or groundwater conditions different than those assumed in development of the lookup tables (e.g., low pH conditions at mine or landfill sites); and

- Sites affected by tides, rivers, streams, heavy rainfall, etc. where there is a potential for erosion of soil and concentration of contaminants in aquatic habitats through transport and deposition of contaminated soil particles.

The need for detailed human health or ecological risk assessments in these cases should be discussed with the overseeing regulatory agency on a site-by-site basis.

Soil ESLs do not consider potential water- or wind-related erosion and deposition of contaminated particles in a sensitive ecological habitat. This may especially be of concern for contaminants that are known to be bioaccumulative in aquatic organisms (e.g., mercury, PCBs and organochlorine pesticides) or heavy metals that are only moderately toxic to humans but highly toxic to aquatic and terrestrial biota (e.g., copper). At sites that pose an elevated threat to sensitive aquatic habitats, measures should be taken to mitigate potential erosion and runoff concerns.

Evaluation of landfills and sites impacted by mine wastes may in particular require a more detailed evaluation of contaminant fate and transport in soil and groundwater, as well as groundwater-surface water interactions, due to low pH issues. Screening levels for leaching of metals in soil are not considered reliable and are not included in the Tier 1 ESLs. Lab-based methods to evaluate this potential hazard are discussed in Chapter 4.

It is conceivable that soil, groundwater and soil gas screening levels developed to address the emission of chlorinated volatile organic compounds to indoor air may not be adequately conservative in some cases. This is most likely to occur in enclosed buildings sites with poor ventilation designs or buildings with flooded basements. Additional guidance on the site-specific evaluation of vapor intrusion hazards is provided in Chapter 4.

The groundwater screening levels presented in the lookup tables do not directly address the impact of long-term discharges of contaminated groundwater on sediment quality. The accumulation of potentially toxic metals in sediment over time could require a more detailed evaluation at some sites. The buildup of highly-sorptive (lipophilic), organic contaminants in sediment over time could likewise be a concern for petroleum-contaminated sites that are immediately adjacent to sensitive aquatic habitats (e.g., PAHs and other heavy petroleum compounds).

Direct-exposure screening levels for construction and trench workers are incorporated into the Tier 1 soil EALs (see Appendix 1). The screening levels consider ingestion and dermal contact with contaminated soil as well as the inhalation of vapors and dust, based on a construction worker exposure scenario. *The model used to evaluate inhalation of vapors does not fully consider soil that is being disturbed during excavation or exposed in trenches, however.* **Actions to minimize exposure of workers to volatile contaminants in soil during construction or trench-related activities should be included in a properly prepared health and safety plan.**

2

Environmental Screening Levels

2.1 Introduction

Tier 1 *Environmental Hazard Evaluations* are based the use of pre-approved, *environmental screening levels* (Tier 1 ESLs) to screen soil, soil gas and groundwater data for potential environmental hazards. Tier 1 ESLs for soil and groundwater are summarized in Tables A through D. Related screening levels for soil gas, indoor air and surface water are presented in Table E and F. A detailed discussion of the Tier 1 ESLs is provided in Appendix 1.

The presence or absence of potential environmental hazards is determined by the direct comparison of representative site data to the Tier 1 ESLs. Exceeding the Tier 1 ESL for a specific chemical does not necessarily indicate that the contamination poses a significant threat to human health or the environment, only that additional evaluation is warranted. The level of detail required for the additional evaluation will vary. In some cases it may be more cost-beneficial to simply remediate the site to the Tier 1 ESLs than to conduct an advanced evaluation. A more detailed evaluation of specific environmental hazards is generally warranted in cases where significant cleanup costs may be incurred, where public sensitivity of the site is high or where long-term, *in-situ* management of the contamination is being considered.

More advanced approaches for evaluating specific hazards are presented in Chapter 4. The advanced approaches range from relatively simple methods that do not require significant expertise in the specific hazard under investigation to very complex methods that will require a high level of technical expertise. It is anticipated, however, that only a very small number of sites will warrant highly technical and detailed environmental hazard evaluations.

The ESL Surfer (Excel-based electronic lookup tables) included with this guidance provides a relatively quick and easy method to screen site data and, as needed, identify specific, potential environmental hazards. Sample printouts from the Surfer are included in the appendices of the EHE report for reference. **Use of the ESL Surfer to prepare *Environmental Hazard Evaluations* is strongly recommended.**

2.2 Default Conceptual Site Models

The Tier 1 ESL lookup tables are organized to reflect three of the most important factors that control the magnitude of environmental hazards posed by contaminated soil and groundwater:

- Accessibility of the impacted soil (e.g., currently or potentially exposed at the ground surface versus isolated in the subsurface);
- Beneficial use of the groundwater immediately underlying the site or otherwise potentially threatened by the release (e.g., drinking water resource threatened versus no drinking water resource threatened);
- Current and anticipated future use of the site (e.g., residential land use permitted or commercial/industrial land use only).

These factors are incorporated into a total of eight *conceptual site models* (CSM) that describe default site conditions used to develop the Tier 1 ESLs. The CSM and associated Tier 1 ESLs that most directly applies to the site under investigation are selected to screen for potential environmental hazards. The CSMs are based on four initial site scenarios:

	Drinking Water Resource Threatened	Drinking Water Resource NOT Threatened
Shallow soils	A	B
Deep soils	C	D

A. Contaminated soil within three meters of ground surface ("Shallow Soils"), groundwater is a current or potential source of drinking water;

B. Contaminated soil within three meters of ground surface ("Shallow Soils"), groundwater is *not* a current or potential source of drinking water;

C. Contaminated soil *not* within three meters of ground surface ("Deep Soils"), groundwater is a current or potential source of drinking water; and

D. Contaminated soil *not* within three meters of ground surface ("Deep Soils"), groundwater is *not* a current or potential source of drinking water.

The lookup tables for soil and groundwater Tier 1 ESLs are or organized with respect to the same site scenarios (refer to Tables A-D). Separate soil screening levels are then provided in each table for unrestricted (e.g., residential) versus commercial/industrial land-use scenarios. Note that the final Tier 1 ESL will not vary for differing land uses if the driving environmental hazard is tied soil leaching of contaminants from soil and contamination of underlying groundwater resources (refer to Section 1.2). For deep soils (Tables C and D), the Tier 1 ESLs only vary if vapor intrusion is the driving environmental hazards. Screening levels for other environmental hazards are otherwise identical (refer to Appendix 1).

The Tier 1 ESLs for exposed (shallow) soils assume that contaminated soil is present at the ground surface or could be excavated and spread out at the ground surface at some time in the future. The ESLs further assume that there are no restrictions on current or future use of the property, including potential use as residential housing, schools, day care, health care, etc. This approach minimizes the need for restrictions on future site use and highlight soils that must be properly managed if complete remediation to unrestricted future use is not feasible.

Alternative soil screening levels for sites that will be restricted to commercial/industrial use only area included in the ESLs. Use of these screening levels for final site closure should be discussed with the overseeing regulatory agency on a case-by-case basis, however, and could require the implementation of formal engineered and institutional controls.

Additional discussion of the primary factors used to prepare the CSMs and Tier 1 ESL lookup tables is presented in the following sections. Compilation of the Tier 1 ESLs is discussed in more detail in Section 2.3 and Appendix 1.

2.2.1 Groundwater Beneficial Use

Groundwater in areas designated for use as a source of public water supply should be treated as a potential source of drinking water unless otherwise approved by the overseeing regulatory agency. **All groundwater should be considered a**

potential source of drinking water unless otherwise approved by the overseeing regulatory agency. Drinking water standards published by the USEPA are incorporated by reference into Guam EPA Administrative Rules (GEPA 1997b). The selection of drinking water screening levels for contaminants that lack promulgated standards is discussed in Appendix 1.

For the purposes of this document, it is also assumed that all shallow groundwater will ultimately discharge to a body of surface water and potentially impact aquatic organisms (see Section 1.2). Soil and groundwater ESLs were therefore developed to be protective of both drinking water resources and aquatic habitats. This is discussed in greater detail in Chapters 2 and 3 of Appendix 1.

Site-specific factors may render some groundwater unsuitable for potential drinking water purposes (e.g., elevated Total Dissolved Solids (TDS) in a groundwater management zone located in an industrialized area). Environmental Screening Levels presented in Tables B (shallow soils) and D (deep soils) of this document are intended for use at such sites. The ESLs presented in these tables consider the potential discharge of groundwater to surface water but do not consider potential impacts to sources of drinking water. The ESLs also consider vapor intrusion and “gross contamination” concerns such as the presence of free product or odor concerns if contaminated groundwater were to discharge into a nearby surface water body. This is a common problem at petroleum contaminated sites adjacent to bays and rivers.

In general, soil and groundwater screening levels are more stringent for sites that threaten a potential source of drinking water (see Tables A and B). This is particularly true for chemicals that are highly mobile in the subsurface and easily leached from impacted soil. For chemicals that are especially toxic to aquatic life, however, screening levels for sites that threaten drinking water resources may be driven by surface water/aquatic habitat protection concerns rather than by drinking water concerns. Many of the metals and pesticides listed in the lookup tables fall into this category (see Section 1.2). Refer to the detailed, F-series lookup tables in Appendix 1 or simply use the ESL Surfer.

2.2.2 Land Use

Land uses are categorized based on the assumed length, duration, and magnitude of potential human exposure. The category "Unrestricted Land Use" is intended for use at sites where future land-use restrictions are not desirable or allowed. This includes sites used as residences, hospitals, day-care centers, and other sensitive purposes (refer to CalEPA 2002). ESLs listed under this category use conservative assumptions regarding long-term, round-the-clock exposure of children and adults to impacted soils in a residential setting (see Appendix 1, Section 3.2 and Appendix 2). It is assumed that the greatest human health impacts posed by a site would result from residential land use exposures. Therefore, sites meeting residential-use ESLs would not pose hazards under any other land uses.

By contrast, the land-use category "Commercial/Industrial Use Only" assumes that only working-age adults will be present at the site on a regular basis, and only during working hours. Direct-exposure assumptions incorporated into commercial/industrial use soil ESLs are less conservative than assumptions used for residential land-use soil ESLs.

Land use should be selected with respect to the current and reasonably anticipated future use of the site in question. Reference to zoning maps and local redevelopment plans is an integral part of this process. Use of the lookup tables for sites with other land uses (e.g., agriculture, parkland, etc.) should be discussed with and approved by the overseeing regulatory agency. As the category heading implies, use of the soil ESLs listed under "Commercial/Industrial Use Only" places implicit land-use restrictions on the affected property. The short-term cost savings of limiting site cleanup to meet only commercial/industrial-use ESLs rather than unrestricted land use should be carefully weighed against potential restrictions on future property use. In addition to land use restrictions, cleanup to commercial/industrial-use ESLs may also encumber the site with long-term environmental monitoring requirements and requirements for future subsurface excavation activities. Implications for land-use restriction are discussed in more detail in Section 2.7.

2.2.3 Exposed Versus Isolated Soils

Tier 1 ESLs for shallow, exposed soils are presented in Tables A and B. Tier 1 ESLs for deep or otherwise isolated soils are presented in Tables C and D. For the purposes of this document, a depth of three meters (approximately 10 feet) was used to delineate between shallow soils, where a potential exists for regular direct exposure of residents and/or office workers, and deep, isolated soils where only periodic exposure during construction and utility maintenance work is considered likely. Three meters is assumed to be the maximum depth that impacted soil could be excavated and left exposed at the surface during typical redevelopment activities (e.g., for swimming pools, utilities, etc.; CalEPA 1996a). A minimum, default depth of one-meter is recommended for commercial/industrial properties to distinguish between shallow and isolated soils. Subsurface activities below this depth are likely to be closely supervised by the property owner, who will presumably be aware of contaminated soil at depth on the property and manage the soil appropriately. Landscaping and other less supervised activities could disturb and expose soils shallower than this depth.

An evaluation of vapor emissions from deep soils to outdoor air may be required for sites that are heavily contaminated with volatile chemicals. The potential intrusion of vapors from both deep and shallow sources into overlying buildings and to outdoor air must also be considered, regardless of the depth of the contaminated soil (refer to Chapter 4 and Appendix 1). In some cases, contaminated soil may be left in place at shallower depths with appropriate institutional controls, upon review and approval by the overseeing regulatory agency.

The full suite of environmental hazards noted in Figure 1-2 was considered in development of ESLs for shallow soils. For deep soils, regular exposure of residents or commercial/industrial workers and impacts to terrestrial flora and fauna was not considered. As a result, deep-soil ESLs for low-mobility chemicals are generally much higher than corresponding shallow-soil ESLs (e.g., compare PCB ESLs in Tables A and C). However, for chemicals that are highly mobile, e.g., easily leached from soil or potentially emitted to the air as a volatile gas, groundwater and indoor-air protection concerns usually drive selection of the final ESL regardless of the depth of the impacted soil. This is the case for several of the highly volatile, chlorinated organic compounds. As a result, corresponding shallow and deep soil ESLs for high-mobility chemicals are identical (e.g., compare benzene ESLs in Tables A and C).

If contamination is present in both shallow soil and deep soil, it may be appropriate to use a separate set of screening levels for each zone (e.g., Table A for the shallow soils and Table C for the deep soils). Soil that is located under paved areas or buildings can also be considered to be isolated if appropriate, long-term management actions are implemented. This is most applicable to commercial/industrial sites where activities on the property are closely controlled. This isolation of contaminated soil under properties to be used for more sensitive purposes is generally not recommended but can be discussed with the overseeing regulatory agency on a case-by-case basis. For example, the isolation of easily recognizable, petroleum-contaminated soil under the parking lot of a high-density residential development would be more acceptable than the isolation of soil heavily contaminated with dioxins or other persistent chemicals that are difficult to recognize in the field. Controls for long-term management of contaminated soil that is left in place at a site must be document in a site-specific *Environmental Hazard Management Plan*. This is discussed in Chapter 5.

The pros and cons of remediating all soil on a property to criteria for unrestricted reuse should be evaluated on a site-by-site basis. While potentially more costly in the short term, doing so would eliminate concerns regarding future disturbance and reuse of deeper soils.

2.2.4 Threat to Surface Water Habitats

The conceptual site models used to develop the Tier 1 ESLs assume that contaminated groundwater at all sites could at some time migrate offsite and discharge into a body of surface water (refer to Section 2.2). This discharge could occur due to the natural downgradient migration of groundwater or to human activities such as dewatering of excavations at construction sites.

Promulgated water quality standards and correlative screening levels for contaminants that lack promulgated standards are presented in Table F. Water quality standards published by the USEPA for the protection of aquatic habitats are incorporated by reference into Guam EPA Administrative Rules (GEPA 1997a). The selection of screening levels for contaminants that lack promulgated standards is discussed in Appendix 1. Tidally influenced portions of creeks, streams and rivers and the bays they flow into are considered to be *estuarine* environments. Screening levels for estuarine environments are based on the more stringent of screening levels for marine (saltwater) versus freshwater environments but do not consider drinking water standards or screening levels. Chronic surface water standards (or equivalent) are incorporated into the groundwater screening levels to address potential aquatic habitat protection concerns.

In freshwater environments, screening levels (or promulgated standards) for most chemicals for drinking water concerns are generally much lower than corresponding standards for toxicity to aquatic organisms. For many pesticides and heavy metals, however, aquatic habitat goals are more stringent than drinking water toxicity goals and therefore drive the selection of final Tier 1 ESLs (e.g., dieldrin, endrin and endosulfan). This is reflected in the final groundwater screening levels for these contaminants (refer also to Appendix 1 and the ESL Surfer).

The groundwater ESLs for potential impacts to aquatic habitats do not consider dilution of groundwater upon discharge to a body of surface water. Benthic flora and fauna communities situated below or at the groundwater/surface water interface are assumed to be exposed to the full concentration of chemicals in impacted groundwater. Use of a generic dilution factor to adjust the surface water protection screening levels with respect to dilution of groundwater upon discharge to surface water is therefore not generally acceptable. Consideration of alternative groundwater screening levels for the protection of surface water quality may, however, be appropriate on a site-specific basis (e.g., use of acute aquatic screening levels for groundwater in highly developed, harbor areas, refer to section 4.3.3).

The groundwater ESLs also do not consider surface water standards for bioaccumulation concerns. As discussed above, the use of chronic surface water standards to screen contaminants in groundwater is considered to be adequately protective of benthic habitats at most sites.

The soil and groundwater screening levels presented in the lookup tables also do not directly address long-term impacts of contaminated groundwater on sediment quality. Site-specific concerns could include the accumulation of highly sorptive chemicals in sediment over time due to long-term discharges of impacted groundwater. This may be especially true for groundwater impacted with metals or highly sorptive (lipophilic) chemicals, including PAHs and other heavy petroleum compounds.

Potential erosion and runoff of contaminated surface soils from impacted sites may also need to be considered on a site-by-site basis, particularly at sites impacted with metals, PCBs, organochlorine pesticides and similar compounds that are situated near a sensitive aquatic habitat. The need for a more detailed, ecological risk assessment of impacts to sediment should be evaluated on a site-by-site basis and discussed with the overseeing regulatory agency (refer to Chapter 4).

2.3 Compilation of Environmental Screening Levels

A detailed discussion of the compilation of all screening levels is provided in Appendix 1. Approximately 150 chemicals are listed in the lookup tables. For each chemical, a screening level was compiled to address each of the environmental hazards noted above, as applicable and available. The lowest of the individual screening levels for each hazard was selected for inclusion in the summary lookup tables. This ensures that the Tier 1 ESLs are protective of all potential environmental concerns and provides a tool for rapid screening of site data. Where ESLs are exceeded, the detailed tables provided in Appendix 1 can be used to identify the specific environmental concerns that may be present at the site.

A summary of the sources used to compile screening levels for individual environmental hazards is provided in Figure 2-1. A detailed discussion of each source and associated models is provided in Appendix 1. In most cases, the screening levels were drawn from published references (e.g., published drinking water and surface water standards). In other cases, published models were used to develop screening levels for the subject environmental hazard (e.g., vapor intrusion screening levels).

An example of the selection of summary, Tier 1 ESLs for benzene is presented in Figure 2-2 (surface soils, drinking water resource threatened, residential land use). For soil, the screening level for leaching hazards (0.22 mg/kg) is lower than the screening levels for each of the other environmental hazards. This screening level is therefore selected as the Tier 1 ESL presented in Table A of the summary lookup tables. For groundwater, the screening level for drinking water toxicity concerns drives environmental hazards and is selected as the Tier 1 ESL presented in Table A (5 ug/L, the primary drinking water standard). A more detailed discussion of this example is provided in Appendix 1.

The driving environmental hazard for a specific chemical depends largely on the toxicity and mobility of the chemical. This can been seen by a review of the detailed lookup tables in Appendix 1 or by using the ESL Surfer to browse through various chemicals under different site scenarios. Tier 1 ESLs for highly mobile or highly toxic chemicals in soil are typically driven by leaching or vapor intrusion concerns (e.g., see selection process for benzene Tier 1 ESL in Figure 2-2). Tier 1 ESLs for chemicals that are relatively immobile in soil but highly toxic to humans are typically driven by potential direct-exposure concerns (e.g., PCBs and lead). In contrast, Tier 1 ESLs for heavy metals that are relatively non-toxic to humans are typically driven by ecological concerns or ceiling levels for general resource degradation (e.g., copper and total chromium). For chemicals that have particularly strong odors, pose explosive hazards, or could cause sheens on surface water the selection of Tier 1 ESLs may be driven by gross contamination concerns (e.g., Total Petroleum Hydrocarbons (TPH) and phenols). The consideration of gross contamination becomes especially important in the selection of EALs for relatively immobile chemicals in deep or otherwise isolated soils (refer to Section 4.5)

Driving environmental hazards are similar for groundwater. Tier 1 ESLs for contaminants that are highly toxic to humans tends to be based on drinking water toxicity concerns (e.g., PCE; assuming the groundwater is a potential source of drinking water). Screening levels for taste and odor concerns drive the selection of Tier 1 ESLs for several, less toxic chemicals in drinking water supplies (e.g., xylenes and ethylbenzene). Tier 1 ESLs for contaminants that are highly toxic to aquatic organisms are often based on chronic surface water standards, even if the groundwater is used as a source of drinking water (e.g., DDT and dieldrin). Vapor intrusion into buildings drives the selection of Tier 1 ESLs for carcinogenic, highly volatile contaminants for groundwater that is not used as a source of drinking water (e.g., PCE and vinyl chloride).

2.4 Contaminants of Potential Concern at Petroleum Release Sites

Petroleum is a complex mixture of hundreds of different compounds composed of hydrogen and carbon or "hydrocarbon" compounds (API 1994). The bulk of these compounds are evaluated collectively under the all-inclusive category of “total petroleum hydrocarbons (TPH)”, typically measured in three ranges: gasoline, middle distillates, and residual fuels. Gasoline-range TPH is a petroleum mixture characterized by a predominance of branched alkanes and aromatic hydrocarbons with carbon ranges of C6 to C12 and lesser amounts of straight-chain alkanes, alkenes, and cycloalkanes of the same carbon range (see also NEIWPCC 2003, included in Appendix 7). Total Petroleum Hydrocarbon associated with middle distillates (e.g., kerosene, diesel fuel, home heating fuel, jet fuel, etc.) is characterized by a wider variety of straight, branched, and cyclic alkanes, PAHs (especially naphthalenes and methyl naphthalenes), and heterocyclic compounds with carbon ranges of approximately C9 to C25. Residual fuels (e.g., Fuel Oil Nos. 4, 5, and 6, lubricating oils, mineral oil, used oils, and asphalts) are characterized by complex polar PAHs, naphthenoaromatics, asphaltenes, and other high-molecular-weight saturated hydrocarbon compounds with carbon ranges that in general fall between C24 and C40.

Due to the complex nature of petroleum mixtures, petroleum contamination must be evaluated in terms of both Total Petroleum Hydrocarbon (TPH) and target "indicator chemicals" for the specific type of petroleum product released (e.g., benzene, toluene, ethylbenzene and xylenes or “BTEX”, methyl tertiary butyl ether [MTBE], polynuclear aromatic hydrocarbons [PAHs], etc.). Target indicator chemicals typically make up only a small fraction of the total petroleum present but are important players in the assessment of environmental hazards posed to human and the environment. The list of target analytes that should be included for specific types of petroleum products is summarized in Figure 2-3.

A total of fifteen priority pollutant PAHs are listed in the USEPA Preliminary Remediation Goal guidance (USEPA 2004):

- acenaphthene
- acenaphthylene
- anthracene
- benzo(a)anthracene
- benzo(b)fluoranthene
- benzo(g,h,i)perylene
- benzo(a)pyrene
- benzo(k)fluoranthene
- chrysene
- dibenzo(a,h)anthracene
- fluoranthene
- fluorene
- indeno(1 ,2,3)pyrene,
- methylnaphthalenes (1- and 2-)
- naphthalene
- phenanthrene
- pyrene

The majority of the PAHs are not present in gasolines or middle distillate fuels at concentrations that would drive environmental hazards and cleanup actions. As indicated in the figure, the suite of PAHs that should be tested for at a given site depends on the type of the petroleum product released (after MADEP 2002a).

Volatile components of petroleum that are not specifically identified as target indicator compounds in Figure 2-3 but reported as separate compounds by the laboratory using Method 8260 or similar methods can in general be ignored (e.g., alkanes, alkenes, alkyl benzenes and other aromatics not specifically identified as target indicator compounds; refer to Section 2.11 and NEIPCC 2003). These compounds are included under the umbrella analysis for TPH in general and do not need to be evaluated (or even reported) separately. This is based on the assumption that the toxicity factors selected for TPH area adequately conservative for the mixture of compounds present in fuels beyond the target compounds noted in Figure 2-3 (refer to Appendix 1, Chapter 5).

Soil, groundwater and soil gas samples must always be tested for TPH, however, in addition to targeted, individual chemicals. Laboratory analysis for TPH as gasolines and middle distillates is generally carried out using gas chromatography, modified for "gasoline-range" organics ("Volatile Fuel Hydrocarbons") and "diesel-range" organics ("Extractable Fuel Hydrocarbons"), respectively (e.g., EPA Method 8015). Analysis for TPH as residual fuels up to the C40 carbon range can be carried out by gas chromatography, infrared absorption, or gravimetric methods. The latter methods are rarely used, however, due to their inability to discriminate the type of the petroleum present and interference with organic material in the soil.

Environmental screening levels for TPH are developed by assigning representative fate and transport properties and toxicity factors to surrogates for each TPH category and applying the same models and approaches as used for the target, indicator compounds (refer to Appendix 1). A more in-depth analysis of the specific components of the TPH can be carried out in a site-specific environmental hazard assessment as needed.

From an environmental hazard standpoint, cleanup of releases of gasolines is usually driven by a combination of TPH and benzene, with fuel oxygenates such as MTBE playing an important role in some cases. The cleanup of middle distillate fuel releases is usually driven by TPH, rather than by VOCs or PAHs. Naphthalene and methylnaphthalenes are two potential exceptions, since they can be present in middle distillate fuels at relatively high concentrations and are somewhat more volatile and mobile and TPH in general. Naphthalene is under study as a contaminant of interest in research on vapor intrusion, although it is unlikely that naphthalene as a vapor intrusion hazard would be a driving environmental concern at petroleum release sites due to the relatively low naphthalene content of typical petroleum mixtures. At sites where naphthalene could pose a vapor intrusion hazard, the most significant environmental hazards present would be posed by the very high concentrations of TPH, rather than by the naphthalene.

Soil and groundwater contaminated with middle distillate fuels must also be tested for BTEX (refer to Figure 2-3). Although BTEX rarely drives cleanup for releases of middle distillate fuels, their presence or absence is a useful indicator of past gasoline releases at the site or the migration of gasoline-contaminated groundwater onto the property from offsite sources. Testing for naphthalene at gasoline release sites is also recommended (refer to Figure 2-3).

By the nature of their manufacturing origin and intended use, the chemical composition of release sites contaminated by gasolines and middle distillates can be presumed with reasonable confidence. By contrast, the chemical composition of soil and groundwater contaminated by residual fuels, used oils, coal tar, asphalt, and other heavy petroleum mixtures is less predictable. Engine combustion processes may add PAHs, VOCs, and metals to used motor oils. Releases from used oil storage tanks may contain other liquids disposed of in the tanks, such as cleaning solvents, PCB transformer oils, or pesticides, in addition to used oil. Due to this potential for additional contaminants, the list of analytes for residual fuels is quite large. The need to test for certain analytes can be ruled out on a site-by-site basis, however, if it can be documented with confidence that the product released was fresh and uncontaminated. For example, releases of unused lube oil, transformer oils, mineral oils, virgin hydraulic oils and similar products do not require testing for PAHs and other chemicals if it can be demonstrated that product released was never heated to high temperatures (potentially producing PAHs) and not likely to be contaminated with solvents or metals.

2.5 Contaminants of Potential Concern for Former Agricultural Lands

Testing of soils is recommended for sites where long-term application of pesticides may have occurred before they are developed for unrestricted (e.g., residential) or commercial/industrial use. This is especially pertinent to large tracts of former agricultural land, golf courses and nurseries. This also includes military bases where housing complexes that may have been treated with organochlorine-based termiticides are being demolished and redeveloped with new homes (refer to discussion of technical chlordane in Section 4.2).

In the case of former agricultural lands, contamination is likely to be heaviest in former pesticide mixing and staging areas, seed dipping areas and storage areas, although heavy contamination could occur in association with bagasse piles, settling ponds, former plantation camp areas, etc. Residual contamination in former fields is likely to be much lower, although significant arsenic contamination has been identified in some areas of former sugar cane fields in Hawai'i (HDOH 2006a, HDOH 2008a).

Types of pesticides commonly used in agricultural lands in Hawai'i include:

Pesticide Group & Related Contaminants	**Standard USEPA Laboratory Method**
Organochlorine pesticides	8081A
Organophosphorus pesticides	8141A
Chlorinated herbicides	8151A
*Triazine herbicides	8141A/8270C
Pentachlorophenol	8151A/8270C
Carbamates	8321A
Fumigants	8260
Dioxins/furans	8280/8290
Heavy metals (primarily arsenic, lead & mercury)	various

*Includes: ametryn, atrazine and simazine

The above list is not intended to be comprehensive, nor is it intended to represent a required list of target analytes. Specific pesticides of concern should be based on a review of the historical use of the site with a focus on pesticides that may be persistent in soil above Tier 1 (and Tier 2) ESLs. Soil and groundwater screening levels for the majority of commonly used, persistent pesticides in are included in this document. To obtain screening levels for pesticides not listed in the lookup tables, contact the overseeing regulatory agency office or follow the guidelines used to develop the Tier 1 ESLs in Appendix 1. Additional guidance on the selection of target pesticides in former agricultural areas will be provided in the HDOH *Technical Guidance Manual* (HDOH 2008a).

Organochlorine pesticides are known to be very persistent in soils, as are arsenic and lead. Organophosphate pesticides, chlorinated herbicides, triazines, carbamates and pentachlorophenol are susceptible to biological and chemical breakdown over time and are more likely to be persistent above levels of potential concern in heavily contaminated, pesticide mixing areas than in fields. Testing of former field areas for the full suite of pesticides at a screening level is generally recommended, however (excluding fumigants beyond one-year of last application). As discussed in Chapter 4, significant levels of arsenic (associated with the use of lead arsenate or arsenic trioxide) and dioxins/furans (associated with the use of pentachlorophenol, 2,4,5 TP, etc.) can remain in soil even though the parent pesticide has degraded below levels of concern. Fumigants are not likely to persist in shallow soils more than one year after use due to a propensity to volatilize into the atmosphere and degrade or be carried downward in leachate. The collection of shallow soil gas data (e.g., five ft bgs) in additional to soil data is recommended if fumigant contamination is suspected (refer to Section 4.4).

2.6 Laboratory Reporting Limits and Ambient Background

In cases where an ESL for a specific chemical is less than the standard, method reporting limit for a commercial laboratory (as agreed upon by the overseeing regulatory agency), it is generally acceptable to consider the method reporting limit in place of the screening level. Potential examples include groundwater screening levels that are in the parts-per-trillion range for some PAHs and pesticides (e.g., PCBs, DDT, benzo(a)pyrene, etc.). Most of the contaminants involved are highly sorptive and not significantly mobile in groundwater. Lower reporting limits could be required in rare cases where discharges of groundwater known to be contaminated with these chemicals poses a significant threat to an aquatic habitat.

In the case of both soil and groundwater, sample analyses that are below the method reporting limit for the subject chemical should be reported in summary tables as “ND” (“non-detect”) with the laboratory method reporting level noted in parentheses (e.g., “ND (<0.5 ug/L)”). An alternative is to simply note “ND” in the cell for the chemical and sample number and note the method reporting limit table at the bottom of the table for each chemical.

Background concentrations of metals in soils should be used in place of risk-based screening levels to evaluate sites for possible contamination if higher than the action levels. For example, background concentrations of arsenic in soils typically range from 5 mg/kg to 20 mg/kg, with some soils containing in excess of 40 mg/kg (refer to Appendix 1). This is above the USEPA Region Screening Level for arsenic in soil of 0.39 mg/kg for residential exposure and 1.9 mg/kg for commercial/industrial exposure (USEPA 2008, refer to Appendix 1). The USEPA RSLs assume, however, that 100% of the arsenic in the soil is bioavailable or potentially toxic. This is not the case for arsenic contamination in most soils. Site-specific bioaccessibility tests are recommended when a total arsenic concentration of 20 mg/kg is exceeded (refer to Chapter 4).

Risk-based action levels are no longer available for total chromium in soil (USEPA 2008). As an alternative, an assumed background concentration of 65 mg/kg is incorporated into the ESL lookup tables for initial site screening (based on total chromium in coralline soils, USN 2006). Background total chromium concentrations could be higher in areas not underlain by carbonate rocks. Testing of soil for Cr III and CrVI should be carried out at sites where expected background levels of total chromium are exceeded.

2.7 Land-Use Restrictions Inherent in Tier 1 ESLs

Allowing the option to tie screening levels or cleanup levels to site-specific land use and exposure conditions can save considerably in investigation and remediation costs. For example, the action level for polychlorinated biphenyls (PCBs) in surface soils is 1.1 mg/kg in residential areas but up to 7.4 mg/kg for commercial/industrial areas (based on a target cancer risk of 10^{-5} and noncancer hazard quotient of 1.0). Higher levels can potentially be safely left in place if proper institutional and engineered controls are implemented and an adequate Environmental Hazard Management Plan is prepared (refer to Chapter 5).

The use of cleanup levels less stringent than those appropriate for unrestricted land use may place significant restrictions on future use of the property. For example, if a site is remediated to meet ESLs (or alternative criteria) intended for commercial/industrial land use then the site could not be used for residential purposes in the future without additional evaluation. In some cases, this may require that a formal covenant to the deed be recorded to restrict future use of the property. Deed covenants are generally not necessary for petroleum-release sites unless significant vapor intrusion hazards are present (refer to Chapter 4). Residual petroleum contamination will naturally degrade once the source of the release and gross contamination are removed. Petroleum-contaminated soil or groundwater is also easily recognized at levels that pose potential direct exposure hazards in the field.

The use of alternative screening levels for deep or otherwise isolated soils assumes that the impacted soil will remain isolated below the ground surface "for eternity" (refer to Section 4.5). For single-family residential areas, future disturbance of soil situated deeper than three meters is generally considered to be unlikely (CalEPA 1996). The use of alternative ESLs for soil located below this depth is reasonable (see Section 2.2.3 and Chapter 4). For commercial/industrial sites, soils situated below a depth of one meter are assumed be “isolated” and not likely to be exposed during unauthorized subsurface activities. For persistent contaminants, the placement of formal institutional controls on the property is recommended to clearly document the presence of isolated contamination and prevent inadvertent disturbance in the future (refer to Chapter 5).

During the redevelopment of properties for commercial/industrial or high-density residential use, excavation and removal of soils from depths up to five or greater is possible (e.g., for underground parking garages, elevator shafts, utilities, etc.). The need to impose enforceable institutional controls for proper management of deep or otherwise isolated, contaminated soils at commercial/industrial properties where action levels for isolated soils are applied should be discussed with HDOH on a site-by-site basis.

In general, land-use restrictions inherent in the selection of EALs from the Tier 1 lookup tables (or assumptions used in site-specific risk assessments) should be kept as minimal as possible. **When preparing EHEs for commercial/industrial sites, concentrations of chemicals in impacted soils left in place should always be compared to action levels for both unrestricted land use and commercial/industrial land use only.** If the soils in fact meet EALs for unrestricted land use after cleanup then this should be clearly stated in the site closure report. There is no need to compare confirmation data to action levels for commercial/industrial land use only. Recognizing this upfront will help avoid unnecessary delays should the site be considered for more sensitive uses in the future (e.g., residential, school day care, health care, etc.).

The long-term isolation of contaminated soil under pavement, buildings or some other type of caps should be avoided if at all possible. Leaving contaminated soil in place at a site imposes significant and oftentimes unnecessary burdens on future use and development of a site. This may be unavoidable, however, for soil contaminated with chemicals that require treatment and disposal at off-island, hazardous waste facilities (e.g., dioxins). If done, actions to prevent future disturbance of the soil should be clearly described in an *Environmental Hazard Management Plan* prepared for the site (refer to Chapter 5). The need for a formal covenant to the property deed should be also discussed with HDOH (generally not required for petroleum-contaminated soil or groundwater). A foresighted approach in the use of Tier 1 EALs or alternative, site-specific cleanup levels will allow more flexibility in future use of a site, help avoid unexpected complications during site redevelopment, and minimize the liability of future land owners.

2.8 Cumulative Risks at Sites with Multiple Chemicals of Concern

Risks posed by direct exposure to multiple chemicals with similar health affects are considered to be additive or "cumulative." For example, the total risk of cancer posed by the presence of two carcinogenic chemicals in soil is the sum of the risk posed by each individual chemical. The same is true for chemicals that cause noncarcingenic health effects. A summary of example target health effects for the chemicals listed in the lookup tables is provided in Appendix 1 (Table L).

The Tier 1 ESLs assume that no more than three carcinogenic COPCs, and no more than five noncarcinogenic COPCs, are present at a site. This is based on a combination of conservative exposure assumptions and target risk factors in direct-exposure models. Refer to Chapter 4 and Appendix 1 for additional discussion of this subject. The cumulative health risk may need to be calculated for sites where additional contaminants are present. Refer to Chapter 4 and Appendix 1 for additional information (see also USEPA 2004).

2.9 Chemicals Not Listed in Lookup Tables

Compilation of action levels for chemicals not listed in the current lookup tables is a relatively straightforward process, provided that adequate supporting data are available. A detailed discussion of the development of action levels presented in this guidance is provided in Appendix 1. A summary of the approaches used to develop the action levels is provided in Figure 2-5. To compile action levels for chemicals not listed in the lookup tables, the interested party should use the same approaches or contact the HEER office for assistance.

With the exception of the target, indicator compounds noted in Figure 2-4 and discussed in Section 2.6, individual petroleum-related compounds that are captured and included in TPH analyses do not need to be evaluated separately in an EHE. Action levels for these compounds do not need to be developed. This includes a host of alkanes, alkenes, alkyl benzenes and other aromatics not specifically identified as target indicator compounds that could be reported separately in analytical methods for volatile organic compounds (e.g., refer to NEIWPCC 2003, included in Appendix 7).

Action levels must be developed for all applicable, potential hazards (refer to Sections 1.2 and 2.3). **In particular, the USEPA Regional Screening Levels (RSLs, USEPA 2008a) or the Preliminary Remediation Goals (PRGs) previously published by USEPA Region IX (USEPA 2004) <u>cannot</u> be used as stand alone criteria for the evaluation of contaminated soil** (refer also to Section 2.12.1)**.** This is because the RSLs and PRGs do not consider all potential environmental hazards posed by contaminated soil. In particular, the RSLs do not address potential vapor intrusion ecotoxicity and gross contamination hazards. The PRGs (no longer in use by USEPA as of May 2008) have similar shortcomings but likewise do not fully address potential soil leaching hazards.

2.10 Comparison to Other Published Screening Levels

This Pacific Basin edition of the EHE guidance document represents an update and expansion of guidance published by the California Environmental Protection Agency (CalEPA 2005a), the Hawai'i Department of Health (HDOH 2008a) and the Commonwealth of the Northern Mariana Islands (CNMI 2005). These documents represent a compilation of approaches developed by various environmental agencies in the USA, Canada and other countries. As discussed below, each of these guidance documents represent an expansion of the Preliminary Remediation Goals or "PRGs" developed by Region IX of the U.S. Environmental Protection Agency (USEPA 2004). Differences and similarities between this guidance document and guidance prepared by the other agencies are summarized below.

[Dr. Roger Brewer, the primary author of this document, was also responsible for preparation of the California, Hawai'i and CNMI documents.]

2.10.1 USEPA Region IX PRGs

The 2008 U.S. Environmental Protection Agency (USEPA) *Regional Screening Levels* (RSLs; USEPA 2008a) replace *Preliminary Remediation Goals* (PRGs) previously published by individual regions. This includes PRGs published by USEPA Region IX (USEPA 2004) and referenced in pre-2008 editions of the CNMI and HDOH guidance documents. Like the PRG guidance, the RSL guidance presents risk-based soil, air and tapwater screening levels for a long list of contaminants.

The RSL and PRG models used are essentially identical, with the exception that the 2008 RSLs utilize Unit Risk Factors (cancer concerns) and Reference Concentrations (noncancer concerns) for inhalation of vapors and particulates, rather than Cancer Slope Factors and Reference Doses derived from the former as done in previous editions of the USEPA Region IX PRGs. This does not make a significant difference in the final screening levels. The 2008 USEPA RSL guidance also includes soil screening levels for potential leaching hazards (organic compounds only). Both the direct-exposure and leaching based screening levels take equal precedence.

The USEPA RSL direct-exposure models for soil and for tapwater were retained for use in this document. With the exceptions noted below and in Appendix 1, target risks, toxicity factors and physiochemical constants included in the RSL guidance were also retained for development of the ESLs.

The ESLs represent a significant expansion of the USEPA RSLs to address a more comprehensive suite of environmental hazards potentially associated with contaminated soil and groundwater (refer to Section 1.2). Specific differences include (see Appendix 1 for details):

- Adjustment of soil direct-exposure RSLs for noncarcinogens to a target hazard quotient of 0.2, rather than 1.0, to address potential cumulative health concerns at sites where multiple contaminants are present;
- Extrapolation of inhalation toxicity factors from oral toxicity factors for volatile chemicals in cases where the former are not included in the RSLs (follows approach used in previous editions of the USEPA Region IX PRGs);
- Addition of direct-exposure screening levels for construction and trench worker exposure to contaminated soils;
- Addition of soil, groundwater and soil gas screening levels for vapor intrusion

(indoor-air impact) hazards;
- Addition of groundwater screening levels for the protection of aquatic habitats and surface water quality (discharges of contaminated groundwater to surface water);
- Use of a more rigorous leaching model to develop soil screening levels for protection of groundwater quality (soil leaching hazards);
- Addition of soil screening levels for terrestrial ecotoxicity hazards in urban areas;
- Addition of soil and groundwater "ceiling levels" to address gross contamination hazards, including explosion hazards, odors, sheens and general nuisance and resource degradation concerns;
- Inclusion of soil screening levels for arsenic and total chromium based on natural background; and
- Addition of soil and groundwater screening levels for Total Petroleum Hydrocarbons (TPH).

Use of the USEPA RSL models in the ESLs presented in this guidance is discussed further in Chapter 3 of Appendix 1**. It is important to understand that the USEPA RSLs cannot be used as stand-alone screening levels to evaluate potential environmental hazards posed by contaminated soil and groundwater.** This is clearly stated in the User’s Guide to the RSLs but often ignored in practice, especially at sites that fall under Federal rather than State jurisdiction.

2.10.2 Hawai'i DOH EALs

The Hawai’i Department of Health worked in co-ordination with the USEPA in the early 1990s to publish one of the first guidance documents for the preparation of expedited environmental risk assessments (HDOH 1995). The guidance was updated in 2008 (HDOH 2008a). Lookup tables of soil and groundwater “environmental action levels” (EALs) included in the document addressed soil direct-exposure hazards (similar to the USEPA Region IX “PRGs”) as well as soil leaching and groundwater protection concerns.

The Hawai’i document was updated in 2008 to include a more comprehensive set of environmental hazards very similar to those presented in this guidance document (HDOH 2008a). The updated document is modeled largely after the California EPA document (CalEPA 2005). The Hawai’i action levels incorporate local drinking water and surface water standards when available. Risk-based action levels presented in the Hawai’i document also reflect USEPA toxicity factors for human health hazards, as do the ESLs presented in this guidance.

Unlike this guidance document, the Hawai'i guidance does not at this time present a separate set of action levels for commercial or industrial properties in their summary, Tier 1 lookup tables. Instead, only action levels for residential use of a property are presented. Separate, Tier 1 action levels are also not presented for "deep", isolated soils versus "shallow" soils as included in both this guidance and the California EPA document (see below). Action levels that can be applied to both nonresidential land use and deep soils are, however, included in the appendices of the Hawai'i EAL document. Use of these action levels is permitted in more site-specific, Tier 2 and Tier 3 risk assessments. Hawai'i chose not to include action levels for these site scenarios in their Tier 1 lookup tables in part because in-house risk assessment support was adequate to address these issues on a site-by-site basis as needed.

2.10.3 CNMI DEQ ESLs

The guidance and ESLs presented in this document represent an update and expansion of a similar document prepared for the Commonwealth of the Mariana Islands, Division of Environmental Quality (CNMI 2005). Primary differences include:

- Significant revision of the text to better define and describe the role of *Environmental Hazard Evaluation* in site investigations;
- Enhancement of the ESL Surfer (electronic lookup tables);
- Addition of approximately 30 pesticides and explosives-related contaminants to the ESL lookup tables; and
- Addition of guidance on the following topics (recently published by Hawai'i DOH):
    - *Soil action levels and categories for bioaccessible arsenic* (HDOH 2006a);
    - *Proposed dioxin action levels for East Kapolei brownfield site* (HDOH 2006b);
    - *Pesticides in former agricultural lands and related areas - Updates on investigation and assessment* (HDOH 2007b);
    - *Use of laboratory batch tests to evaluate potential leaching of contaminants from soil* (HDOH 2007a); and
    - *Long-Term management of petroleum-contaminated soil and groundwater* (HDOH 2007c).

The above noted technical memoranda are incorporated into the 2008 edition of the HDOH EHE guidance (HDOH 2008a).

2.10.4 TSCA PCB Standards

Risk-based soil screening for polychlorinated biphenyls (PCBs) are included in the lookup tables of this guidance (refer to Table K series in Appendix 1). The screening levels are calculated based on the same approach used to develop the USEPA Region IX PRGs, with the exception of the use of a target excess cancer risk of 10^{-5} rather than the default of 10^{-6} (refer to Section 1.3 in Appendix 1).

The treatment, storage and disposal of PCBs is also regulated under the Toxics Substance Control Act (TSCA), as described in Title 40, Part 761 of the Code of Federal Regulations. Reviews of TSCA regulations are provided in the USEPA documents *Guidance on Remedial Actions for Superfund Sites with PCB Contamination* (USEPA 1990) and *PCB Site Revitalization Guidance Under the Toxics Substances Control Act* (USEPA 2005). TSCA cleanup regulations are primarily targeted to address spills from operating electrical equipment. TSCA requirements are applicable to materials that contain PCBs in concentrations equal to or great than 50 mg/kg, including soil. Impacted soils containing less than 50 ppm PCBs are not regulated under TSCA, provided that the concentrations are "as found" at the site and the impacted soil has not been mixed with clean soil to reduce total concentrations. *Soils containing PCBs at a concentration greater than 50 mg/kg must be treated and disposed of in accordance with TSCA regulations.*

TSCA regulations present several cleanup standards for PCBs in soil. In general, these cleanup standards are not applicable to sites that are not strictly regulated under TSCA. The cleanup standards primarily apply to spills within and around electrical substations and should not be applied in general to residential or commercial/industrial sites that are found to be contaminated with PCBs. For example, a TSCA cleanup standard of 1.0 mg/kg is often quoted for PCBs in residential areas. This “cleanup level,” presented in 40CFR761 Subpart G for “high occupancy areas” (defined as >6.7 hours exposure per week) is based primarily on laboratory detection levels for PCBs in the 1980s and not strictly risk-based, nor does it reflect currently used toxicity factors for PCBs. Although almost identical to the residential screening level for PCBs in soil of 1.1 mg/kg presented in the ESLs (refer to Table K-1 in Appendix 1), *the TSCA cleanup level of 1.0 mg/kg is not technically supportable and cannot be referred to for use in residential soil cleanup actions.*

TSCA regulations also present a soil cleanup of 25 mg/kg PCBs in "low occupancy areas" (defined as <6.7 hours exposure per week). This cleanup level is presented under "Requirements for decontaminating spills in other restricted access areas." TSCA defines a "restricted access area" as a "...fenced or walled in area" associated with the spill of PCBs in or around an electrical substation or similar area ((40 CFR 760.125(c)(3)). If this doesn't apply to your site, neither does the TSCA cleanup level of 25 mg/kg. *For commercial/industrial sites in general, the TSCA soil cleanup level of 25 mg/kg is not applicable.*

The TCSA cleanup levels are intended to prevent the buildup of high concentrations of PCBs in areas where electrical workers may be exposed to spills on a regular basis (e.g., around transformers and other electrical equipment). They were not intended for use as cleanup levels in residential or commercial/industrial areas where PCB containing equipment is no longer being used or was never used. As described in the Toxics Substances Control Act (TSCA) regulations (40 CFR 761.120(e)(2)), the PCB cleanup levels presented were developed assuming "...(worker) exposures associated with ...typical, electrical equipment-type spills..." This can reasonably be interpreted to refer to isolated and localized leaks and spills related to the normal operation of transformers and other electrical equipment.

TSCA regulations also clearly state that "EPA foresees the possibility of exceptional spill situations in which site-specific risk factors may warrant additional cleanup to more stringent numerical decontamination levels than are required by (the TSCA) policy (40 CFR 761.120(b))." For this reason and as summarized above, *the ESLs for PCBs presented in the lookup tables of this guidance document take precedence in all soil cleanup actions not associated with the normal, ongoing operation of transformers and other electrical equipment.*

2.10.5 Hazardous Waste TCLP Standards

Waste is classified as either "hazardous" or "nonhazardous" in part based on Toxicity Characteristic Leaching Procedure (TCLP) analysis for solids and associated TCLP leachate standards (USEPA 1990). The TCLP leachate standards are intended to determine the type of landfill a waste material must be sent to (USEPA Title 22, Section 66699 - Persistent and Bioaccumulative Toxic Waste). If TCLP standards are exceeded, the waste must in general be sent to a Class I, hazardous waste landfill.

The TCLP test and associated leachate standards **cannot** be used screen soils for potential environmental hazards, including potential leaching hazards. The criteria, developed in the 1980s, are only loosely based on human health and environmental considerations and apply only to soil (and other materials) placed in a lined, regulated landfill. The TCLP test was not intended or designed to model leaching of contaminants from soil in the natural environment. Dilution attenuation factors assumed in the TCLP standards may not be applicable to settings outside of a landfill setting. Refer to Section 1.2 and Appendix 1 for guidance on appropriate methods for screening of contaminated soil and approaches for evaluation of potential leaching hazards.

2.10.6 OSHA Permissible Exposure Limits

The National Institute for Occupational Safety and Health (NIOSH) is the US Federal agency responsible for conducting research and making recommendations for the prevention of work-related disease and injury, including exposure to hazardous chemicals in air (NIOSH 2007). NIOSH develops and periodically revises Recommended Exposure Limits (RELs) for hazardous substances in the workplace. The RELs are used to promulgate Permissible Exposure Limits (PELs) under the Occupational Safety and Health Act (OSHA).

In most cases, OSHA PELs are not appropriate for health risk evaluations for commercial settings where the chemical is not currently being used as part of a regulated, industrial process. This includes sites affected by the migration of offsite releases (e.g., via emissions from a moving plume of contaminated groundwater). OSHA PELs are derived for an occupational setting, where the chemical in question is used in the industrial process, i.e., workers and others who might be exposed to the chemical have knowledge of the chemical's presence, receive appropriate health and safety training, and may be provided with protective gear to minimize exposures. OSHA PELs are derived for adult, healthy workers and are not intended to protect children, pregnant women, the elderly, or people with compromised immune systems.

As one example, the current OSHA PEL for tetrachloroethylene (PCE) is 678,000 $\mu g/m^3$ (100 ppmv, NIOSH 2007). Comparable risk-based screening levels for commercial/industrial exposure settings included in this document fall between 0.68 $\mu g/m^3$ and 10 $\mu g/m^3$ (carcinogenic effects vs noncarcinogenic effects, respectively; refer to Table E-3 in Appendix 1). The PEL is applicable to regulated work areas where PCE is being used and the employees have been properly trained to minimize exposure. The risk-based screening levels for indoor air presented in this guidance document are applicable to all other areas.

3

Environmental Hazard Evaluations

3.1 Steps to Environmental Hazard Evaluation

Environmental Hazard Evaluation (EHE) ties site investigation activities to remedial actions (refer to Figure 1-1). During this stage of the environmental response process, data collected at the site are reviewed and potential environmental hazards posed by contaminated soil and groundwater are identified and evaluated (Figure 3-1). In most cases this will be a relatively simple task and the text of the evaluation itself will be very brief. Although not required, preparation of the EHE is greatly simplified by comparison of the site data to Tier 1 Environmental Screening Levels (Tier 1 ESLs) and in particular by use of the ESL Surfer.

It is important to begin to identify potential environmental hazards at a site as soon as initial soil, groundwater and other data are received. This is used to guide completion of the site investigation as well as initiate discussions regarding the need for remedial actions. Questions that should be considered as part of the EHE include:

1) Of the initial list of contaminants of potential concern, which contaminants pose potential environmental hazards under uncontrolled site conditions?
2) What are the specific environmental hazards posed by these contaminants?
3) Are additional site data needed to better define the extent and magnitude of contamination or the potential environmental hazards identified?
4) Is an advanced evaluation of a specific environmental hazard warranted?
5) What is the distribution of potential environmental hazards across the site?
6) Are remedial actions required to address the hazards?

Answering these questions is not as difficult as it may at first seem and does not require a significant amount of technical expertise in the field of "risk assessment." Approaching the EHE in a step-wise fashion will ensure that all potential environmental hazards are adequately considered and that the most cost-effective and appropriate remedial actions are selected.

3.1.1 Identify Contaminants of Potential Concern

Contaminants of potential concern (COPCs) are selected based on the known or assumed past use of hazardous chemicals at the site. This is an important part of the Phase I assessment of the site and the subsequent preparation of a sampling and analysis plan. For example, if gasoline was stored at the site then the target COPCs should be TPHgasoline, BTEX, lead and fuel oxygenates. If the site was used to mix pesticides then the specific types of pesticides should be identified. Related contaminants such as arsenic, lead, mercury and dioxins should also be considered COPCs. Chapters 2 and 4 provide additional guidance for petroleum- and pesticide-contaminated sites.

The list of contaminants of potential concern can be quickly narrowed down once representative initial data are obtained by comparing the data to the Guam EPA Tier 1 Environmental Screening Levels (Tier 1 ESLs, refer to Chapter 2). If the representative concentration of a contaminant does not exceed the corresponding Tier 1 ESL then it can be reasonably assumed the contaminant does not pose a significant environmental hazard. If the Tier 1 ESL *is* exceeded, then additional evaluation of that contaminant is warranted. Contaminants that exceed the Tier 1 ESLs should continue to be considered COPCs and carried through the environmental hazard evaluation process, as described below.

3.1.2 Identify Potential Environmental Hazards

A summary of common environmental hazards posed by contaminated soil and groundwater is provided in Chapter 1 (see also Figure 1-2). A detailed evaluation of each environmental hazard on a site-specific basis would be an arduous and time consuming task. Fortunately, this level of effort will rarely be necessary. As discussed in Chapter 1, a simple comparison of site data to the Tier 1 ESLs offers a relatively rapid and cost-effective alternative to detailed environmental hazard evaluations and related risk assessments. Use of the ESL Surfer included with this guidance to identify potential environmental hazards and expedite Tier 1 EHEs is highly recommended.

Example printouts of the ESL Surfer are provided in Figures 3-2a (data input form), 3-b (detailed environmental hazards) and 3-2c (EHE summary report). To use the Surfer, select the appropriate site scenario information from the pulldown list (groundwater utility, depth to top of contaminated soil and land use), select the target contaminant, and (optional) input the representative concentration of the contaminant in soil or groundwater (Figure 3-2a). Note that soil screening levels for direct exposure, vapor intrusion and gross contamination hazards are higher (i.e., less stringent) for commercial/industrial land use than for unrestricted ("residential") land use. Soil screening levels for leaching hazards are unchanged since, in the absence of required, engineered controls (e.g., pavement over contaminated areas), use of the land for residential versus commercial purposes in itself does not necessarily alter the threat to groundwater.

The Surfer will generate Tier 1 ESLs for the selected chemical and site scenario. If included, the Surfer will also indicate if the input soil and/or groundwater concentration exceeds the Tier 1 ESLs. The input concentrations are compared to screening levels for specific environmental hazards in the second worksheet (Figure 3-2b). The Surfer flags hazards where the screening level is exceeded. A separate, summary report is generated that can be printed and included in the *Environmental Hazard Evaluation* report for the site (Figure 3-2c).

The example presented in Figures 3-2a, b and c is based on an assumed residential land use scenario with contaminated soil situated less than three meters below the ground surface ("shallow soils"). Groundwater is a current or potential source of drinking water. In the example, the input concentrations of benzene in soil (5.1 mg/kg) and in groundwater (150 µg/L) cause the Tier 1 ESLs for both media to flagged (Figure 3-2a). A look at the detailed screening levels worksheet (Figure 3-2b) indicates that benzene in soil at the input concentration could pose soil direct exposure, vapor intrusion and leaching hazards. Groundwater contaminated with 150 µg/L benzene poses drinking water toxicity concerns but no other potential hazards. These potential hazards are summarized in the Summary EHE Report worksheet of the Surfer. This worksheet can be printed and included in the appendices of the formal EHE, with a brief discussion of the potential environmental hazards flagged and recommended followup actions included in the text of the report. Recall that this does not necessarily mean that the contamination does in fact pose the hazards indicated, only that the potential exists and that additional evaluation is warranted.

3.1.3 Complete the Site Investigation

The objective of the site investigation is to determine the extent and magnitude of contamination to the degree needed for adequate identification of potential environmental hazards. Determining the extent of contamination to "non-detect" levels of targeted COPCs is rarely necessary. Site investigation activities can be considered complete when the vertical and lateral extent of contamination above Tier 1 ESLs is determined. In some cases (e.g., investigation of commercial/industrial areas with land use restrictions), the delineation of contamination to higher screening levels is acceptable. Be aware that the distribution of contamination could be discontinuous. For example, irregular pulses of releases over time can result in groundwater plumes that taper off to less than ESLs with increasing distance from the source and then rise again, as an older slug of contaminants is encountered.

The identification of potential environmental hazard(s) and completion of the site investigation is an iterative process. For example, if direct exposure to contaminated soil is flagged as a potential hazard then site data should be reviewed to ensure that the limits of contamination are adequately identified. Estimating representative contaminant concentrations across exposure areas (e.g., residential yards, commercial lots) rather than specific spill areas is generally acceptable. This is because a person is assumed to have equal access (and therefore equal exposure) to all parts of the site, not just the contaminated areas. For large industrial complexes, the property may need to be divided into smaller decision units based on specific exposure areas (e.g., specific work areas at an industrial site). The collection of multi-increment sample data in specific exposure areas to better estimate exposure point concentrations should also be considered. As discussed in Chapter 4, the collection of bioaccessibility data for arsenic-contaminated soil is recommended when the concentration of total arsenic exceeds 20 mg/kg. This is used to better evaluate direct exposure concerns.

If soil leaching hazards are identified then specific spill areas should be identified and treated as separate decision units. Unlike direct exposure hazards, data collected outside of contaminated areas should *not* be considered when estimating representative soil concentrations. This is because the decision unit is the spill area, not the site as a whole, and the target "receptor" of concern is the groundwater that directly underlies the contaminated soil. If Tier 1 soil screening levels for leaching concerns are exceeded then laboratory batch leaching test data can be collected for the target contaminants and a more advanced evaluation of leaching concerns carried out (refer to Chapter 4). Batch tests can also be used to confirm the cleanup of soils contaminated with chemicals that could threaten groundwater resources. Keep in mind that soil data are *not* necessarily good indicators of potential groundwater contamination. This is especially true for chlorinated solvents. Releases of wastewater contaminated with solvents may not leave an identifiable smear zone in vadose-zone soil due to the low sorptive capacity of the solvent compounds.

Soil or groundwater data flagged for potential vapor intrusion hazards almost always mean that soil gas samples should be collected at the site. The model used to develop the soil and groundwater actions levels for vapor intrusion estimate soil gas concentrations of the target contaminants based on assumed default soil properties and are considered to be conservative. Actual soil gas data for the site are much more reliable for evaluation of this hazard. The collection of methane data is also useful at sites with heavy petroleum contamination.

3.1.4 Evaluate Targeted Environmental Hazards

Potential environmental hazards flagged by comparison of site data to Tier 1 ESLs (or approved alternative screening levels) may or may not in fact exist at the site. The ESLs intentionally assume uncontrolled current and future site conditions in order to minimize future restrictions on use of the property (i.e., unpaved, soil exposed at the surface, contaminants not strongly bound to soil, nearby aquatic habitats, etc.). Actual site conditions could differ, causing the contaminants to pose a much lower threat to human health and the environment than a simple, screening level evaluation might imply. In these cases a more advanced and site-specific evaluation of targeted hazards is advisable and in some cases could even be required. Example approaches for evaluation of specific environmental hazards are provided in Chapter 4.

3.1.5 Identify Potential Additional Environmental Hazards

The ESLs are intended to address common environmental hazards at sites where contaminated soil and groundwater are identified. The majority of these sites will be located in industrialized or urbanized areas where the threat to sensitive ecological habitats is limited. Additional, potential environmental hazards should be identified and evaluated as appropriate on a site-by-site basis (refer to discussion of ESL limitations in Section 1.6). This could include the runoff of contaminated soil into aquatic habitats and impacts on sediment quality, bioaccumulation of contaminants aquatic organisms, uptake of contaminants in produce, explosive hazards associated with methane buildup, etc. (refer also to Chapter 4 – *Advanced Environmental Hazard Evaluations*).

3.1.6 Prepare Environmental Hazard Maps

Question Five asks about the distribution of environmental hazards across the site. Instead of thinking in terms of contaminants and contaminant concentrations, it is now important to start thinking in terms of the actual hazards posed by the contaminants at the site. What areas of the site pose potential direct exposure or vapor intrusion hazards? What areas of the site pose potential leaching hazards? In what areas will grossly contaminated soil likely be encountered during future subsurface activities?

Understanding the site in terms of environmental hazards rather than just contaminant concentrations is important, since this understanding serves as the basis for cleanup decision-making as well as long-term management plans. For the latter, the post-cleanup, "as-built" *environmental hazard maps* can be especially useful. As discussed in the previous sections, this can be accomplished by comparison of site data to ESLs (or acceptable alternatives) for targeted hazards. While not necessarily required to complete a project, such maps can help guide completion of and summarize the results of a site investigation, as well as assist those tasked with the preparation of remedial actions. A combination of contaminant distribution maps and environmental hazard maps may, however, be required for sites where contamination above screening levels for unrestricted future use of the property is to be left in place and managed over time.

An example soil environmental hazard map (based on a former pesticide mixing area) where soil is contaminated with dioxin, arsenic, chlorinated pesticides, and heavy oil is presented in Figure 3-3. Areas of specific hazards were delineated by comparison of soil data to detailed environmental screening levels (e.g., refer to Guam EPA ESL Surfer). Remedial options could vary with respect to the specific environmental hazard(s) posed in a given area. As an interim measure, contaminated soil that poses direct exposure hazards can be consolidated and placed under a well-managed soil cap. Areas of contaminated soil that pose leaching concerns will, in contrast, require some type of impermeable cap. Immediate removal of soil that is grossly contaminated with petroleum is recommended.

An example groundwater environmental hazard map is presented in Figure 3-4 (based after a former gasoline bulk fuel terminal). Contaminated soil has been removed. Remaining groundwater contamination poses several potential hazards, including vapor intrusion, toxicity to aquatic habitats, and gross contamination along the shoreline (odors and sheens). Areas of specific hazards were delineated by comparison of groundwater data to detailed environmental screening levels (e.g., refer to Guam EPA ESL Surfer). The site was to be redeveloped for residential use. Soil gas data confirmed potential vapor intrusion hazards. Aggressive treatment of the area of groundwater that posed vapor intrusion hazards was required prior to redevelopment. Aggressive remediation of groundwater that posed acute aquatic toxicity hazards and gross contamination (odors and sheens) within 50 meters of the shoreline was also required. Long-term monitoring of remaining groundwater contamination was required.

As described above, property owners, developers, and their consultants can utilize environmental hazard maps to help prioritize aggressive (and often costly) site cleanup actions by focusing resources on the most pressing hazards first. In many cases this may permit redevelopment of the site prior to the completion of final cleanup actions and the generation of funds to address remaining environmental hazards through less aggressive and presumably less costly measures (e.g., focused treatment of spill areas, in situ treatment of remaining groundwater contamination, long-term monitoring, institutional and engineering controls, etc.).

3.1.7 Recommend Followup Response Actions

Determining the most appropriate response to address environmental hazards at contaminated sites depends on a number of factors, including the presence or absence of hazards under current conditions, the planned future use of the site, the cost-benefit of postponing cleanup until a later time, natural attenuation of contaminants over time, regulatory requirements, etc. A partial list of potential recommendations is provided under Item 7 in Section 3.2. Refer also to advanced environmental hazard evaluation approaches discussed in Chapter 4.

Preparing a simple summary of environmental hazards posed under current site conditions versus unrestricted site conditions can aid in the selection of appropriate response actions. What types of environmental hazards could the contamination pose under uncontrolled (unrestricted) site conditions? What controls are currently in place to eliminate or reduce these hazards? What types of additional actions are needed to address existing hazards? What type of response actins are needed to fully eliminate the environmental hazards and allow unrestricted, future use of the site? What type of hazards will still be present at the site following the recommended response action in the absence of engineered or institutional controls? Do recommended controls need to be formally implemented at the site (e.g., via a covenant to the deed)? An example format for summarizing these issues is provided in Figures 3-5a (contaminated soil) and 3-5b (contaminated groundwater).

When practicable, full cleanup of contaminated soil and groundwater to permit future unrestricted use of the property is desirable. If full cleanup will not be carried out, the extent and magnitude of remaining contamination must be summarized and the potential environmental hazards posed by the contamination under uncontrolled conditions clearly described. The need for institutional and engineering controls must then be evaluated. These controls could include restrictions on activities such as excavation or well drilling, installation of vapor mitigation systems under buildings, capping of contaminated soil to prevent exposure or leaching, long-term monitoring of groundwater, etc. These actions must be described in a site-specific, *Environmental Hazard Management Plan*. The preparation of *Environmental Hazard Management Plans* is discussed in more detail in Chapter 5.

3.2 Preparation of Environmental Hazard Evaluation Reports

The *Environmental Hazard Evaluation* (EHE) should serve as "stand alone" report that provide a good summary of environment impacts at a site and the existing or potential hazards posed by the contamination. The report should include the following information:

1. Site Background

    - Describe past and current site uses and activities.
    - Describe reasonably anticipated future site uses and activities. (*Always* include a comparison of site data to ESLs for unrestricted ("residential") land use to evaluate need for formal land use restrictions and other institutional and engineered controls; see Section 2.7).

2. Summary of investigations (including to-scale maps with a north arrow):

    - Identify all types of impacted media (soil, groundwater, surface water, etc.).
    - Identify all sources of chemical releases.
    - Identify initial chemicals of potential concern.

- Identify magnitude and extent of impacts that exceed ESLs to extent practicable and applicable (include maps of site with isoconcentration contours for soil and groundwater as practicable).
- Identify nearby groundwater extraction wells, bodies of surface water and other potentially sensitive ecological habitats.
- Ensure data are representative of site conditions.

3. Applicability of Tier 1 ESLs or alternative screening levels:
    - Do Tier 1 ESLs exist for all chemicals of concern?
    - Does the site have a high public profile and therefore require a higher degree of decision confidence (including preparation of a detailed, human health risk assessment)?
    - Do soil and groundwater conditions at the site differ significantly from those assumed in development of the lookup tables (e.g., low pH at mine sites)?
    - Do impacts pose a heightened threat to sensitive ecological habitats (e.g., presence of endangered or protected species)?
    - Have more than three carcinogens or five chemicals with similar noncarcinogenic health effects been identified (excluding petroleum, see Section 2.8)?
    - Other issues as applicable to the site.
4. Selection of soil and groundwater categories:
    - State the regulatory beneficial use of impacted or potentially impacted groundwater beneath the site; discuss the actual, likely beneficial use of groundwater based on measured or assumed quality of the groundwater and the hydrogeologic nature of the soil or bedrock containing the groundwater.

- Characterize the soil type(s) and location of impacted soil as applicable to the lookup tables (e.g., soil stratigraphy, soil texture and permeability, depth to and thickness of impacted soil, etc.).

5. Selection of ESLs and comparison to site data.

   - Summarize how Tier 1 ESLs were selected with respect to the information provided above and additional assumptions as applicable.
   - Compare site data to the selected summary Tier 1 ESLs (presented in Volume 1) and identify areas of soil or groundwater that pose potential environmental hazards.

6. Identification of potential environmental hazards:

   - Identify specific, potential environmental hazards by comparison of site data to detailed ESLs for individual hazards (use the ESL Surfer; detailed tables presented in Volume 2, Appendix 1).
   - Identify any additional, potential environmental hazards not specifically addressed by the ESLs (refer to Section 3.1.5).
   - Discuss specific, potential environmental hazards present at site.
   - Consider presentation of environmental hazard maps in the EHE to help guide followup remedial actions and long-term site management plans.

7. Conclusions and recommendations for followup actions, such as:

   - Recommendation for more advanced evaluation of specific, environmental hazards (e.g., direct exposure, vapor intrusion or leaching hazards);
   - Recommendation for an evaluation of remedial alternatives, including site-specific human health or ecological risk assessments;
   - Recommendation for land-use restrictions and/or institutional controls based on the identified environmental hazards and in the absence of full site cleanup (e.g., requirements for caps, etc.; need for covenant to deed to restrict land use to commercial/industrial purposes only, etc).

- Recommendation for preparation of an *Environmental Hazard Management Plan.*

The conclusions and recommendations of the EHE should be incorporated into the remedy selection process.

The above elements are not intended to be exhaustive or representative of an exact outline required for all Tier 1 EHEs. The level of detail required for an EHE will vary depending on the complexity of the site and the ease at which contamination concerns can be addressed. For relatively simple sites, the EHE can be included as a separate chapter in the post-remediation report with ESL Surfer printouts for target COPCs included in the appendices. As discussed above, both maps that summarize the extent and magnitude of contamination as well as maps that depict areas of specific environmental hazards (or some combined form of the maps) are very useful components of EHEs. This information may then be passed on to persons developing remediation action plans for active cleanup of contaminated areas and/or Environmental Hazard Management Plans for long-term management of sites that cannot be fully cleaned up.

Conditions that pose immediate or short-term environmental hazards should be addressed as quickly as possible. This includes exposure of residents or workers to potentially harmful levels of contaminants in soil ("direct exposure"), impacts to water supply wells, intrusion of vapors or methane into overlying structures (including explosion hazards) and discharges of free product to surface water.

Note that the approach described above is referred to as Environmental "Risk" Assessment in previous guidance documents (e.g., CNMI 2005, CalEPA 2005). The term "risk" is replaced with the term "hazard" in this guidance document. This was done to emphasize the fact that some environmental concerns are not necessarily toxicological in nature, as the term "risk" is often interpreted to indicate. Examples include explosion hazards, leaching of contaminants from soil to groundwater, and even general gross contamination concerns. Human health and ecological risk assessments are of course important components of an *Environmental Hazard Evaluation*, but they cannot be used as stand-alone tools to determine the need for potential cleanup actions at sites where petroleum-contaminated soil and groundwater are identified (refer to Section 1.2). Additional information on human health and ecological risk assessments is provided in Chapter 4.

4

Advanced Environmental Hazard Evaluations

4.1 Tentatively Identified Environmental Hazards

Potential environmental hazards posed by contaminated soil and groundwater can be identified by direct comparison of site data to Tier 1 Environmental Screening Levels (Tier 1 ESLs) or approved, alternative screening levels (refer to Chapter 3). The Tier 1 ESLs assume uncontrolled and unrestricted current and future site conditions. Conservative assumptions are also made about mobility, persistence and toxicity of the target contaminants. This approach allows sites with minimal contamination to be quickly cleared for unrestricted use, without the need for time consuming and costly investigations and assessments.

A more detailed review of specific environmental hazards should be considered when costly remedial actions could be required. A summary of advanced evaluation approaches is provided in Figures 4-1a (soil) and 4-1b (groundwater). For example:

- At arsenic sites, relatively inexpensive bioaccessibility tests typically indicate that the majority of arsenic in pesticide-contaminated soil is so tightly bound to the soil that it is essentially nontoxic. This can significantly reduce or even eliminate the need for capping or aggressive treatment of contaminated soil.

- Long-term monitoring of petroleum-contaminated groundwater is likely to indicate that the groundwater contaminant plume will rapidly shrink once the source of the release and gross contamination is removed (see Chapter 5). This can be used to support a remedy of focused, aggressive treatment in the immediate release area and natural attenuation as the selected remedy in outer areas of the plume.

- Soil gas data provide a much more realistic idea of vapor intrusion hazards initially flagged by a comparison or soil or groundwater data to Tier 1 screening levels for this concern. Collection of soil gas data and comparison to screening levels for potential vapor intrusion hazards will expedite the identification of buildings or even specific areas of buildings at high risk for potential indoor air impacts (see Table E).

- If direct-exposure to contaminated soil is the driving environmental hazard at a site and the contamination cannot be cost-effectively removed, then placement of a restriction on future land use can reduce or even eliminate the need for aggressive remedial actions (e.g., commercial/industrial land use only).

Although "advanced," these and other approaches for a more site-specific review of potential environmental hazards flagged during the Tier 1 environmental hazard evaluation are not necessarily costly and do not necessarily require a significantly greater amount of technical expertise.

These and other example approaches for more advanced evaluations are outlined below. These evaluations can be relatively simple, such as the use of groundwater monitoring data to evaluate leaching and plume migration hazards or soil gas data to better evaluate vapor intrusion hazards. Other approaches can be very time-consuming and do require more technical expertise, such as the preparation of a human health or ecological risk assessment.

A brief overview of human health risk assessments and ecological risk assessments are provided at the end of this section. Although the nomenclature and intent of the two types of documents is often confused, it is important to understand that a traditional human health risk assessment _cannot_ be used in place of an *Environmental Hazard Evaluation*. Human health risk assessment focuses on toxicological risks to humans associated with direct exposure to contaminated soil, groundwater, or air. While these risks are important, direct exposure is only *one* of several potential environmental hazards that are addressed in a more comprehensive EHE (refer to Section 1.2). Screening levels specifically developed to screen for potential direct exposure concerns are incorporated in the Tier 1 ESLs (based on USEPA Region IX Preliminary Remediation Goals, see below). Preparation of a traditional, human health risk assessment is generally only necessary at sites where exposure of residents or workers to contamination above target, risk-based screening levels is taking place and cannot be immediately remedied or where significant contamination is to be managed in place in residential or other sensitive use developments (schools, day care centers, medical facilities, etc.; refer to Section 4.2.1.3). In some cases, legal needs on the part of the responsible party could also require preparation of a detailed human health risk assessment.

4.2 Advanced Evaluations of Contaminated Soil

Example approaches for advanced evaluation of environmental hazards posed by contaminated soil are presented in Table 4-1a. A brief discussion of highlighted topics is provided below.

4.2.1 Direct Exposure

4.2.1.1 Tier 2 Direct Exposure Model

This guidance document includes an easy-to-use, Excel-based spreadsheet model (available for download from Guam EPA webpage) that calculates site-specific, Tier 2 direct-exposure screening levels for soil based modifications to default site conditions and human exposure assumptions. The model uses the same equations used to develop the USEPA Region IX Preliminary Remediation Goals and the Tier 1 screening levels for direct exposure hazards (PRGs, refer to Appendix 1). Printouts of the model input pages (first two worksheets, two pages) should be included in the Environmental Hazard Evaluation. All changes made to default input parameter values must be discussed and supported in the text of the report.

A copy of the first page of the model is provided in Figure 4-2. To use the model, simply select the contaminant of concern, select the land use exposure scenario, and adjust the soil parameter values as appropriate based on site data. Assumed soil properties typically have very little effect on calculated direct-exposure screening levels. An exception is the input thickness of contaminated soil for volatile chemicals. The USEPA source model assumes that the emission of a volatile chemical from contaminated soil remains constant over the entire 30-year exposure period (USEPA 1996, 2004). This constant emission progressively depletes the mass of the chemical in the soil over time. For highly volatile chemicals such as vinyl chloride and even benzene, maintaining the model's theoretical vapor emission rate over 30 years would require the volume of contaminated soil to be tens of meters thick. This is not realistic for most sites.

The Tier 2 direct-exposure model includes an alternative, "mass-balanced" volatilization factor that establishes a maximum, long-term vapor emission rate based on the mass of contaminant present and the assumed exposure duration (default exposure duration = 30 years, USEPA 1996). To adjust the soil screening levels simply input the site-specific thickness of soil above Tier 1 ESLs. The spreadsheet automatically generates an adjusted, Tier 2, direct-exposure screening level for the selected land use. A screening level is also generated for construction worker exposure. If the latter is lower than the Tier 2 screening level for the selected exposure scenario then it is selected as the final, screening level. Risk-based soil screening levels for construction workers can in particular be more stringent than those for commercial workers at sites where soils are contaminated with metals that are highly toxic via inhalation in dust (e.g., beryllium, Cr VI, cobalt, etc.; refer to Table K-2 in Appendix 1).

Changing the input site parameters beyond the assumed exposure scenario will have very little effect on screening levels for nonvolatile chemicals. This is because the thickness of contaminated soil at a site (or more correctly the mass of the contaminant present) does not play a significant role in estimating the risk or calculating soil screening levels for nonvolatile contaminants. Exposure assumptions (exposure duration, target risk etc.) can be adjusted in the spreadsheet. However, most of these assumptions are essentially “fixed” for the noted exposure scenario and will require review by a toxicologist for approval.

4.2.1.2 Tier 2 Screening Levels for Arsenic, Dioxin and Technical Chlordane

The Hawai’i Department of Health (HDOH) has issued Tier 2 screening levels related to direct exposure hazards for arsenic, dioxin and technical chlordane in soil (HDOH 2006a, 2006b and 2007a, HDOH 2008a). Copies of the HDOH technical memorandums guidance documents are provided in Appendix 8. Use of these guidance documents is recommended. The screening levels are based on slight modifications to the USEPA Region IX Preliminary Remediation Goals and more recent Regional Screening Levels (USEPA 2004, 2008). The modifications as used in Hawai’i have been discussed in detail with USEPA Region IX. No adjustment of the HDOH Tier 2 screening levels is necessary for use in Guam and other areas of the Pacific Basin.

A summary of the Tier 2 screening levels is provided below. These screening levels and associated guidance may be used in place of the Tier 1 ESLs provided that other contaminants are not present above their respective Tier 1 (or Tier 2) screening levels for direct-exposure hazards. If elevated levels of other contaminants are present, then the cumulative health risk posed by all of the contaminants should be estimated and evaluated in a site-specific, human health risk assessment. The potential use of soil contaminated with arsenic, dioxins and technical chlordane as daily (short-term) or interim (long-term) fill at landfills is discussed in the respective summary tables for each contaminant.

Potential leaching hazards posed by arsenic and chlordane should be evaluated separately. Although relatively immobile, these contaminants could pose potential leaching concerns under some conditions. Dioxins do not pose a potential leaching threat under any condition. Refer to Chapter 4 for guidance on the site-specific evaluation of leaching hazards.

Arsenic

A detailed discussion of HDOH Tier 2 action levels and guidance for arsenic is provided in Appendix 8 (HDOH 2008b). A summary is provided in Figure 4-3a (unrestricted land use) and Figure 4-3b (commercial/industrial land use only). Total arsenic analyses should be used to initially screen soils for potential contamination concerns. If the reported total concentration of arsenic exceeds 20 mg/kg (assumed upper limit of natural background), then the samples should be tested for *bioaccessible* arsenic.

Bioaccessible arsenic is the fraction of the total arsenic in ingested soil that could be available for absorption by a person's digestive tract and pose health risks. Equivalent concentrations of bioaccessible arsenic in soil are calculated by multiplying the reported total concentration of arsenic by the fraction that is determined to be bioaccessible by site-specific bioaccessibility tests. Refer to the August 2006 HDOH technical memo provided in Appendix 8 for additional information. USEPA guidance for lead-contaminated soil calls for use of the <250 micron soil fraction in bioaccessibilty tests (USEPA 2000). This guidance also applies for bioaccessibility tests carried out on arsenic-contaminated soils.

The HDOH Tier 2 arsenic action levels do not consider potential leaching of arsenic from soil and subsequent impacts to groundwater. The use of laboratory batch tests to evaluate this potential hazard is recommended. Refer to Section 4.2.3 for additional information.

Dioxin

A detailed discussion of HDOH Tier 2 action levels and guidance for dioxins is provided in Appendix 9 (HDOH 2008c; update to 2006 HDOH technical memorandum). A summary is provided in Figure 4-4a and 4-4b. Dioxins are contaminants of potential concern in former agricultural areas due to their presence as manufacturing-related impurities in pesticides, especially pentachlorophenol, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 2,4,5-

trichlorophenoxypropionic acid (2,4,5-TP or Silvex). These pesticides were commonly used in sugar cane and other operations. Dioxins can also be created when organic material is burned in the presence of chlorine.

Quantification of dioxins in soil for use in human health risk assessments requires conversion of congener-specific GC/MS data to Toxicity Equivalent (TEQ) dioxin concentrations by use of Toxicity Equivalence Factors (TEFs; WHO 2005). The TEQ concentrations for individual congeners are then added together to calculate a total TEQ dioxin concentration for the sample. Tier 2 soil screening levels presented in the HDOH guidance are applicable to adjusted TEQ dioxin data.

Laboratory bioassay methods offer a cheaper alternative for dioxin analysis in comparison to standard GC/MC methods (typically 50% or less than GC/MS; HDOH 2007a). Methods currently available include CALUX and Cape Technology's DF1 kit (refer to HDOH 2006a memo in Appendix 8), with CALUX currently in most use. Bioassay data are reported directly in terms of TEQ concentrations and do not require conversion using congener-specific TEFs. Ten percent of the samples (minimum two per site) should be tested using GC/MS to confirm bioassay-based TEQ dioxin data. The GC/MS analyses should be conducted on samples with the highest-reported bioassay TEQ dioxin results.

Dioxins (and furans) are not considered to be significantly mobile in soil due to their strong sorption to organic carbon and clay particles (koc >30,000 cm^3/g; refer to Section 3.4 in Appendix 1). Consideration of soil leaching hazards is therefore not considered to be necessary. Pesticides associated with dioxins could pose potential leaching and groundwater contamination hazards, however, and should be included in testing and evaluation

Technical Chlordane

A summary of HDOH Tier 2 action levels for Technical Chlordane is provided in Figure 4-5 (HDOH 2007a, Appendix 8). Soils adjacent to or under buildings that are known or suspected to have been treated with termiticides should be tested for organochlorine pesticides before reuse in open exposed areas (USEPA Method 8081A, HDOH 2007a). For "chlordane," the laboratory should report the total concentration of the *technical chlordane* mixture rather than individual chlordane isomers and related compounds found in the mixture (e.g., heptachlor). This must be specifically requested on the Chain of Custody form and discussed with the laboratory in advance. Laboratories should also be instructed to report any additional organochlorine pesticides that are not typically found in technical chlordane (e.g., DDT, dieldrin, endrin, etc.).

Technical chlordane is not considered to be significantly mobile in soil due to it's relatively strong sorption to organic carbon and clay particles (koc >30,000 cm^3/g; refer to Section 3.4 in Appendix 1). Technical chlordane mixtures contain multiple compounds with differing degrees of potential mobility, however. Laboratory batch tests are therefore recommended to evaluate potential leaching hazards for soil that is to be left in place at a site with a representative concentration of technical chlordane that exceeds 15 mg/kg technical. Refer to Section 4.2.3 for additional information.

4.2.1.3 Human Health Risk Assessment

The preparation of a traditional, human health risk assessment may be required at heavily contaminated sites that are unlikely to be cleaned up in the near term and/or in cases where contamination is to be managed in place at sites being used for residential or other sensitive land use purposes (see Section 4.1). A detailed risk assessment is rarely required for petroleum-contaminated sites. An in depth review of the preparation of human health risk assessments is beyond the scope of this guidance document. Selected references for additional information are provided below:

- USEPA Preliminary Remediation Goals: (USEPA 2004).
- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2002a);
- Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (USEPA 2002b);
- Assessing the Significance of Subsurface Contaminant Vapor Migration to Enclosed Spaces (Johnson et al. 1998, 2002);
- Exposure Factors Handbook (USEPA 1997a);
- Health Effects Summary Tables (USEPA 1997b);
- Superfund Soil Screening Guidance: Technical Background Document (USEPA 1996);
- Supplemental Guidance For Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities (CalEPA 1996a);
- Standard Provisional Guide for Risk-Based Corrective Action (ASTM 1995);

- Preliminary Endangerment Assessment Guidance Manual (CalEPA 1994); and
- Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A) (USEPA 1989a).

As discussed in Section 1.2, it is important to ensure that all potential environmental hazards are adequately evaluated at sites where human health risk assessments are carried out.

4.2.2 Vapor Intrusion Into Buildings

Detailed guidance on advanced approaches for evaluation of vapor intrusion hazards is provided in Section 4.4. A more site-specific evaluation usually begins with the collection of soil gas data once concentrations of volatile contaminants in soil or groundwater exceed Tier 1 screening levels for this potential hazard. The use of site-specific vapor intrusion models in the absence of soil gas data is strongly discouraged.

4.2.3 Leaching and Contamination of Groundwater

Soil leaching hazards drive the selection of final, Tier 1 ESLs for the majority of organic contaminants presented in the lookup tables. That is, screening levels for leaching hazards are lower than screening levels for direct exposure, vapor intrusion, ecotoxicity and gross contamination hazards (refer to Tables A through D in Appendix 1). Leaching and contamination of groundwater resources will therefore be a common concern at most contaminated sites. In addition, screening levels for leaching hazards are not incorporated into the Tier 1 ESL for metals, since the existing models are very unreliable. If metals are suspected to be potentially mobile, this concern must be evaluated a site-by-site basis.

Laboratory batch tests are recommended for more site-specific evaluations of soil leaching hazards. Batch tests can also be used to confirm the cleanup of soils contaminated with chemicals that could threaten groundwater resources. A summary of this approach is provided in the Hawai‘i Department of Health guidance document *Use of laboratory batch tests to evaluate potential leaching of contaminants from soil* (HDOH 2007b). Four basic questions are posed:

1. “Is the contaminant potentially mobile?”

2. “What is the concentration of the contaminant in leachate in the primary source area?”

3. “What is the concentration of the contaminant in leachate at the point that the leachate reaches the top of the water table?” and

4. “What is the concentration of the contaminant in groundwater after the leachate has impacted the groundwater?”

Each of these questions should be answered in a site-specific evaluation of potential soil leaching concerns.

The approach is relatively simple. As discussed in Chapter 1, decision units for contaminants that pose potential leaching hazards should be defined as specific spill areas (refer to Section 1.4). A representative sample is collected. The sample is tested for the target contaminant of potential concern. If the reported concentration of the contaminant exceeds the Tier 1 screening level for leaching hazards, or if it is a potentially mobile metal, then a split of the sample is also tested using the Synthetic Precipitation Leaching Procedure (SPLP) batch test method. In this method, 100 grams of soil are placed in two liters of buffered, de-ionized water and the mixture is agitated for a set period of time. The ratio of the mass of contaminant that remains sorbed to the soil compared to the mass that goes into solution is the *desorption coefficient*, or K_d. If the K_d value is greater than 20, then the contaminant is considered immobile and no further action is required to address leaching hazards. If the Kd value is less than 20 then the estimated concentration of the contaminant in leachate and ultimately in groundwater is compared to target groundwater screening levels and the need for further action is evaluated. (Note that direct comparison of SPLP data to target groundwater screening levels is not technically correct or appropriate in most cases.)

A detailed discussion of the approach is provided in the referenced HDOH guidance (HDOH 2007b). The guidance includes an easy-to-use, Excel-based spreadsheet model that can be used to calculate K_d values and estimate contaminant concentrations in leachate and groundwater (available for download from the Guam EPA webpage). A copy of the input page of the model is provided in Figure 4-6. **Use of batch tests to confirm the adequacy of soil screening levels for leaching hazards and final cleanup actions is strongly recommended at sites that overlie highly valued and vulnerable groundwater resources.** Batch tests can be run on confirmation soil samples in conjunction with standard soil analyses at minimal added costs (including TPH).

4.2.4 Gross Contamination

Gross contamination of soil includes the presence of potentially mobile free product, offensive odors, unaesthetic appearance, generation of explosive vapors, and general resource degradation. Although it may seem counterintuitive, it is possible for soil to be so heavily contaminated with some chemicals that the soil is flammable but is not considered "toxic" in the classic toxicological sense. Acetone, methyl ethyl ketone, xylenes, and even gasoline (in the absence of significant benzene content) are a few examples. Gross contamination hazards generally drive cleanup of soil contaminated with these chemicals.

When gross contamination hazards are flagged in the Tier 1 Environmental Hazard Evaluation then a check of actual conditions in the field is strongly recommended. Soil heavily contaminated with diesel fuel may not pose a direct-exposure hazard but its presence at or near the surface in a new residential development would most likely not be welcome. Advanced evaluation of gross contamination hazards for potentially flammable or explosive contaminants can be carried out by the comparison of soil gas data to lower explosive limits for the target contaminants (refer to NIOSH 2007). Note that the OSHA PELs are not appropriate for evaluation of gross contamination hazards (refer to Section 2.10.5).

Both TPH and methane should be included in soil gas analyses for petroleum-contaminated sites (see Sections 2.4 and 4.4.4). Published guidance on the evaluation of methane hazards includes:

- CalEPA, 2005, *Advisory on Methane Assessment and Common Remedies at Schools Sites* (June 16, 2005) California Environmental Protection Agency, Department of Toxic Substances Control.

A copy of this guidance is provided in Appendix 8.

4.2.5 Terrestrial Ecotoxicity

Detailed, ecological risk assessments will not be required for the majority of sites overseen by the overseeing regulatory agency. The need for a detailed evaluation of terrestrial ecotoxicity hazards should be based on an inspection of the site by a qualified individual and the identification of potentially threatened habitats and endangered or threatened species.

4.3 Advanced Evaluations of Contaminated Groundwater

Example approaches for advanced evaluations of environmental hazards posed by contaminated groundwater are presented in Table 4-1b. A brief discussion of highlighted topics is provided below.

4.3.1 Drinking Water Resource Contamination

Screening levels for drinking water are not easily adjustable. Toxicity-based drinking water screening levels for approximately 40% of the chemicals listed in the lookup tables are based on promulgated standards and cannot be changed (refer to Appendix 1). Screening levels for the remaining chemicals as based on a USEPA model for tapwater. The latter could in theory be adjusted based on alternative exposure assumptions and toxicity factors but the approach used is relatively straight forward and rigid and adjustment is considered unlikely. The same is true for drinking water screening levels based on gross contamination, taste and odor concerns.

Site-specific evaluations of threats to drinking water resources should instead focus on plume mobility and the long-term persistence of the chemicals released. Nearby groundwater supply wells should be identified. Long-term monitoring should be carried out to assess plume mobility. Groundwater fate and transport models may be useful in some cases, but should not be relied upon in the absence of actual groundwater monitoring data and aquifer data. Petroleum plumes rarely migrate more than a few hundred feet from the release area. Persistent chemicals such as chlorinated solvents, MTBE, pesticides, and other persistent chemicals pose the greatest long-term threat to drinking water resources. In some cases, the installation of sentinel wells between the contaminant plume and a threatened well may be required.

4.3.2 Vapor Intrusion into Buildings

Detailed guidance on advanced approaches for evaluation of vapor intrusion hazards is provided in Section 4.4. A more site-specific evaluation usually begins with the collection of soil gas data once concentrations of volatile contaminants in soil or groundwater exceed Tier 1 screening levels for this potential hazard. The use of site-specific vapor intrusion models in the absence of soil gas data is generally discouraged.

4.3.3 Discharges into Aquatic Habitats

Fewer than 20% of the screening levels for aquatic toxicity are based on promulgated surface water standards. While adjustment of non-promulgated actions levels based on alternative study data is feasible, it will rarely be required or beneficial.

As discussed for drinking water concerns, site-specific evaluations of threats to nearby aquatic habitats should instead focus on plume mobility and the long-term persistence of the chemicals released. Nearby, surface water bodies should be identified. Storm sewers and other potential conduits that cross through the plume should also be identified. Long-term monitoring with or without the use of fate and transport models (generally not necessary) should be carried out to assess plume mobility. If plumes are discharging into an aquatic habitat then a more detailed evaluation of surface water and groundwater interaction and impacts on aquatic organisms may be required.

Use of a generic dilution factor to adjust screening levels for the protection of aquatic habitats is not recommended (refer to Chapter 2). This is because benthic organisms that live at the groundwater-surface water interface will not be protected by dilution of groundwater in the water column. Consideration of acute aquatic toxicity screening levels may, however, be appropriate on a site-specific basis (e.g., discharges of groundwater into in highly developed, harbor areas without significant benthic habitats).

4.3.4 Gross Contamination

Gross contamination concerns for groundwater are primarily related to petroleum releases. Check for free product if solubility limits for target contaminants are approached or exceeded. Check shoreline or stream bank areas beside areas of heavily contaminated groundwater for sheens, odors and related gross contamination concerns. Monitor soil gas for methane buildup and potential explosion hazards in areas of heavy petroleum contamination. Be sure to include TPH and methane in soil gas analyses (see Sections 2.4, 4.2.4 and 4.4.4).

4.4 Advanced Evaluation of Vapor Intrusion Hazards

4.4.1 Overview of Vapor Intrusion

Use of the soil, groundwater and soil gas screening levels for vapor intrusion concerns presented in this guidance to initially screen sites contaminated with volatile contaminants is highly recommended. The significance of vapor intrusion hazards is closely tied to local climate conditions and building designs. The mild climate, lack of heating in buildings and general improved ventilation of buildings in tropical and subtropical areas of the Pacific significantly reduces vapor intrusion hazards in comparison to colder areas on the US mainland. The screening levels presented in this guidance document for vapor intrusion hazards are correspondingly less conservative than screening levels used in colder climates.

Volatile organic chemicals (VOCs) can be emitted from contaminated soil or groundwater and intrude into overlying buildings, impacting the quality of indoor air. While actual impacts to indoor air can vary widely from building to building, and even within buildings, it is generally possible to estimate worst case scenarios for use in screening level risk assessments. Soil, soil gas, and groundwater screening levels were developed for this purpose and incorporated into the ESLs A summary of approaches used to develop the screening levels is included in Appendix 1.

Heating, ventilation, and air conditioning (HVAC) systems, basements, strong winds, and other factors can exacerbate vapor intrusion problems by reducing internal air pressure and creating a vacuum effect that enhances the advective flow of vapors through building floors (e.g., USEPA 2003, CalEPA 2004). For buildings with a slab-on-grade design, this can result in the direct flow of subsurface vapors into a building with little or no dilution beforehand. The vapors become diluted as they mix with fresh air being drawn in through the building's HVAC system or through open doors and windows, generally by a factor of 500 to 1,000 for residential buildings and higher for commercial/industrial buildings (see Appendix 1).

For buildings with a crawl space design, subsurface vapors are diluted as they diffuse into and mix with air in the crawl space below the building floor. Additional mixing may or may not occur as the air from the crawl space is pulled into the building. Vapor flux through the building floor could be significantly elevated in comparison to slab-on-grade design buildings due to the operation of an HVAC systems in poorly ventilated rooms (e.g., an unvented closet). This issue is still being evaluated. An initial review of published literature and site data, however, suggests that soil gas-to-indoor air attenuation factors for crawl space design buildings may be very similar to those for slab-on-grade design buildings.

The field of vapor intrusion investigations is still evolving. Approaches to site investigations and evaluation of vapor intrusion concerns presented in guidance documents noted above and discussed below should not be taken as stringent requirements that must be applied at all sites. Appropriate investigation and risk assessment needs should be determined on a site-by-site basis. Site-specific requirements could be less or more stringent than those presented.

Published guidance documents on vapor intrusion hazards and investigations include:

- USEPA: User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings (USEPA 2003 and updates),
- DoD: Tri-Services Handbook for the Assessment of the Vapor Intrusion Pathway (DoD 2008);
- California: *Guidance for the Evaluation of the Vapor Intrusion to Indoor Air Pathway* (CalEPA 2004);
- Massachusetts: *Indoor Air Sampling And Evaluation Guide* (MADEP 2002b);
- New Jersey: Vapor Intrusion Guidance, New Jersey Department of Environmental Protection (NJDEP 2005); and
- New York: *Guidance for Evaluating Soil Vapor Intrusion in the State of New York* (NYDEH 2006).

4.4.2 Collection of Soil, Groundwater and Soil Gas Data

4.4.2.1 Stepwise Approach to Vapor Intrusion Evaluation

The direct collection and analysis of indoor air samples may seem to be an easy way to evaluate vapor intrusion concerns. However, identification of the sources of VOCs identified is complicated by the presence of the same chemicals in auto emissions and in many household goods (aerosol sprays, dry-cleaned clothing, cleaners, etc.). For example, ambient levels of benzene in outdoor air in urban areas (related to auto exhaust) typically exceed the indoor air screening level presented in Table E (0.085 $\mu g/m^3$) by an order of magnitude or more. Ambient levels of dry cleaning solvent (tetrachloroethylene) and other chlorinated solvents in indoor air may also exceed the screening levels presented in Table E.

As an alternative, the sequential collection and evaluation of groundwater data or soil data (see below), soil gas data and, if needed, indoor air data is recommended. These data can then be compared to screening levels for vapor intrusion concerns presented in this document and areas of elevated concern quickly identified. The following approach is recommended (refer also to CalEPA 2004):

1) Compare soil and/or groundwater data to appropriate screening levels for vapor intrusion concerns (see Tables E-1a and E-1b of Appendix 1 or the ESL Surfer); for sites with significant impacts to vadose-zone soils, proceed directly to Step 2;

2) For areas where screening levels for vapor intrusion concerns are approached or exceeded or sites where significant releases to vadose-zone soils have occurred, collect shallow soil gas samples immediately beneath (preferred) or adjacent to buildings and compare results to soil-gas screening levels (refer to Table E in this volume or Table E-2 in Appendix 1).

3) At buildings where soil-gas screening levels for vapor intrusion concerns are approached or exceeded, further evaluate the need to carry out an indoor air study.

A more detailed discussion is provided below. **Site data should not be averaged over an area greater than the existing or anticipated floor space area of a building for initial evaluation of vapor intrusion hazards.** A denser area of data coverage may be required for buildings with isolated rooms directly above the slab.

The screening levels are based on scientific models for vapor intrusion into buildings as well as a growing body of data from actual field investigations. A detailed discussion of the screening levels is presented in Appendix 1. The use of site-specific vapor intrusion models for soil and groundwater is discouraged, especially in the absence of soil gas data. The models used are highly sensitive to parameters such as soil vapor permeability and moisture**. If site-specific models *are* carried out then it is imperative to include a 15cm of highly permeable fill material, as done for the models used to develop screening levels in this guidance (e.g., "sand" in model default soil types, refer to Appendix 1, Section 2.4.1).** This will help reflect likely site conditions and ensure a realistic vapor flow rate through the floor slab.

4.4.2.2 Collection and Evaluation of Soil Data

Soil data are *not* considered to be highly reliable for detailed evaluation of vapor intrusion hazards. The collection and use of soil gas data is instead preferred (refer to Section 4.4.2.4). Vapor intrusion screening levels for soil should only be applied to sites where relatively minor releases of volatile contaminants have occurred and the collection of soil gas data is not considered to be necessary and/or feasible.

4.4.2.3 Collection and Evaluation of Groundwater Data

Groundwater data should be collected at all sites where significant releases of VOCs are known or thought to have occurred and compared to screening levels presented in Appendix 1 of this document (Table E-1a, see also Tables F-1a and F-1b). Vapor emission rates are controlled by the concentration of VOCs in the upper few feet or even inches of the water table. Sample data should be collected from this zone, preferably by direct push, grab sample methods or monitoring wells with short (e.g., five foot) well screens. This helps to avoid mixing deeper, less contaminated groundwater with shallow groundwater. It is important to ensure that monitoring well screens span the top of the water table.

Screening levels for vapor emissions from groundwater into overlying buildings are incorporated into the F-series tables in Appendix 1 and the summary tables presented at the end of this volume as well as the ESL Surfer (electronic version of the ESL lookup tables). Imported fill material or disturbed native soils should be considered to be highly permeable in site-specific assessments unless vapor flow data into existing buildings indicate otherwise. This is incorporated into the updated USEPA spreadsheets by use of a default vapor flow rate into buildings of approximately five liters per minute per $100m^2$ of floor space ("Qsoil").

The groundwater screening levels for vapor intrusion concerns are based on an assumed three-meter depth to groundwater (see Appendix 1). These screening levels may not be adequately conservative for use at sites with shallower water tables. Proceeding directly to the collection of soil gas data directly below building floors or adjacent, paved areas is instead preferable.

4.4.2.4 Collection and Evaluation of Soil Gas Data

Soil gas samples should be collected at sites where soil or groundwater data suggest potentially significant vapor intrusion concerns. Among other sources, the collection of soil gas data is discussed in the California EPA document *Soil Gas Advisory* (CalEPA 2003). Approaches to soil gas studies are also presented in the above-noted vapor intrusion guidance document prepared by the California EPA (CalEPA 2004) and the New York Department of Environmental Health (NYDEH 2006).

Soil gas samples should be collected over the core of the groundwater plume and in nearby areas of concern (e.g., near residential homes, commercial buildings, utility corridors, etc.). Ideally, samples should be collected immediately beneath the foundations of existing buildings ("subslab"). If it is impractical to collect subslab samples, then samples should be collected from paved areas immediately adjacent to buildings. In unpaved areas, soil gas samples should be collected from a depth of 1.5m (five feet) below ground surface (bgs). Samples collected from depths less than 1.5m in open (i.e., unpaved) areas are considered unreliable due to the increased potential to draw in ambient surface air (CalEPA 2004). The collection of deeper soil gas samples and soil-type data may also be useful in evaluating the lateral and vertical extent of VOCs in the subsurface, as well as in evaluation of deeper utility corridors to serve as preferential pathways for vapors into enter a building.

The collection of additional soil geotechnical data should be considered if site-specific modeling of vapor flow rates or indoor-air impacts is to be carried out, (e.g., soil grain-size analysis, moisture content, fraction organic carbon, etc.). For existing buildings with slab-on-grade construction, data must be collected from the fill material immediately beneath the slab. This is the layer of soil that controls the advective (pressure-induced) flow of vapors into the building. In most cases, the soil consists of a relatively dry, silty sand or sandy silt that exhibits a relatively high vapor permeability. This assumption is incorporated into the vapor intrusion models used to develop the action levels presented in this guidance (refer to Appendix 1). It is inappropriate to use deeper soil data to model this layer, since increased clay and moisture contents could significantly under predict the ability of the soil to convect vapors into the building. For undeveloped sites where there are no existing buildings, the presence of layer of dry, permeable fill material under future buildings should be assumed. Data can, however, be collected from deeper layers of soil and used to model these layers in the vapor intrusion model. Care should be taken to ensure that the final soil stratigraphy incorporated into the model is reflective of actual field conditions.

The use of lab-based, soil vapor permeability tests to replace the default vapor flux rate (Qsoil) of 5 liters/minute (per $100m^2$ of ground floor area) used in the USEPA models is, however, discouraged. These tests often do not adequately take into account enhanced permeability due to soil heterogeneities, soil fractures, relict root structures, shallow fill material, disturbance during redevelopment, and other types of secondary permeability.

Both subslab sample data and shallow soil gas data (i.e., $\leq$1.5m bgs) should be compared to the soil gas screening levels presented in Table E. Where screening levels are approached or exceeded, the need to carry out an indoor air study should be more closely evaluated. Approaches for determining when an indoor air study should be carried out are still being developed. The California EPA vapor intrusion guidance recommends that an indoor air study be carried out if site-specific, soil-gas-to-indoor vapor intrusion models suggest that impacts to indoor air may exceed a cumulative excess cancer risk of 10^{-6} or a noncancer hazard index >1.0 (CalEPA 2004).

While this approach is generally appropriate for unrestricted land use scenarios (e.g., residential, schools, day care, day care, etc.), it may be impractical in areas of high ambient outdoor air pollution or for commercial/industrial buildings where similar chemicals are being used or stored inside of the building. For example, the concentration of benzene and other auto exhaust-related contaminants in outdoor air near roadways can exceed risk-based screening levels by up to two orders of magnitude. In such cases, impacts to indoor air related to vapor intrusion from subsurface contamination can easily be masked by existing outdoor air pollution entering the building. In such cases, sampling of indoor air would not be useful. Decisions for cleanup of contaminated soil and groundwater for vapor intrusion concerns should instead be based on an evaluation of soil gas data in conjunction with ideal target indoor air goals, even if these goals cannot be currently met due to other sources of contamination, such as vehicle exhaust in ambient air. If soil gas screening levels are exceeded, then cleanup of the source areas to reduce vapor intrusion concerns should be considered.

An alternative approach for determining when indoor air studies are needed at commercial/industrial (C/I) settings if soil gas screening levels for commercial/industrial sites are exceeded is described below:

Step 1. Confirm and Evaluate Soil Gas Data.

- Confirm soil gas data with a second round of sampling in targeted areas of potential concern (e.g., co-located with hot spots identified in first round of soil gas data collection and previously identified hot spots in soil and/or groundwater). If significant differences in reported concentrations of VOCs are reported at individual sample points and ESLs were exceeded in one or both sampling events, consider the installation of permanent vapor monitoring wells in a denser grid (e.g., 15m to 20m grid) and additional sampling until the range of potential site conditions is adequately defined. Statistical approaches may be required at sites where wide temporal variations in concentrations of VOCs in soil gas are identified.

- If soil gas ESLs for noncarcinogens are not exceeded and ESLs for carcinogens are not exceeded by more than one order of magnitude (equivalent to a target risk of 10^{-5}), then no further action is warranted (refer to Table E-2 in Appendix 1).

- If soil gas ESLs are exceeded by more than amounts noted above, use the USEPA soil gas spreadsheet to calculate a site-specific, cumulative excess cancer risk and noncancer hazard index (USEPA 2003, see web address in references). For example, input site-specific building and soil type data into USEPA spreadsheet for each chemical of concern and add up the calculate risks and hazard indices. Input a default vapor flux rate of 5 liters/minute per $100m^2$ of floor space. Print out spreadsheet results for each chemical of concern; calculate cumulative risks and include in letter report with recommendations for additional actions (see Step 2). [The USEPA spreadsheet protection password is "ABC."]

Step 2. Evaluate site-specific vapor intrusion risks.

- **Site-specific, cumulative excess cancer risk <10^{-5} and/or cumulative noncancer hazard index <1.0 (and potential impacts to indoor air less than existing pollution in ambient, outdoor air).** Testing of indoor air not required. Install permanent vapor monitoring probes in areas of primary concern and test quarterly for a period of one year to confirm soil gas data. If concentrations of VOCs do not increase significantly (i.e., to exceed cumulative 10^{-5} excess cancer risk or HI>1.0), no further action is warranted under current site conditions. Additional evaluation may be warranted if building conditions change or if new buildings are constructed over impacted areas.

- **Site-specific, cumulative excess cancer risk >10^{-5} and/or cumulative noncancer hazard index >1.0.** Install permanent vapor monitoring probes and resample soil gas. If resampling of soil gas indicates a potential indoor air risk <10^{-5} and/or cumulative noncancer hazard index <1.0, carry out quarterly monitoring for one year to confirm (see above). Carry out indoor air testing if soil gas data suggest a potential excess cancer risk of >10^{-5} and/or a cumulative noncancer hazard index >1.0 is confirmed (refer to Section 2.8.3).

The above approach for commercial/industrial settings is intended to be general guidance only and should not be used as a strict requirement. The appropriateness of the approach should be evaluated on a case-by-case basis. As discussed below, the collection of indoor air samples for sites with petroleum-related vapor intrusion hazards is discouraged unless reported levels of TPH and target indicator VOCs are greater than 1,000 times anticipated, ambient indoor air concentrations (see Section 4.4.4).

4.4.2.5 Soil Gas and Tight Soils

At sites where soil gas samples cannot be collected using traditional methods due to tight soil conditions (e.g., wet, clayey soils), other approaches should be attempted. In many cases, simply moving the collection probe over a few feet from the initial location will address the problem. If problems still persist, the installation of temporary soil vapor probes encased in permeable sand packs and capped with a bentonite clay mixture can be considered (refer to CalEPA 2002). The diameter and depth of the vapor probe borehole should be adjusted to allow sufficient pore space for the collection of soil gas samples. Adequate time (generally several weeks) should be allowed for VOCs in the surrounding clays to equilibrate with soil gas in the vapor probe sand pack.

Passive soil gas sampling techniques may also prove useful in tight soils, provided that the actual concentrations of VOCs present can be quantified (e.g., recent advances in "Gore™ Sorbers). This approach has not been widely used at this time and is still being evaluated. Where possible, both "active" and passive soil gas data should be collected in amenable areas of a site and used to verify the interpretation of passive soil gas data from areas where active data could not be collected.

At sites where groundwater is impacted with VOCs and the collection of soil gas data is simply not possible, groundwater data should be compared to conservative screening levels and the need to go directly to crawl space and/or indoor air sampling evaluated. At "soil only" sites, soil data should be similarly collected and compared to conservative screening levels (see below).

4.4.2.6 Use of Soil Data

Soil screening levels for potential vapor intrusion concerns are incorporated in the ESL lookup tables (see Appendix 1, Table A-D series and Table E-1b). At sites where minor releases of volatile chemicals have occurred (e.g., small spills around underground storage tank fill ports), direct comparison of soil screening levels to site data is generally acceptable. If soil screening levels are exceeded, the need to collect soil gas samples and further evaluate vapor intrusion concerns should be evaluated. **At sites where significant releases of volatile chemicals have occurred, the direct use of soil gas data in conjunction with soil data is strongly recommended.**

An advantage of the soil vapor intrusion model is the inclusion of “mass-balance” considerations in the evaluation of potential long-term impacts to indoor air. As discussed in the following section, this issue is not included in the soil gas vapor intrusion models or corresponding screening levels. (Mass balance issues are also not considered in the groundwater models. The continued migration of contaminated groundwater from upgradient areas is assumed to provide an ongoing source of VOCs to areas of concern, however, and mass-balance issues are less relevant.)

4.4.2.7 Soil Gas and Mass-Balance Issues

At sites with high levels of VOCs in soil gas but a limited total mass of VOCs in soil, a mass balanced approach to the evaluation of vapor intrusion concerns may be appropriate. For example, it is not uncommon to find relatively high levels of PCE in soil gas immediately beneath the floors of dry cleaners but relatively little PCE in soil samples collected in the same area. Most of the PCE is in vapor phase, with very little total mass present. This is most likely related to the presence of dry soil with very little organic carbon directly under the floor of the building.

Based on soil gas data alone, the vapor intrusion models may predict unacceptable, long-term impacts to indoor air. The actual mass of VOCs present may be insufficient to maintain initial impacts over the full span of the exposure duration assumed in development of the screening levels, however. In such cases, the screening levels presented in could be overly conservative for evaluation of long-term, chronic health risk concerns and a more site-specific evaluation of vapor intrusion concerns may be warranted.

4.4.3 Collection and Evaluation of Indoor Air Data

In some cases, the collection of indoor data will be necessary to further evaluate vapor intrusion concerns. The collection of indoor air data without soil gas data and, if applicable, crawl space data is not recommended. Such data are critical in determining the source of any VOCs identified in indoor air. Guidance on the collection and evaluation of indoor air data is provided in the above-noted

California EPA document (CalEPA 2004) and will not be repeated in detail here. Additional information is available in the Massachusetts Department of Environmental Protection document *Indoor Air Sampling And Evaluation Guide* (MADEP 2002b).

The California EPA guidance document provides a table of recommended actions at sites where impacts to indoor air are identified (CalEPA 2004). A slightly modified version of that table is provided below:

***Indoor Air Sampling Results**	**Response**	**Activities**
Risk: <10^{-6} HI: <0.5	No Further Action	Confirm that vapor intrusion impacts are not likely to increase in the future.
Risk: 10^{-4} to 10^{-6} HI: 0.5 to 1.0	Monitoring +/- Mitigation	Collect soil gas, indoor air and/or crawl space samples semi-annually as appropriate. Mitigation may be recommended in some cases to reduce exposure even though health risk goals may not be exceeded.
Risk: >10^{-4} HI: >1.0	Mitigation Required	Institute engineering controls to mitigate exposure and collect soil gas samples and indoor air samples semiannually to verify mitigation of exposure.

*Contaminants identified in indoor air that are directly linked to the intrusion of subsurface vapors.
Risk = Cumulative excess cancer risk
HI = Hazard Index – Cumulative risk posed by sum of noncancer hazard quotients of specific chemicals of concern.

The original CalEPA guidance calls for monitoring +/- mitigation of indoor air impacts if the cumulative Hazard Index (HI) is between 1.0 and 3.0, with mitigation required if the HI exceeds 3.0. Acute inhalation action levels for some contaminants can be approached at HI of 3.0, however (e.g., benzene). For the purpose of this guidance, an HI of 1.0 was therefore selected as a default target for mitigation of indoor air impacts. This can be reviewed on a site-specific basis as needed.

If structures in the subject area are underlain by crawl spaces then the concurrent collection air samples from these areas should also be considered. Crawl space data should be compared directly to indoor air data. As discussed above, the dilution of VOCs in crawl spaces as air is pulled into a building is difficult to predict.

The above are initial recommendations only. Ultimate actions required at a given site should be determined on a case-by-case basis in coordination with the overseeing regulatory agency. As noted in the California EPA guidance document, indoor air data should be used to better ascertain human health concerns when potentially significant impacts are implied by soil gas and other subsurface data. The California EPA document recommends that at least two rounds of indoor air data be collected prior to determining appropriate response activities. The scope of specific responses should be determined on a case-by-case basis in coordination with the overseeing regulatory agency. Active mitigation of indoor air impacts may be recommended (or even required) at sites where a reduction of individual exposure is desired even though health risk objectives noted above are not exceeded. A contingency plan based on the data to be collected should be included as part of the indoor air sampling plan.

If vapor intrusion concerns are primarily for future buildings, then remediation of VOC impacts prior to construction should be considered. If this is not feasible (e.g., due to impacts from a continuing offsite source) then institutional and engineering controls to mitigate vapor intrusion concerns should be incorporated into future building designs. The scope and oversight of these controls should be determined on a site-specific basis in coordination with the overseeing regulatory agency. Long-term oversight requirements are typically much more stringent for residential properties. In some cases, formal incorporation of engineered controls into building permits may be warranted with long-term oversight of the controls being undertaken by the planning agency.

4.4.4 Special Considerations for Petroleum-Contaminated Sites

A discussion of contaminants of potential concern for petroleum is provided in Section 2.4 (see also Figure 2.3). As noted, TPH and not benzene or other individual volatile chemicals generally drives vapor intrusion risks for releases of middle distillates and even gasolines. Vapor intrusion screening levels for TPH in soil and groundwater cannot easily be calculated using the USEPA models referenced above and are not included in the ESL lookup tables. The analysis of soil gas samples for TPH is instead required (sometimes reported as Total Volatile

Hydrocarbons or similar terms). The standard used for the analyses should be similar to the product released at the site.

Testing of indoor air for petroleum-related contaminants associated with the intrusion of vapors from subsurface sources is rarely useful. Common household cleaners, glues and other products can contain petroleum and serve as indoor sources of contamination (look for “Flammable” on labels). Auto exhaust is also a major contribution to petroleum-related contaminants in outdoor air. Unless the building is located directly over heavily contaminated soil or free product on shallow groundwater, petroleum vapors related to other indoor and outdoor sources will overwhelm additional contamination related to vapors emitted from underlying soil and groundwater.

For example, ambient concentrations of benzene in urban, outdoor air related to auto-exhaust typically ranges from 1to >5 ug/m^3 (ATSDR 2007), well above the risk-based, screening level for residential exposure of 0.25 ug/m^3 (refer to Table E). Although less published data are available, ambient concentrations of TPH in indoor and outdoor air can exceed 1,000 ug/m^3 (based on unpublished data for sites in Hawai’i and California), well above the residential indoor air screening level of 51 ug/m^3. As a general rule, indoor air should only be tested if concentrations of target contaminants in soil gas exceed at least 1,000 times anticipated levels in ambient air (default soil gas:indoor air dilution factor for residences; 2,000 for commercial/industrial buildings). This correlates to a concentration of TPH in soil gas of 1,000,000 ug/m^3 before impacts to indoor air might exceed ambient, background levels and 1,000 ug/m^3 for benzene.

This does not mean that the additional contamination of indoor air related to vapor intrusion is not a concern. If reported levels of TPH, BTEX or other contaminants in soil gas exceed screening levels (or approved alternatives) then lower floor of the building should be inspected and cracks and gaps (e.g., around utilities) should be sealed. The building heating, air conditioning and ventilation (HVAC) system should also be inspected to ensure that it is operating properly (e.g., maintaining a positive indoor air pressure) and that adequate fresh air is being brought into the building.

It is also important to screen for methane in soil gas samples. Additional evaluation of methane explosion hazards is required if methane levels in soil exceed 5,000 ppmv (10% of the lower explosive level; refer to Section 4.2.4). TPHgasoline vapors could also pose explosion hazards at some sites. An evaluation of potential vapor intrusion and explosion hazards will in particular be needed at sites where full cleanup of heavily contaminated soil and groundwater is not practicable and long-term monitoring or residual contamination is required.

4.5 Environmental Hazard Evaluations for Parklands

It is strongly recommended that sites that are to be used as parks or wildlife refuges be remediated to meet unrestricted land use when practicable. Potential hazards posed to eco-habitats should also be evaluated. Recreational-use exposure scenarios used in human health risk assessments often incorporate much lower exposure frequencies (e.g., days per year visited) and durations (total number of years) than traditional, residential exposure scenarios. This implies that substantially higher concentrations of contaminants can be left in place in a park area and not pose a threat to users of the park. Risk-based cleanup levels based on recreational land-use scenarios can even be higher (less stringent) than levels typically allowed for commercial/industrial properties.

This intuitively goes against the concept of park lands as a "refuge" for humans and wildlife. Assumption of a limited exposure frequency and duration (e.g., 100 days per year for ten years) also puts an implicit restriction on the number of days and years that an individual can visit the park incurring an unacceptably high contaminant dose. Long-term, future uses of such properties are also difficult to predict. Additionally, public parks are typically frequented by children, young mothers, elderly people, and other more-sensitive subpopulations. This issue is usually omitted from standard, human health risk assessments.

Remediation of proposed parklands to unrestricted land-use standards may in some cases not technically or economically practicable. If cleanup is not feasible, and the property is intended for recreational use, then the appropriateness of allowing unrestricted access to the area should be carefully evaluated. Institutional controls may be needed, such as the imposition of access restrictions on the property or posting of signs at the property entrance that warn of potential environmental hazards.

4.6 Ecological Risk Assessment

Preparation of a more detailed Ecological Risk Assessment may be required in some cases to better evaluate and document impacts to terrestrial and aquatic habitats. An Ecological Risk Assessment is a detailed appraisal of the actual or potential effects of a hazardous waste site on plants and animals other than people or domesticated species (USEPA 1989b). Published guidance documents for preparation of Ecological Risk Assessments include the following:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA 1997c);
- Guidance for Ecological Risk Assessments at Hazardous Waste Sites and Permitted Facilities (CalEPA 1996b); and
- Risk Assessment Guidance for Superfund: Volume II Environmental Evaluation Manual (USEPA 1989b).

Detailed guidance regarding the preparation of Ecological Risk Assessments is beyond the scope of this Manual, and the above list of references is not intended to be comprehensive. Additional Ecological Risk Assessment guidance should be referred to as needed.

5

Long-Term Management of Contaminated Sites

An expanded discussion of the long-term management of contaminated sites will be included in revisions to the Hawai'i Department of Health (HDOH) *Technical Guidance Manual* (HDOH 2008a, anticipated Fall 2008). In the interim, refer to the HDOH guidance published for the long-term management of petroleum-contaminated sites (HDOH 2007c, provided in Appendix 8). Although focused on petroleum contamination, the guidance can also be expanded to other types of releases that require long-term management.

As discussed in petroleum guidance, an *Environmental Hazard Management Plan* (EHMP) should be prepared for all sites where residual contamination in soil and groundwater exceeds action levels for unrestricted land use.

A basic EHMP should include the following information (or be included in a document that contains the same information):

- Brief summary of the site background and history of contaminant releases;
- Identification of specific contaminants of concern, including TPH, "Target Indicator Compounds" and any other contaminants associated with the release (refer to Step 1);
- Clear depiction of the extent and magnitude of remaining contamination in soil, groundwater and/or soil gas, presented on easily readable, to-scale maps with a north arrow (refer to Step 2);
- Identification and discussion of all potential environmental concerns (refer to Step 3);
- Requirements for long-term monitoring of contaminants in soil, groundwater, and/or soil gas;
- Discussion of engineering and/or institutional controls needed to address identified environmental concerns, including caps, barriers, etc., needed to eliminate exposure pathways;
- Guidance on the proper management and disposal of contaminated soil and/or groundwater encountered during future site activities;
- Measures for repair or replacement of engineered controls that are

disturbed or breached during future site activities; and

- Any other information required to adequately mitigate and manage remaining environmental concerns at the site.

The scope of EHMPs for individual sites will vary based on the nature and extent of the remaining contamination, as well as the potential environmental hazards posed by the contamination. A relatively short and simple discussion of proper management procedures in the final closure report may be adequate for sites where only a small amount of petroleum-contaminated soil or groundwater has been left in place and only gross contamination hazards remain. A more detailed EHMP that includes formal restrictions on site use and engineered controls to prevent exposure to residual contaminants may be required at sites where contamination is to be left in place that poses significant environmental hazards if not managed properly. A brief *Fact Sheet* that summarizes key elements of the EHMP in simple, non-technical terms may also be required for large, complex sites where significant public review is anticipated.

The use of engineered controls to prevent exposure to contaminated soil or groundwater is generally discouraged for properties that are to be developed for single-family homes or town homes where residents could dig in their yards. This is because long-term management of the controls by residents cannot be assured (e.g., maintenance of clean soil caps over contaminated soil). Permanent soil caps in commercial/industrial sites or high-density residential sites should at least 30cm (twelve inches) thick (USEPA 2003). For garden areas, at least 60cms (24 inches) of clean fill is recommended (USEPA 2003). If offsite disposal alternatives do not exist, contaminated soil could also be placed under building pads or other paved areas, provided that the location of the soil is properly surveyed and documented in the EHMP. Utility trenches should also be backfilled with clean soil in order to reduce exposure of future workers and avoid accidental reuse of excavated soil in areas where workers and residents may be exposed to residual contaminants. Contaminated soil that is to be isolated at depth should in general be kept at least one meter above the highest groundwater level.

The above is not necessarily a comprehensive list of issues that must be taken into consideration at sites where contaminated soil and groundwater are to be left in place. Plans for long-term management of contaminated soil on properties should be discussed with the overseeing regulatory agency.

6

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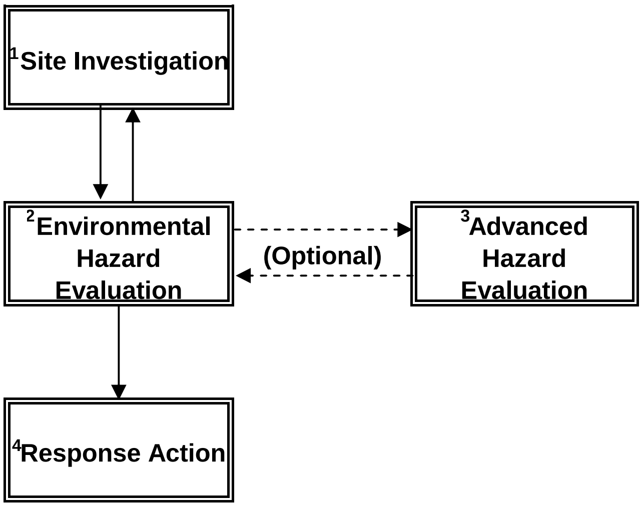
FIGURES

Figure 1-1. Overview of the Environmental Site Assessment Process



1. The extent and magnitude of contamination above levels of potential concern is determined during the site investigation stage of the process.

2. Potential environmental concerns at contaminated sites are identified in a preliminary Environmental Hazard Evaluation (EHE). Specific, potential hazards are evaluated in more detail as needed (see below). The final EHE is used determine the need for response actions.

3. An advanced evaluation of specific environmental hazards can be carried out as needed. For example, soil gas data can be collected to better evaluate vapor intrusion hazards; soil batch tests can be carried out to better evaluate leaching hazards; a site-specific human-health risk assessment and/or ecological risk assessment can be prepared to better define risks to human and ecological receptors; etc. The conclusions are used to help support the need for response actions.

4. The most appropriate response action to address the identified environmental hazards is identified and implemented. This could include no further action, active remediation, long-term management, etc.

Figure 1-2. Summary of common environmental hazards associated with contaminated soil and groundwater.

Contaminated Soil	
Environmental Hazard	**Description**
Human Health Risk	
• Direct Exposure	Exposure to contaminants in soil via incidental ingestion, dermal absorption and inhalation of vapors or dust in outdoor air.
• Vapor Intrusion	Emission of volatile contaminants from soil and intrusion into overlying buildings.
Leaching	Leaching of contamination from soil by infiltrating surface water (rainfall, irrigation, etc.) and subsequent contamination of groundwater resources.
Impacts to Terrestrial Habitats	Toxicity to terrestrial flora and fauna
Gross contamination	Includes potentially mobile free product, odors, aesthetics, generation of explosive vapors, general resource degradation, etc.
Contaminated Groundwater	
Environmental Hazard	**Description**
Human Health Risk	
• Contamination of drinking water supplies	Toxicity concerns related to contamination of groundwater that is a current or potential source of drinking water.
• Vapor Intrusion	Emission of volatile contaminants from groundwater and intrusion into overlying buildings.
Impact to Aquatic Habitats	Discharges of contaminated groundwater and toxicity to aquatic organisms
Gross contamination	Includes taste and odor concerns for contaminated drinking water supplies, free product, potential, sheens and odors on surface water, general resource degradation, etc.

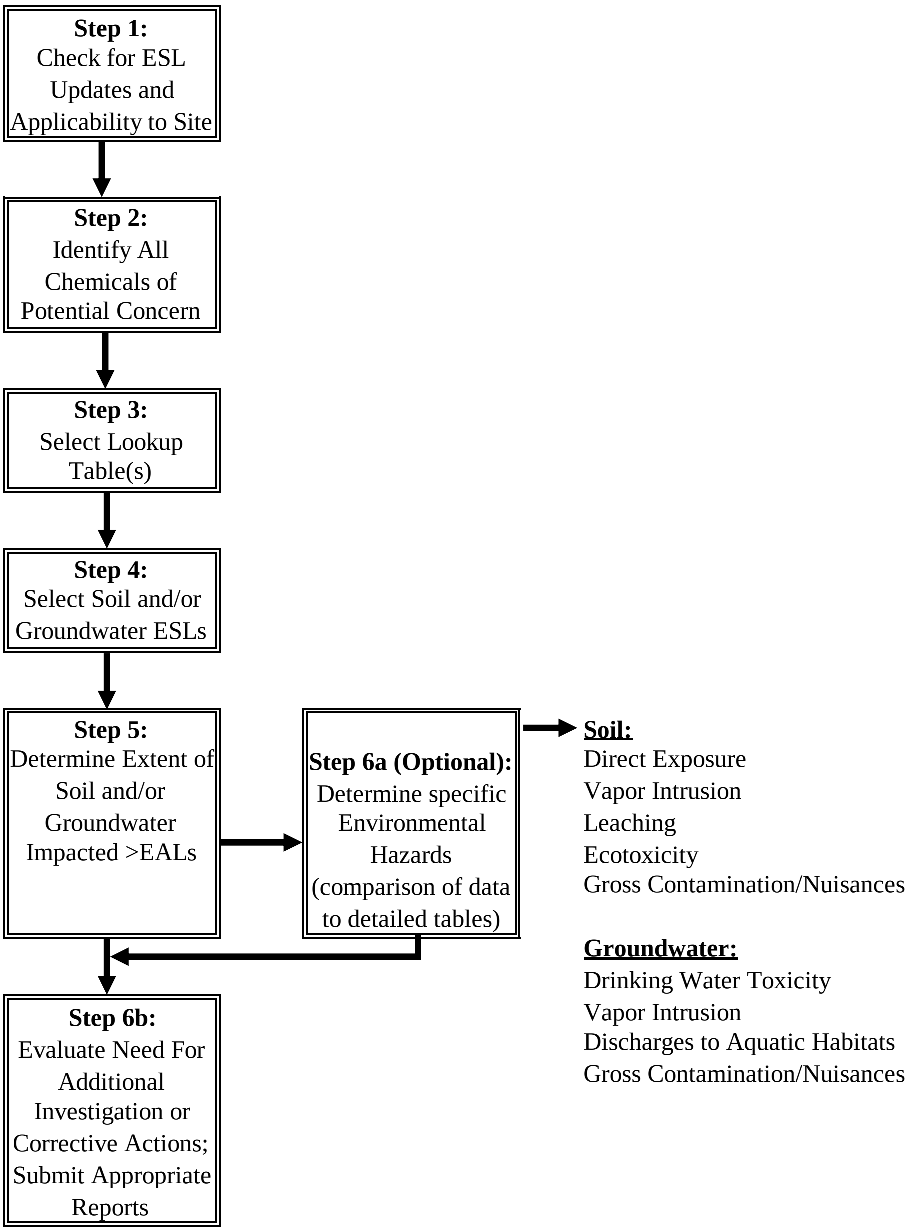


Figure 1-3. Steps for use of the Tier 1 ESL lookup tables during the site assessment process. Although not necessary for sites where cleanup to Tier 1 ESLs can easily be attained, identification of specific environmental hazards is recommended and in particular required for sites where long-term, on-site management of contaminated soil and groundwater is proposed.

Figure 2-1. Primary references for compilation of Tier 1 Environmental Screening Levels.

Soil

Environmental Hazard	**Primary Reference**	**Comments**
Direct Exposure	USEPA Region IX Preliminary Remediation Goals (PRGs)	PRGs for noncancer concerns adjusted to a Hazard Quotient of 0.2 (i.e., divided by five)
Vapor Intrusion	USEPA Vapor Intrusion Guidance and Model	Model formatted for use in tropical to temperate climates with shallow groundwater
Leaching	Massachusetts Department of Environment Soil Leaching Model	Model modified to reflect target groundwater screening levels
Terrestrial Ecotoxicity	Ontario Ministry of Environment Compilation	Screening levels applicable to non-sensitive, urban environments only
Gross Contamination	Massachusetts Department of Environment Gross Contamination Guidance	Generic approach for gross contamination concerns

Groundwater

Environmental Hazard		**Primary Reference**	**Comments**
Drinking Water Toxicity		Local Agency Primary Maximum Contaminant Levels	USEPA Region IX Tapwater PRG model used for chemicals that lack Primary MCLs
Vapor Intrusion		USEPA Vapor Intrusion Guidance and Model	Model formatted for use in tropical to temperate climates with shallow groundwater
Discharges to Aquatic Habitats		USEPA Surface Water Standards	USEPA and other sources referred to for chemicals that lack surface water standards
Gross Contamination	Drinking Water Resource	Local Agency Secondary Maximum Contaminant Levels	Alternative references used for chemicals that lack Secondary MCLs
	Non-Drinking Water Resource	Massachusetts Department of Environment Gross Contamination Guidance	Generic approach for gross contamination concerns

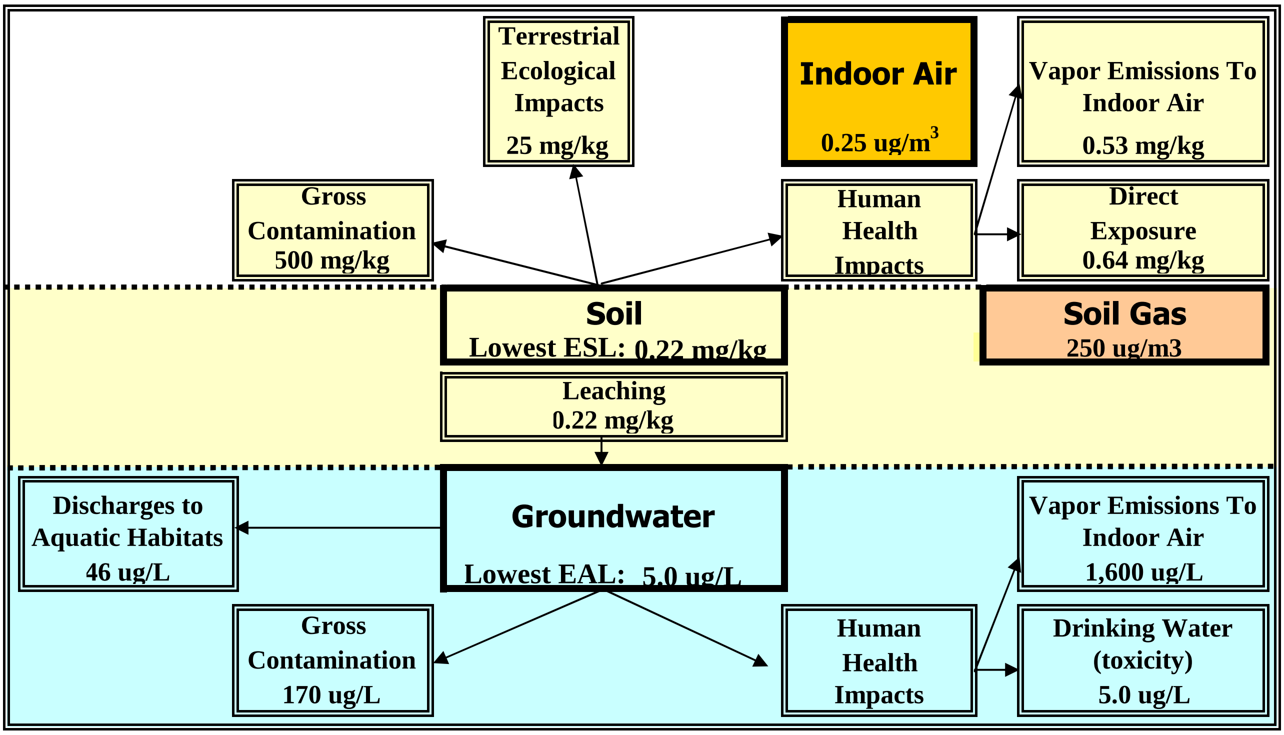


Figure 2-2. Detailed screening levels used to select final, Tier 1 soil and groundwater ESLs for benzene (assumes residential land use, exposed soils, groundwater is a source of drinking water).

Figure 2-3. Target analytes for releases of petroleum products.

Petroleum Product	Media	Recommended Target Analytes
Gasolines	Soil	TPH, benzene, toluene, ethylbenzene, xylenes (BTEX), naphthalene, MTBE and appropriate additives and breakdown products (e.g., DBA, TBA, lead, etc.)
	Soil Gas	Same as soil plus methane
	Groundwater	Same as soil
Middle Distillates (diesel, kerosene, stoddard solvent, heating fuels, jet fuel, etc.)	Soil	TPH, BTEX, naphthalene, methylnaphthalenes (total 1- and 2-)
	Soil Gas	Same as soil plus methane
	Groundwater	Same as soil
Residual Fuels (lube oils, hydraulic oils, mineral oils, transformer oils, Fuel Oil #6/Bunker C, waste oil, etc.)	Soil	TPH, *VOCs, naphthalene, methylnaphthalenes plus remaining 15 priority pollutant PAHs, plus PCBs and heavy metals unless otherwise justified
	Soil Gas	TPH, VOCs, naphthalene, methylnaphthalenes, methane
	Groundwater	same as soil

*VOC: Volatile Organic Compounds, including BTEX and chlorinated solvent compounds

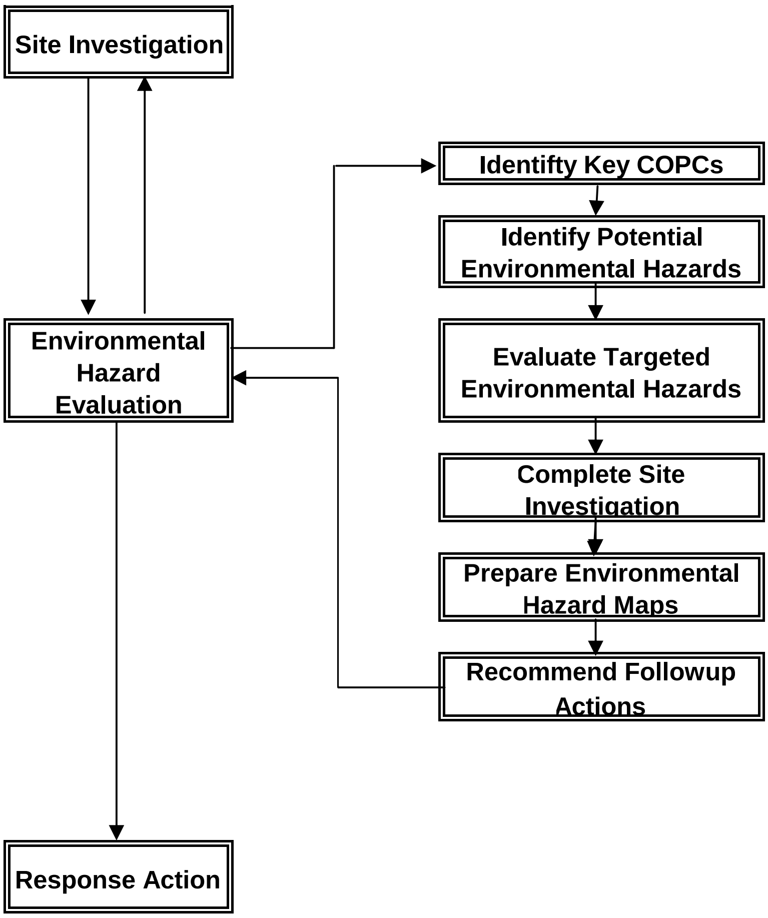


Figure 3-1. Overview of the Environmental Hazard Evaluation process.

Tier 1 Environmental Screening Levels Surfer

Pacific Basin Edition
(Guam EPA Summer 2008)

Steps 1 and 2:
Click in cell and use pull-down boxes to make selection.

STEP 1: Select Site Scenario:

Land Use:	Residential
Depth of Impacted Soil:	Shallow Soil
Groundwater Utility:	Drinking Water Resource

STEP 2: Select Contaminant

BENZENE

STEP 3 (optional): Enter site data.
(Potential environmental concerns highlighted in Red on Detailed ESL worksheet.)

Soil (mg/kg):	5.1
Groundwater (ug/L):	150

Final Tier 1 ESLs

Soil (mg/kg):	2.2E-01	X
Groundwater (ug/L):	5.0E+00	X

(Refer to detailed screening levels in next worksheet for origin of Final ESLs.)

ESLs exceeded. Refer to detailed ESLs to indentify potential environmental concerns and determine need for addition action.

Notes

Potential for natural attenuation (biodegradation, etc.) not considered for leaching and groundwater protection concerns. Use batch tests and site-specific models and/or groundwater monitoring to evaluate leaching concerns as needed (see Chapter 4).

Figure 3-2a. Printout of ESL Surfer input page, using benzene at noted concentrations in soil and groundwater as an example.

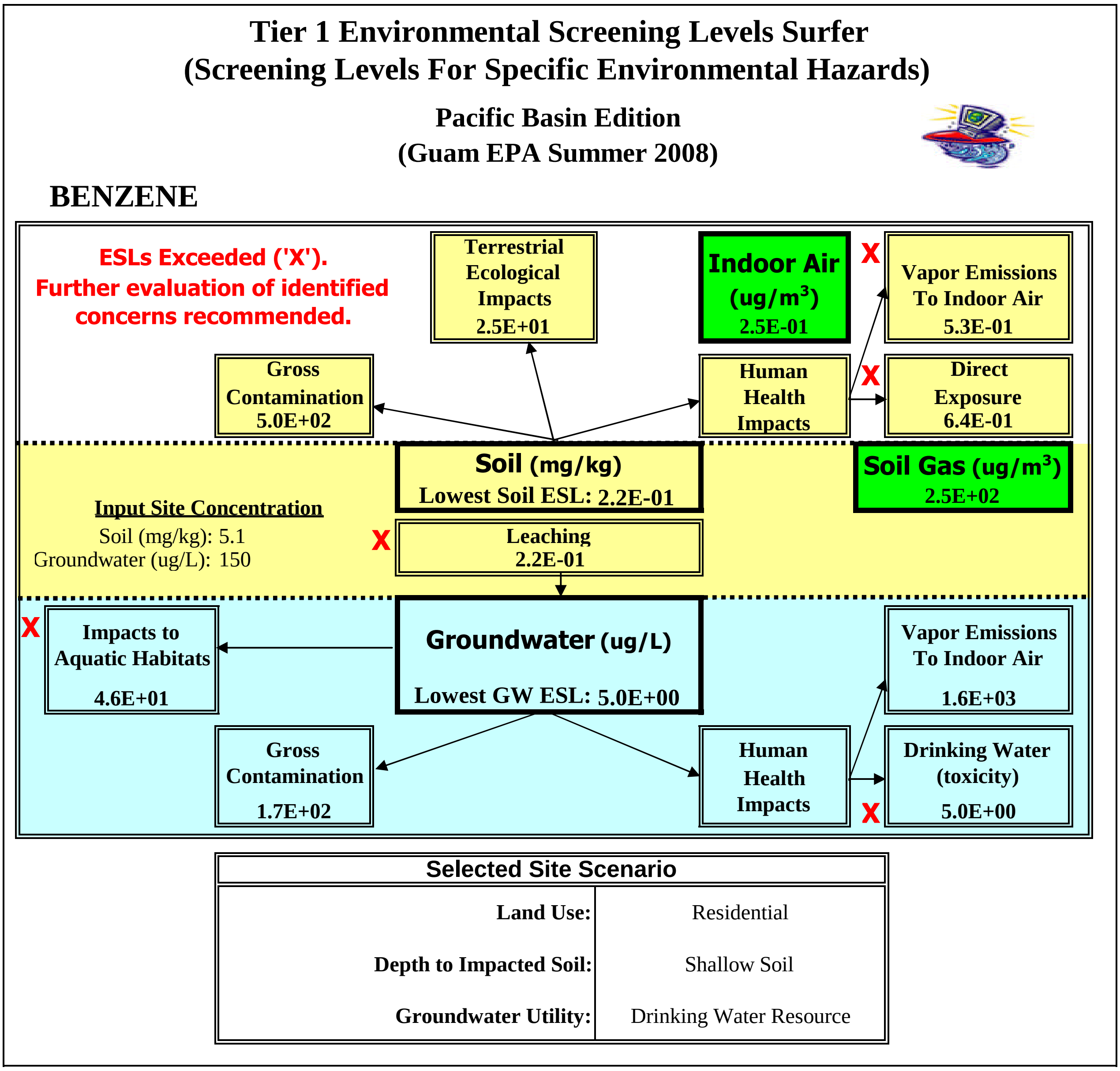


Figure 3-2b. Printout of ESL Surfer detailed environmental hazard identification page, using benzene at noted concentrations in soil and groundwater as an example.

Tier 1 ENVIRONMENTAL HAZARD EVALUATION SUMMARY REPORT

Pacific Basin Edition (Guam EPA Summer 2008)

Site Name:	Example
Site Address:	
Site ID Number:	
Date of ESL Search:	

Selected Site Scenario

Land Use:	Residential
Depth to Impacted Soil:	Shallow Soil
Groundwater Utility:	Drinking Water Resource

Selected Chemical of Concern:	**BENZENE**

Input Site Concentrations:

Soil (mg/kg):	5.1
Groundwater (ug/L):	150

Soil Tier 1 ESLS:	**Units**	**ESL**	**Tier 1 ESL Exceeded?**	**Referenced Table**
Direct Exposure:	mg/kg	6.4E-01	Yes	Table A-1:
Vapor Emissions To Indoor Air:	mg/kg	5.3E-01	Yes	
Terrestrial Ecotoxicity:	mg/kg	2.5E+01	No	
Gross Contamination:	mg/kg	5.0E+02	No	
Groundwater Protection (Leaching):	mg/kg	2.2E-01	Yes	
Lowest Soil ESL:	**mg/kg**	**2.2E-01**		
Basis: Groundwater Protection (Leaching)				

Groundwater Tier 1 ESLs:	**Units**	**ESL**		**Referenced Table**
Drinking Water (Toxicity):	ug/L	5.0E+00	Yes	Table F-1a
Vapor Emissions To Indoor Air:	ug/L	1.6E+03	No	
Aquatic Ecotoxicity:	ug/L	4.6E+01	Yes	
Gross Contamination:	ug/L	1.7E+02	No	
Lowest Groundwater ESL:	**ug/L**	**5.0E+00**		
Basis: Drinking Water				

Other Tier 1 ESLs:	**Units**	**ESL**	**Referenced Table**
Indoor Air:	ug/m^3	2.5E-01	Table E-3
Shallow Soil Gas:	ug/m^3	2.5E+02	TableE-2

Figure 3-2c. Printout of ESL Surfer summary report, using benzene at noted concentrations in soil and groundwater as an example. This page can be printed and included in the appendices of the Environmental Hazard Evaluation report. (Referenced table from Appendix 1.)

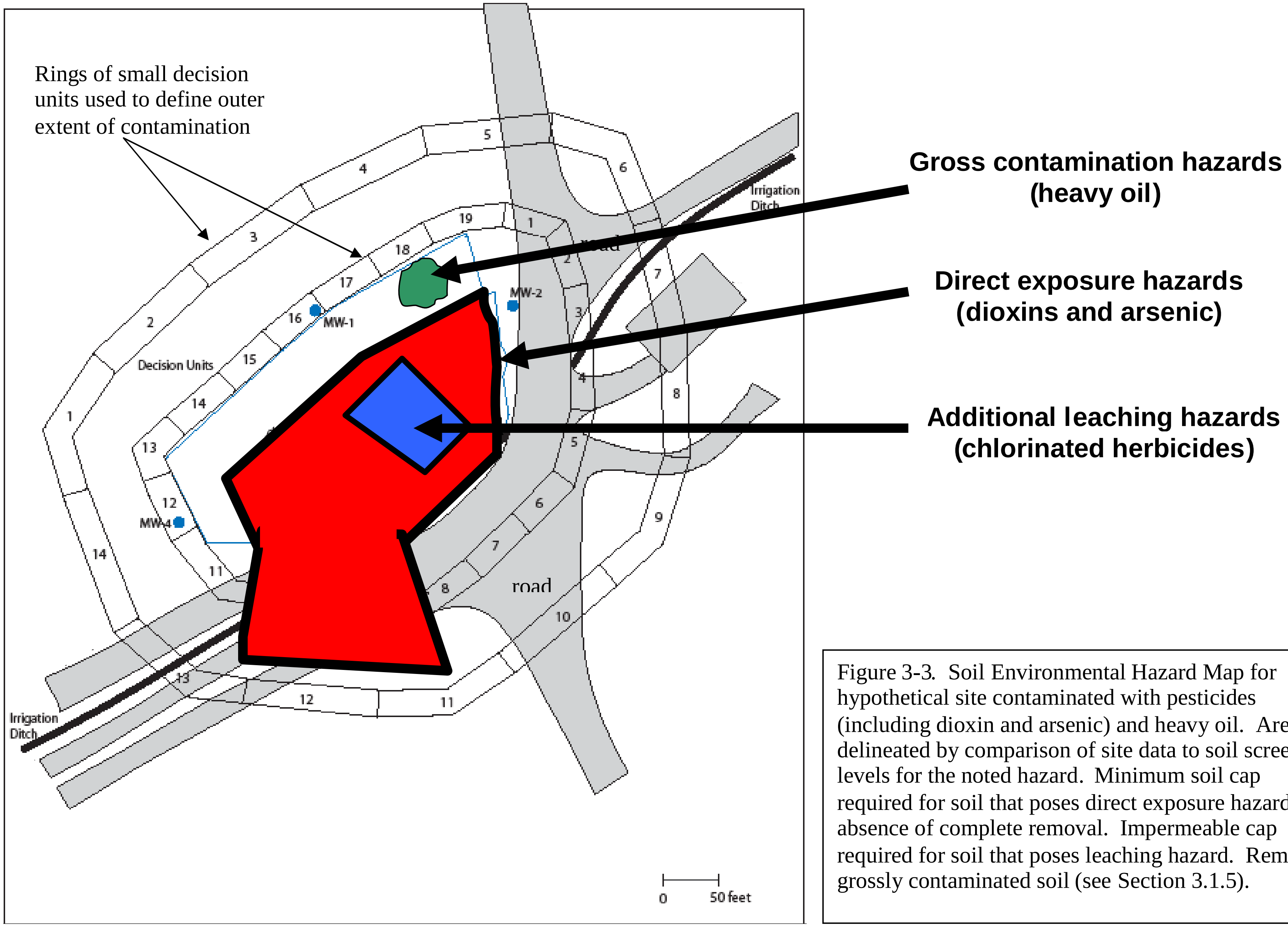


Figure 3-3. Soil Environmental Hazard Map for hypothetical site contaminated with pesticides (including dioxin and arsenic) and heavy oil. Areas delineated by comparison of site data to soil screening levels for the noted hazard. Minimum soil cap required for soil that poses direct exposure hazard in absence of complete removal. Impermeable cap required for soil that poses leaching hazard. Remove grossly contaminated soil (see Section 3.1.5).

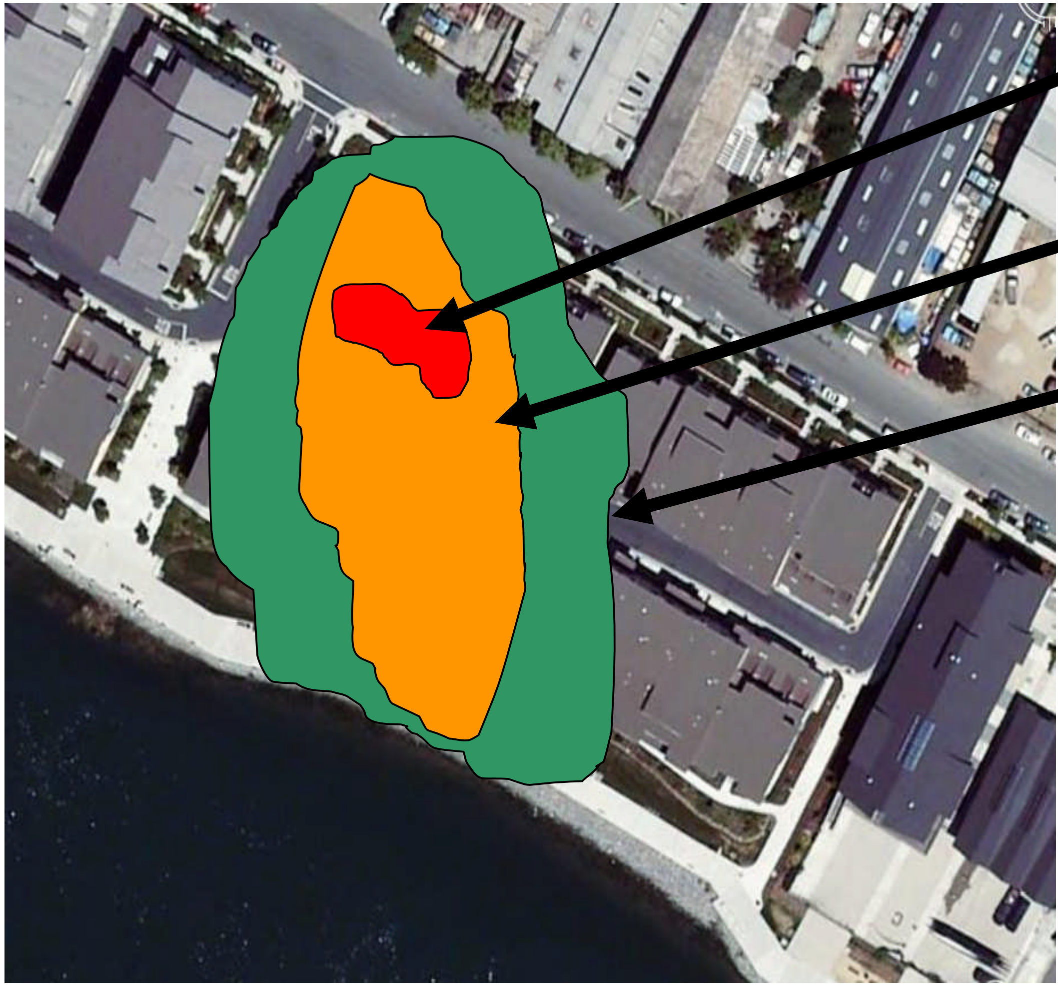


Figure 3-4. Groundwater Environmental Hazard Map for hypothetical site contaminated with petroleum. Areas delineated by comparison of site data to soil screening levels for the noted hazard. Aggressive remediation should focus on removal of vapor intrusion hazard so property can be redeveloped. Aggressive remediation of groundwater that poses acute aquatic toxicity hazards and gross contamination (odors, sheens) within 50 meters of the shoreline also recommended. Long-term monitoring of remaining groundwater contamination required (see Section 3.1.5).

	Key Questions	[1,2]Common Environmental Hazards Posed by Contaminated Soil Direct Exposure	Vapor Emissions to Indoor Air	Terrestrial Ecological Impacts	Gross Contamination	Leaching to Groundwater
PRE-RESPONSE	Before this response action, [3]**under unrestricted use** of the property, could the release have posed this environmental hazard?					
	Before this response action, [4]**under current conditions,** did the release pose this environmental hazard?					
	If the answer to the first question is YES and the second question is NO, then describe the **existing conditions prior to this response action** that provide controls for this hazard.					
RESPONSE ACTIONS	Describe the cleanup methods used in this response action that addressed this hazard:					
POST-RESPONSE	After this response action, [3]**under unrestricted use,** could the release pose this environmental hazard?					
	If the answer to the above is YES, then describe the **engineering controls and institutional controls** used to provide controls for this hazard:					

Figure 3.5a. Example format for summary of environmental hazards posed by contaminated soil under current and unrestricted site conditions before and after response actions.

	Key Questions	[1,2]Common Environmental Hazards Posed by Contaminated Groundwater			
		Drinking Water Toxicity	**Vapor Emissions to Indoor Air**	**Discharge to Surface Water**	**Gross Contamination**
PRE-RESPONSE	Before this response action, [3]**under unrestricted use** of the property, could the release have posed this environmental hazard?				
	Before this response action, [4]**under current conditions,** did the release pose this environmental hazard?				
	If the answer to the first question is YES and the second question is NO, then describe the **existing conditions prior to this response action** that provide controls for this hazard.				
RESPONSE ACTIONS	Describe the cleanup methods used in this response action that addressed this hazard:				
POST-RESPONSE	After this response action, [3]**under unrestricted use,** could the release pose this environmental hazard?				
	If the answer to the above is YES, then describe the **engineering controls and institutional controls** used to provide controls for this hazard:				

Figure 3.5b. Example format for summary of environmental hazards posed by contaminated groundwater under current and unrestricted site conditions before and after response actions.

Figure 3-5 notes

1. Refer to Section 1.2 and Figure 1-2 for summary of common environmental hazards posed by contaminated soil and groundwater
2. Compare representative site data for targeted contaminants to Environmental Screening Levels (ESLs, or equivalent) for the noted environmental hazard.
3. Unrestricted site conditions: Assumes an absence of current and/or future controls to prevent disturbance of contaminated soil or groundwater or the migration of contaminants into indoor air or nearby bodies of surface water (e.g., caps, vapor mitigation systems, land use restrictions, etc.).
4. Takes into account the presence of existing caps, lack of buildings threatened by vapor emissions, restrictions on land use, absence of water supply wells, monitoring data that indicate groundwater plumes are not migrating or expanding and threatening offsite wells or surface water bodies, etc.

Figure 4-1a. Example approaches to advanced evaluation of environmental hazards associated with contaminated soil.

Environmental Hazard	Example Site-Specific Evaluation Approaches
Direct Exposure	• Use of multi-increment sample data to evaluate direct exposure concerns in targeted decision units. • Use of Tier 2 Direct Exposure Spreadsheet to calculate alternative screening levels. • Use of laboratory bioaccessibility tests to better evaluate arsenic toxicity. • Preparation of a site-specific human health risk assessment that considers engineered and institutional controls to eliminate or minimize exposure pathways, alternative exposure assumptions, alternative target risks, etc.
Vapor Intrusion	• Collection of soil gas data to better evaluate vapor intrusion or explosive hazards. • Preparation of site-specific vapor intrusion model.
Leaching	• Collection of groundwater data. • Use of laboratory batch test model to evaluate contaminant mobility and estimate concentrations in source area leachate.
Impacts to Terrestrial Habitats	• Field inspection to determine the presence or absence of potentially significant, terrestrial ecological habits. • Preparation of a detailed, ecological risk assessment.
Gross Contamination	• Field inspection of petroleum-contaminated soil to evaluate potential gross contamination concerns (especially in existing or planned residential areas).

Figure 4-1b. Example approaches to advanced evaluation of environmental hazards associated with contaminated groundwater.

Environmental Hazard	Example Site-Specific Evaluation Approaches
Contamination of Drinking Water Resources (toxicity and/or taste & odor hazards)	• Identification and monitoring of nearby, groundwater supply wells and guard wells. • Long-term monitoring of groundwater to evaluate plume migration potential. • Use of groundwater plume fate & transport models in combination with long-term monitoring to evaluate plume migration potential.
Vapor Intrusion	• Collection of soil gas data to better evaluate vapor intrusion or explosion hazards. • Preparation of site-specific vapor intrusion model.
Impacts to Aquatic Habitats	• Use of groundwater data to evaluate plume expansion and migration over time. • Use of fate and transport models to predict long-term migration potential of groundwater contaminant plumes.
Gross Contamination	• Check groundwater for free product. • Check discharge areas for sheen and other gross contamination concerns.

TIER 2 DIRECT-EXPOSURE RISK ASSESSMENT MODEL

Pacific Basin Edition (Guam EPA Summer 2008)

Calculates Tier 2 direct-exposure action levels for soil. Assumes exposure by ingestion, inhalation and dermal contact. Addresses mass-balance issues for volatile chemicals by accounting for thickness of contaminated soil (nonvolatile chemicals not affected). Does not address potential vapor intrusion concerns, nuisance concerns, leaching concerns or ecological concerns. Use default values in absence of site-specific data.

(Steps 1 through 3 - Use pull-down boxes to select options.)

Step 1. Select Contaminant:	BENZENE
Step 2. Select Exposure Scenario:	Residential/Sensitive Land Use

Step 3. Input Site Data:	***Tier 1 Default**	**Site-Specific**
Thickness impacted soil (m)	infinite	1,000.0
Soil density (g/cm^3)	1.50	1.50
Particle density (g/cm^3)	2.65	2.65
Soil moisture content (ml/g)	0.10	0.10
Fraction organic carbon in soil	0.006	0.006

*Default site parameter values from USEPA Region IX PRGs (USEPA 2004).

Step 4. *Adjust Default Exposure Assumptions (see attached worksheet)

*Generally not recommended in a Tier 2 assessment. Includes Tier 1 chemical toxicity factors.

***Tier 2 Direct Exposure Action Levels**

BENZENE

		(mg/kg)
Residential/Sensitive Land Use	Cancer Concerns:	6.4E-01
	Noncancer Concerns:	6.5E+00
	Tier 2 Direct Exposure Action Level:	**6.4E-01**
****Construction/Trench Workers**	Cancer Concerns:	5.9E+02
	Noncancer Concerns:	2.7E+02
	Tier 2 Direct Exposure Action Level:	**2.7E+02**

**Construction/Trench worker action levels take precedence over residential or commercial/industial action levels if lower.

PROJECT NAME: ______________________ Guam EPA Site ID No.: __________

SPREADSHEET PREPARED BY: ______________________ DATE: __________

SIGNATURE: ______________________

COMPANY: ______________________

SUPPORTING SITE INVESTIGATION REPORT(S) (Note report title, date, and preparer's name and address):

Figure 4-2. Primary input page of Tier2 Direct Exposure Model for site-specific calculation of soil screening levels for direct exposure to contaminants in soil. Exposure assumptions and target risks can be modified in a second worksheet as warranted. All modifications to default site characteristics and exposure assumptions must be discussed and supported in the text of the Environmental Hazard Evaluation report.

Figure 4-3a. Arsenic Tier 2 action levels, soil categories and recommended actions for sites with unrestricted ("residential") land use.

Total Arsenic (≤ 2 mm size fraction)	**Action**
≤20 mg/kg	Within range of natural background. No further action required and no restrictions on land use.
>20 mg/kg	Exceeds typical background. Re-evaluate local background data as available. Test soil for bioaccessible arsenic if background is potentially exceeded.
Bioaccessible Arsenic (≤250µm size fraction)	**Action**
R-1 Soils (≤4.2 mg/kg)	No further action required and no restrictions on land use.
R-2 Soils (>4.2 but ≤23 mg/kg)	Within USEPA range of acceptable health risk. Consider removal and offsite disposal of localized spill areas when possible in order to reduce potential exposure (not required for large, former field areas). Use of soil as interim (long-term) cover at a regulated landfill may also be possible. For existing homes, consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). For new developments on large, former field areas, notify future homeowners of elevated levels of arsenic on the property (e.g., include in information provided to potential buyers during property transactions).

Figure 4-3a (cont.). Arsenic Tier 2 action levels, soil categories and recommended actions for sites with unrestricted ("residential") land use.

<table>
<tr>
<td>R-3 Soils
(>23 mg/kg)</td>
<td>For existing homes, removal or onsite isolation of exposed soil is strongly recommended. Consider a minimum 30cm (one foot) cover of clean fill material (60cm or two feet in potential garden areas) if soil cannot be removed. An easily identifiable marker barrier should be placed between the contaminated soil and the overlying fill (e.g., orange construction fencing or geotextile/geonet material). In the interim, take measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). Children should avoid areas of bare soil and regular work in gardens areas.

For new residential developments, removal and offsite disposal of soil should be strongly considered. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers). Use of soil as daily cover at a regulated landfill may be possible if concentrations of bioaccessible arsenic meet C-2 commercial/industrial soil criteria.

If offsite disposal is not feasible but redevelopment of the property is still desired, consider use of soil as structural fill under public buildings, parking lots, private roads, or other paved and well-controlled structures. If capping in open areas is unavoidable, consider a 30cm (one foot) minimum cap thickness with an easily definable marker barrier placed between the soil and the overlying clean fill (e.g., orange construction fencing or geotextile fabric). Capping of R-3 soils on newly developed, private lots is not recommended due to difficulties in ensuring long-term management of the soil. Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of the soil in the future.

Require formal, long-term institutional controls to ensure appropriate management of soil in the future (e.g., Covenants, Conditions and Restrictions (CC&Rs), deed covenants, risk management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.</td>
</tr>
</table>

Figure 4-3b. Tier Arsenic Tier 2 action levels, soil categories and recommended actions at sites restricted to commercial/industrial land use only.

Total Arsenic (≤ 2 mm size fraction)	**Action**
≤20 mg/kg	Within range of natural background. No further action required and no restrictions on land use.
>20 mg/kg	Exceeds typical background. Re-evaluate local background data as available. Test soil for bioaccessible arsenic if background is potentially exceeded.
Bioaccessible Arsenic (≤250μm size fraction)	**Action**
C-1 Soils (>4.2 mg/kg but ≤19 mg/kg)	No remedial action required. However, consider remediation of commercial/industrial properties to meet Residential R-1 (preferred) or R-2 screening levels when feasible in order to minimize restrictions on future land use. Note that this may require a more detailed sampling strategy than typically needed for commercial/industrial properties (e.g., smaller decision units). Require formal, long-term institutional controls to restrict use of property to commercial/industrial purposes if the site will not be investigated to the level of detail required for future, unrestricted land use (i.e., inform potential buyers, deed covenants, risk management plans, etc.).
C-2 Soils (>19 but ≤95 mg/kg)	Within USEPA range of acceptable health risk. Remedial actions vary depending on site-specific factors, including current and planned use, available options for onsite isolation or offsite disposal, and technical and economical constraints (see text). Potential actions include: Consider removal and offsite disposal of small, easily identifiable "hot spots" when possible in order to reduce the average concentration of bioaccessible arsenic on the property. Use of C-2 soils as daily cover at a regulated landfill may also be possible. For sites that have already been developed, consider a minimum 30cm (one foot) cover of clean fill material if the soil cannot be removed (15cm or six inches minimum interim fill). If capping of soil is not feasible, consider measures to reduce daily exposure to soil (e.g., maintain lawns, ensure good hygiene, etc.). For new developments, consider isolation of soil under buildings, private roads or other permanent structures if technically and economically feasible. If isolation under permanent structures is not feasible, consider a minimum 30cm (one foot) cover of clean fill material. Maintain landscaping and lawns in open areas where soil will not be capped. Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of contaminated soil in the future. Require formal, long-term institutional controls to restrict use of site to commercial/industrial purposes only and ensure appropriate management of soil if exposed in the future (e.g., inform potential buyers, deed covenants, risk

Figure 4-3b (cont). Tier Arsenic Tier 2 action levels, soil categories and recommended actions at sites restricted to commercial/industrial land use only.

	management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.
C-3 Soils (>95 mg/kg)	Removal of soil at existing commercial/industrial sites strongly recommended. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers). If C-3 soils cannot be removed for technical or economic reasons, consider a minimum 30 cm (one-foot) cover of clean fill material (60 cm or two feet in potential deep landscaping areas) and placement of an easily identifiable marker barrier between the clean fill and the underlying soil (e.g., orange construction fencing or geotextile/geonet material). For new developments, removal and offsite disposal of soil should be strongly considered. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure screening level for construction and trench workers). If offsite disposal is not feasible but redevelopment of the property is still desired, consider use of soil as structural fill under public buildings, private roads, or other paved and well-controlled structures. If capping in open areas is unavoidable, consider a one-foot minimum cap thickness with an easily definable marker barrier placed between the soil and the overlying clean fill (e.g., orange construction fencing or geotextile/geonet material). Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of contaminated soil in the future. Require formal, long-term institutional controls to ensure appropriate management of soil in the future (e.g., inform potential buyers, deed covenants, risk management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.

Figure 4-4a. TEQ dioxins Tier 2 action levels, soil categories and recommended actions for sites with unrestricted ("residential") land use.

Dioxins (TEQ)	Action
R-1 **≤42 ng/kg**	No further action required.
R-2 **>42 but ≤450 ng/kg**	Within USEPA range of acceptable health risk. Consider removal and offsite disposal of localized spill areas when possible in order to reduce potential exposure (not required for large, former field areas). Use of soil as interim (long-term) cover at a regulated landfill may also be possible. For existing homes, consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). For new developments on large, former field areas, notify future homeowners of elevated levels of dioxin on the property (e.g., include in information provided to potential buyers during property transactions).
R-3 **>450 ng/kg**	Residential use not recommended in absence of remedial actions to reduce potential exposure. Refer to actions recommended for arsenic contaminated soils that fall within the R-3 residential soil category (Figure 4-3a).

*Updated to reflect dioxin toxicity factors in September 2008 USEPA RSLs (USEPA 2008a).

Figure 4-4b. TEQ dioxins Tier 2 action levels, soil categories and recommended actions at sites restricted to commercial/industrial land use only.

Dioxins (TEQ)	Action
C-1 **≤170 ng/kg**	No further action required.
C-2 **>170 but ≤1,800 ng/kg**	Within USEPA range of acceptable health risk. Remedial actions vary depending on site-specific factors, including current and planned use, available options for onsite isolation or offsite disposal, and technical and economical constraints. Refer to actions recommended for arsenic contaminated soils that fall within the C-2 commercial/industrial soil category (Figure 4-3b). Disposal of soil in a regulated landfill or use as daily fill may be limited by the Federal ban on soil with >1,000 ng/kg TEQ dioxins from landfills.
C-3 **>1,800 ng/kg**	Commercial/industrial use not recommended in absence of remedial actions to reduce potential exposure. Refer to actions recommended for dioxin contaminated soils that fall within the C-3 commercial/industrial soil category (Figure 4-3b).

*Updated to reflect dioxin toxicity factors in September 2008 USEPA RSLs (USEPA 2008a).

Figure 4-5. Technical Chlordane Tier 2 screening levels for soil (assumes no other contaminants are present above Tier 1 or Tier 2 ESLs).

Exposure Scenario	Direct Exposure (mg/kg)	[1]Leaching (mg/kg)	[2]Final Tier 2 Screening Level (mg/kg)
Unrestricted ("residential")	16	29	16
Commercial/Industrial Only	65	29	29

1. Appendix 1. See additional guidance for evaluation of soil leaching hazards in Chapter 4.
2. Lowest of direct-exposure and leaching soil screening level

Batch Test Leaching Model
(Version: April 2008)
Hawai'i Department of Health
Hazard Evaluation and Emergency Response Office

-Refer to accompanying technical memorandum for background and use of this spreadsheet (HDOH 2007).
-Spreadsheet calculates Kd desorption coefficient based on input contaminant concentration in soil and Batch Test data.
-Correlative concentration of contaminant in leachate calculated based on estimated Kd value (may differ from batch test data).
-Future impacts to groundwater estimated using simple groundwater/leachate dilution factor.
-Alternative model based on soil gas data provided in accompanying worksheet.
-Possibility of past impacts to groundwater not considered and must be evaluated separately.
-Check to ensure that this is an up-to-date version of the spreadsheet.
-Password to unprotect worksheet is "EAL" (under Tools menu).

STEPS:
1. Select chemical from pulldown list (unlisted chemicals - unprotect spreadsheet and input chemical name and chemical constants).
2. Input total contaminant concentration and SPLP (or other applicable batch test) concentration.
3. Input sample properties. Use default values if sample-specific data are not available.
4. Input Batch Test method information. Default SPLP method parameter values noted.
5. Input groundwater:leachate dilution factor (DF of 1.0 = no dilution; USEPA default = 20, USEPA 2001).
6. Input target groundwater action level for comparison to model calculation of groundwater impacts (optional).
7. Spreadsheet calculates sample-specific Kd value and dissolved-phase concentration of contaminant in saturated sample.
8. Spreadsheet calculates concentration of contaminant in groundwater following impact by leachate.

Step 1: Select Contaminant (use pulldown list)	**PERCHLORATE**

Step 2: Input Sample Data	**DEFAULT**	**INPUT**
[1]Concentration in soil sample (mg/kg)	N/A	9.2E+00
[1]Concentration in Batch Test solution (ug/L)	N/A	3.7E+02
Step 3: Input Sample Properties ([5]USEPA soil defaults noted)		
Sample density (g/cm^3)	1.50	1.50
Particle density (g/cm^3)	2.65	2.65
Fraction air-filled porosity (assume saturated soil)	0.00	0.00
Step 4: Batch Test Method Data (SPLP defaults noted)		
[2]Batch Test Solution Volume (ml):	2,000	2,000
[2]Batch Test Solution Density (g/cm^3):	1.0	1.0
[2]Batch Test Sample Weight (grams)	100	100

	DEFAULT	**INPUT**
[3]**Step 5: Input Groundwater/ Leachate Dilution Factor**	20	20
[4]**Step 6 (optional): Input Target Groundwater Concentration (ug/L)**		6.0E+00

Model Results	
[5]Kd partition Coefficient (cm^3/g):	4.9E+00
[6]Estimated Concentration in Source Area Leachate (ug/L):	1.8E+03
[7]Estimated Concentration in Groundwater (ug/L):	8.9E+01

Chemical Constants (selected from Constants worksheet)	
Kh (atm m3/mole)	0.00E+00
Kh (dimensionless)	0.00E+00
Solubility (ug/L)	2.00E+08

Kd <20. Contaminant potentially mobile in leachate for concentration and soil type tested. Soil leaching and groundwater impact concerns must be further addressed if target groundwater action level is exceeded.

Calculations:	
Sample porosity - total	0.43
Sample porosity - air-filled	0.00
Sample porosity - water-filled	0.43
Batch Test Solution Mass (grams)	2.0E+03
Batch Test Sample Mass (grams)	1.0E+02
Sample Mass:Solution Mass Ratio (gm/gm)	5.0E-02
Total Mass of Contaminant (ug)	9.2E+02
Mass Contaminant in Batch Test Solution (ug)	7.4E+02
Mass Contaminant Sorbed to Soil (ug)	1.8E+02
Concentration Sorbed (ug/kg)	1.8E+03
Batch Test Percent Solid Phase	19.6%
Batch Test Percent Dissolved Phase	80.4%
Batch Test Solid-Phase Contaminant Conc. (mg/kg)	1.8E+00
Batch Test Solution Contaminant Conc. (ug/L)	3.7E+02

Figure 4-6. Input page of Hawai'i Department of Health Soil Batch Leaching Test model (HDOH 2007b).

TABLES

TABLE A: SHALLOW SOIL (≤3M BGS) - WATER IS A CURRENT OR POTENTIAL SOURCE OF DRINKING WATER

Notes:

- Always compare final soil data for commercial/industrial sites to residential ESLs and evaluate need for formal land-use restrictions (see Section 2.7).

TABLE A. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (≤3m bgs)
Groundwater IS Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Shallow Soil [2]Unrestricted Land Use (mg/kg)	[1]Shallow Soil Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
ACENAPHTHENE	2.0E+01	2.0E+01	2.0E+01
ACENAPHTHYLENE	1.3E+01	1.3E+01	3.0E+01
ACETONE	8.6E-01	8.6E-01	1.5E+03
ALDRIN	2.9E-02	1.0E-01	4.0E-03
AMETRYN	1.1E+00	1.1E+00	1.5E+01
AMINO,2- DINITROTOLUENE,3,6-	6.5E-01	6.5E-01	3.9E+01
AMINO,4- DINITROTOLUENE,2,6-	2.5E-01	2.5E-01	1.5E+01
ANTHRACENE	2.5E+00	2.5E+00	7.3E-01
ANTIMONY	6.3E+00	4.0E+01	6.0E+00
ARSENIC	2.0E+01	2.0E+01	1.0E+01
ATRAZINE	1.1E-02	1.1E-02	2.9E-01
BARIUM	7.5E+02	1.5E+03	2.0E+03
BENZENE	3.1E-01	3.1E-01	5.0E+00
BENZO(a)ANTHRACENE	1.5E+00	1.3E+01	2.7E-02
BENZO(a)PYRENE	1.5E-01	2.1E+00	1.4E-02
BENZO(b)FLUORANTHENE	1.5E+00	1.2E+01	9.2E-02
BENZO(g,h,i)PERYLENE	2.7E+01	2.7E+01	1.0E-01
BENZO(k)FLUORANTHENE	1.5E+01	4.0E+01	4.0E-01
BERYLLIUM	4.0E+00	8.0E+00	2.7E+00
BIPHENYL, 1,1-	5.2E-01	5.2E-01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	3.1E-05	3.1E-05	1.2E-02
BIS(2-CHLOROISOPROPYL)ETHER	3.5E-03	3.5E-03	3.2E-01
BIS(2-ETHYLHEXYL)PHTHALATE	3.5E+01	1.2E+02	6.0E+00
BORON	1.0E+02	5.0E+02	7.3E+03
BROMODICHLOROMETHANE	4.2E-03	4.2E-03	2.2E-01
BROMOFORM	9.1E-01	9.1E-01	1.0E+02
BROMOMETHANE	1.8E-01	3.6E-01	8.7E+00
CADMIUM	1.2E+01	1.2E+01	2.5E-01
CARBON TETRACHLORIDE	2.7E-02	9.7E-02	5.0E+00
CHLORDANE (TECHNICAL)	1.6E+01	2.9E+01	4.0E-03
CHLOROANILINE, p-	1.5E-02	1.5E-02	1.2E+00
CHLOROBENZENE	1.6E+00	1.6E+00	2.5E+01
CHLOROETHANE	2.8E-01	2.8E-01	3.9E+00
CHLOROFORM	1.8E-02	6.3E-02	7.4E+01
CHLOROMETHANE	1.0E-01	1.0E-01	1.8E+00
CHLOROPHENOL, 2-	1.3E-02	1.3E-02	1.8E-01
CHROMIUM (Total)	6.5E+01	6.5E+01	7.4E+01
CHROMIUM III	7.5E+02	7.5E+02	7.4E+01
CHROMIUM VI	8.0E+00	8.0E+00	1.1E+01
CHRYSENE	1.4E+01	1.4E+01	3.5E-01
COBALT	4.0E+01	8.0E+01	3.0E+00
COPPER	2.3E+02	2.3E+02	3.1E+00
CYANIDE (Free)	1.0E+02	5.0E+02	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	2.0E-02	2.0E-02	6.1E-01
DALAPON	1.4E-01	1.4E-01	3.0E+02
DIBENZO(a,h)ANTHTRACENE	1.5E-01	2.1E+00	9.2E-03
DIBROMO,1,2- CHLOROPROPANE,3-	4.5E-03	4.7E-04	2.0E-01
DIBROMOCHLOROMETHANE	1.7E-03	1.7E-03	1.6E-01
DIBROMOETHANE, 1,2-	5.7E-04	5.7E-04	5.0E-02
DICHLOROBENZENE, 1,2-	8.5E-01	8.5E-01	1.0E+01
DICHLOROBENZENE, 1,3-	7.4E+00	7.4E+00	6.5E+01
DICHLOROBENZENE, 1,4-	3.7E-02	1.3E-01	5.0E+00
DICHLOROBENZIDINE, 3,3-	1.9E-01	1.9E-01	1.5E-01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.0E+00	7.2E+00	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.4E+00	4.0E+00	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.7E+00	4.0E+00	1.0E-03
DICHLOROETHANE, 1,1-	9.8E-02	9.8E-02	2.4E+00
DICHLOROETHANE, 1,2-	1.6E-02	5.6E-02	5.0E+00

TABLE A. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (≤3m bgs)
Groundwater IS Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Shallow Soil [2]Unrestricted Land Use (mg/kg)	[1]Shallow Soil Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
DICHLOROETHYLENE, 1,1-	1.2E+00	1.2E+00	7.0E+00
DICHLOROETHYLENE, Cis 1,2-	1.2E+00	2.3E+00	7.0E+01
DICHLOROETHYLENE, Trans 1,2-	2.1E+00	6.2E+00	1.0E+02
DICHLOROPHENOL, 2,4-	3.6E-02	3.6E-02	3.0E-01
DICHLOROPHENOXYACETIC ACID (2,4-D)	2.0E-01	2.0E-01	4.0E+01
DICHLOROPROPANE, 1,2-	4.1E-02	1.5E-01	5.0E+00
DICHLOROPROPENE, 1,3-	1.6E-02	1.6E-02	4.3E-01
DIELDRIN	3.3E-03	3.3E-03	1.9E-03
DIETHYLPHTHALATE	3.1E-02	3.1E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	1.3E+01	1.3E+01	1.1E+02
DIMETHYLPHTHALATE	3.5E-02	3.5E-02	1.5E+00
DINITROBENZENE, 1,3-	1.3E-01	1.3E-01	3.7E+00
DINITROPHENOL, 2,4-	4.4E+00	4.4E+00	7.3E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	2.7E+00	2.7E+00	4.4E+01
DINITROTOLUENE, 2,6- (2,6-DNT)	2.3E+00	2.3E+00	3.7E+01
DIOXANE, 1,4-	1.2E-03	1.2E-03	6.1E+00
DIOXIN (2,3,7,8-TCDD)	4.5E-06	1.8E-05	3.0E-08
DIURON	1.4E+00	1.4E+00	6.0E+01
ENDOSULFAN	3.2E-02	3.2E-02	8.7E-03
ENDRIN	4.0E-03	4.0E-03	2.3E-03
ETHANOL	4.5E+00	4.5E+00	5.0E+04
ETHYLBENZENE	1.6E+00	4.0E+00	3.0E+01
FLUORANTHENE	4.0E+01	4.0E+01	8.0E+00
FLUORENE	7.3E+00	7.3E+00	3.9E+00
GLYPHOSATE	2.0E-01	2.0E-01	6.5E+01
HEPTACHLOR	1.1E-01	3.8E-01	3.6E-03
HEPTACHLOR EPOXIDE	3.1E-03	3.1E-03	3.6E-03
HEXACHLOROBENZENE	3.0E-01	5.7E-01	1.0E+00
HEXACHLOROBUTADIENE	2.0E-01	2.0E-01	8.6E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.5E-02	4.5E-02	8.0E-02
HEXACHLOROETHANE	3.0E-01	3.0E-01	4.8E+00
HEXAZINONE	1.2E+02	1.2E+02	1.2E+03
INDENO(1,2,3-cd)PYRENE	1.5E+00	2.1E+01	9.2E-02
ISOPHORONE	6.9E-01	6.9E-01	7.1E+01
LEAD	2.0E+02	8.0E+02	2.5E+00
MERCURY	4.7E+00	1.0E+01	7.7E-01
METHOXYCHLOR	2.6E+01	2.6E+01	1.9E-02
METHYL ETHYL KETONE	6.9E+00	6.9E+00	7.1E+03
METHYL ISOBUTYL KETONE	4.5E-01	4.5E-01	1.7E+02
METHYL MERCURY	1.6E+00	1.0E+01	3.0E-03
METHYL TERT BUTYL ETHER	2.3E-02	2.3E-02	5.0E+00
METHYLENE CHLORIDE	1.1E-01	1.1E-01	4.8E+00
METHYLNAPHTHALENE, 1-	1.1E+00	1.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	1.0E+00	1.0E+00	2.1E+00
MOLYBDENUM	4.0E+01	4.0E+01	1.8E+02
NAPHTHALENE	4.6E-01	1.9E+00	1.7E+01
NICKEL	1.5E+02	1.5E+02	8.2E+00
NITROBENZENE	1.1E-01	1.1E-01	3.4E+00
NITROGLYCERIN	7.9E-02	7.9E-02	3.7E+00
NITROTOLUENE, 2-	3.2E-03	3.2E-03	6.2E-02
NITROTOLUENE, 3-	6.7E+00	6.7E+00	1.2E+02
NITROTOLUENE, 4-	2.2E-01	2.2E-01	4.2E+00
PENTACHLOROPHENOL	5.6E-01	5.6E-01	1.0E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	1.5E-02	1.5E-02	6.1E-01

TABLE A. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (≤3m bgs)
Groundwater IS Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Shallow Soil: [2]Unrestricted Land Use (mg/kg)	[1]Shallow Soil: Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
PERCHLORATE	7.0E-03	7.0E-03	2.6E+01
PHENANTHRENE	1.1E+01	1.1E+01	4.6E+00
PHENOL	2.2E-01	2.2E-01	5.0E+00
POLYCHLORINATED BIPHENYLS (PCBs)	1.1E+00	7.4E+00	1.4E-02
PROPICONAZOLE	2.4E+01	2.4E+01	2.6E+01
PYRENE	5.6E+01	5.6E+01	2.0E+00
SELENIUM	1.0E+01	1.0E+01	5.0E+00
SILVER	2.0E+01	4.0E+01	1.9E-01
SIMAZINE	1.4E-02	1.4E-02	5.6E-01
STYRENE	1.0E+00	1.0E+00	1.0E+01
TERBACIL	6.1E+00	6.1E+00	4.7E+02
tert-BUTYL ALCOHOL	2.8E-02	2.8E-02	4.5E+00
TETRACHLOROETHANE, 1,1,1,2-	1.6E-02	1.6E-02	5.2E-01
TETRACHLOROETHANE, 1,1,2,2-	1.3E-03	1.3E-03	6.7E-02
TETRACHLOROETHYLENE	7.0E-02	2.5E-01	5.0E+00
TETRACHLOROPHENOL, 2,3,4,6-	4.0E-01	4.0E-01	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	1.0E+02	1.0E+02	3.3E+02
THALLIUM	1.0E+00	1.3E+01	2.0E+00
TOLUENE	3.4E+00	3.4E+00	4.0E+01
TOXAPHENE	4.4E-01	1.6E+00	2.0E-04
TPH (gasolines)	1.0E+02	1.0E+02	1.0E+02
TPH (middle distillates)	1.0E+02	1.0E+02	1.0E+02
TPH (residual fuels)	5.0E+02	1.0E+03	1.0E+02
TRICHLOROBENZENE, 1,2,4-	1.5E-01	4.9E-01	2.5E+01
TRICHLOROETHANE, 1,1,1-	7.1E+00	7.1E+00	6.2E+01
TRICHLOROETHANE, 1,1,2-	2.6E-02	8.2E-02	5.0E+00
TRICHLOROETHYLENE	2.1E-01	3.6E-01	5.0E+00
TRICHLOROPHENOL, 2,4,5-	2.2E+00	2.2E+00	1.1E+01
TRICHLOROPHENOL, 2,4,6-	1.2E+00	1.2E+00	6.1E+00
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	2.9E+00	2.9E+00	3.7E+02
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	4.0E-01	4.0E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	4.6E-05	4.6E-05	1.9E-03
TRICHLOROPROPENE, 1,2,3-	4.0E-01	4.0E-01	2.2E+00
TRIFLURALIN	1.4E+01	1.4E+01	8.7E+00
TRINITROBENZENE, 1,3,5-	5.4E+00	5.4E+00	3.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	4.9E+01	5.2E+01	1.5E+02
TRINITROTOLUENE, 2,4,6- (TNT)	6.8E-01	6.8E-01	2.2E+00
VANADIUM	1.1E+02	2.0E+02	1.9E+01
VINYL CHLORIDE	4.0E-02	3.3E-01	2.0E+00
XYLENES	2.3E+00	2.3E+00	2.0E+01
ZINC	6.0E+02	6.0E+02	8.1E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	4.0	0.0E+00
Sodium Adsorption Ratio	5.0	12	0.0E+00

Notes:

1. Shallow soils defined as soils less than or equal to 3 meters (approximately 10 feet) below ground surface for residential/unrestricted land use and less than one meter (approximately three feet) for commercial/industrial sites.

2. Category "Unrestricted Land Use" generally considered adequate for residential and other sensitive uses (e.g., schools, day-care centers, hospitals, etc.)

3. Assumes potential discharge of groundwater into a freshwater, marine or estuary surface water system.

Source of soil ESLs: Refer to Appendix 1, Tables A-1 and A-2.
Source of groundwater ESLs: Refer to Appendix 1, Table F-1a.
Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).
Soil ESLs intended to address direct-exposure, groundwater protection, ecologic (urban areas) and nuisance concerns under noted land-use scenarios. **Soil gas data should be collected for additional evaluation of potential indoor-air impacts at**

TABLE A. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (≤3m bgs)
Groundwater IS Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Shallow Soil [2]Unrestricted Land Use (mg/kg)	Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)

sites with significant areas of VOC-impacted soil. See Section 2.6 and Table E.
Groundwater ESLs intended to be address drinking water, surface water, indoor-air and nuisance concerns. **Use in conjunction with soil gas screening levels to more closely evaluate potential impacts to indoor-air if groundwater screening levels for this concern approached or exceeded (refer to Section 2.6 and Appendix 1, Table F-1a).**
Aquatic habitat goals for bioaccumulation concerns not considered in selection of groundwater goals (refer to Section 2.7).
Refer to appendices for summary of ESL components.
Soil and water ESLs for ethanol based on gross contamination concerns (see Appendix 1, Chapter 5 and related tables).
TPH -Total Petroleum Hydrocarbons. TPH ESLs must be used in conjunction with ESLs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2 and Appendix 1, Chapter 5.

TABLE B: SHALLOW SOIL (≤3M BGS) - WATER IS NOT A CURRENT OR POTENTIAL SOURCE OF DRINKING WATER

Notes:

- Always compare final soil data for commercial/industrial sites to residential ESLs and evaluate need for formal land-use restrictions (see Section 2.7).
- Assumption that groundwater is not a current or potential source of drinking water should be approved by overseeing regulatory agency prior to use of this table (see Section 2.2).

TABLE B. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (<3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Shallow Soil [2]Unrestricted Land Use (mg/kg)	Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
ACENAPHTHENE	2.3E+01	2.3E+01	2.3E+01
ACENAPHTHYLENE	1.3E+01	1.3E+01	3.0E+01
ACETONE	8.6E-01	8.6E-01	1.5E+03
ALDRIN	2.9E-02	1.0E-01	1.3E-01
AMETRYN	1.1E+00	1.1E+00	1.5E+01
AMINO,2- DINITROTOLUENE,3,6-	6.5E-01	6.5E-01	3.9E+01
AMINO,4- DINITROTOLUENE,2,6-	2.5E-01	2.5E-01	1.5E+01
ANTHRACENE	2.5E+00	2.5E+00	7.3E-01
ANTIMONY	6.3E+00	4.0E+01	3.0E+01
ARSENIC	2.0E+01	2.0E+01	3.6E+01
ATRAZINE	4.6E-01	4.6E-01	1.2E+01
BARIUM	7.5E+02	1.5E+03	2.0E+03
BENZENE	5.3E-01	1.9E+00	4.6E+01
BENZO(a)ANTHRACENE	1.5E+00	1.3E+01	2.7E-02
BENZO(a)PYRENE	1.5E-01	2.1E+00	1.4E-02
BENZO(b)FLUORANTHENE	1.5E+00	1.2E+01	9.2E-02
BENZO(g,h,i)PERYLENE	2.7E+01	2.7E+01	1.0E-01
BENZO(k)FLUORANTHENE	1.5E+01	4.0E+01	4.0E-01
BERYLLIUM	4.0E+00	8.0E+00	2.7E+00
BIPHENYL, 1,1-	5.2E+00	5.2E+00	5.0E+00
BIS(2-CHLOROETHYL)ETHER	2.6E-03	1.1E-02	6.1E+01
BIS(2-CHLOROISOPROPYL)ETHER	6.6E-01	6.6E-01	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	3.5E+01	1.2E+02	3.2E+01
BORON	1.0E+02	5.0E+02	7.3E+03
BROMODICHLOROMETHANE	2.3E-02	8.2E-02	1.6E+02
BROMOFORM	2.9E+01	2.9E+01	3.2E+03
BROMOMETHANE	1.8E-01	5.2E-01	1.6E+02
CADMIUM	1.2E+01	1.2E+01	2.5E-01
CARBON TETRACHLORIDE	2.7E-02	9.7E-02	9.8E+00
CHLORDANE (TECHNICAL)	1.6E+01	2.9E+01	4.0E-03
CHLOROANILINE, p-	6.0E-02	6.0E-02	5.0E+00
CHLOROBENZENE	1.6E+00	1.6E+00	2.5E+01
CHLOROETHANE	2.8E-01	2.8E-01	3.9E+00
CHLOROFORM	1.8E-02	6.3E-02	7.4E+01
CHLOROMETHANE	2.3E-01	8.1E-01	2.9E+02
CHLOROPHENOL, 2-	1.3E-01	1.3E-01	1.8E+00
CHROMIUM (Total)	6.5E+01	6.5E+01	7.4E+01
CHROMIUM III	7.5E+02	7.5E+02	7.4E+01
CHROMIUM VI	8.0E+00	8.0E+00	1.1E+01
CHRYSENE	1.4E+01	1.4E+01	3.5E-01
COBALT	4.0E+01	8.0E+01	3.0E+00
COPPER	2.3E+02	2.3E+02	3.1E+00
CYANIDE (Free)	1.0E+02	5.0E+02	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	5.5E+00	6.2E+00	1.9E+02
DALAPON	1.4E-01	1.4E-01	3.0E+02
DIBENZO(a,h)ANTHTRACENE	1.5E-01	2.1E+00	5.2E-01
DIBROMO,1,2- CHLOROPROPANE,3-	4.5E-03	4.7E-04	2.0E-01
DIBROMOCHLOROMETHANE	1.7E-02	2.8E+00	2.7E+02
DIBROMOETHANE, 1,2-	6.9E-04	2.4E-03	1.2E+01
DICHLOROBENZENE, 1,2-	1.2E+00	1.2E+00	1.4E+01

TABLE B. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (≤3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

	[1]Shallow Soil		
CHEMICAL PARAMETER	[2]Unrestricted Land Use (mg/kg)	Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
DICHLOROBENZENE, 1,3-	7.4E+00	7.4E+00	6.5E+01
DICHLOROBENZENE, 1,4-	3.7E-02	1.3E-01	1.5E+01
DICHLOROBENZIDINE, 3,3-	1.1E+00	3.8E+00	2.5E+02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.0E+00	7.2E+00	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.4E+00	4.0E+00	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.7E+00	4.0E+00	1.0E-03
DICHLOROETHANE, 1,1-	2.6E-01	9.1E-01	4.7E+01
DICHLOROETHANE, 1,2-	1.6E-02	5.6E-02	1.2E+02
DICHLOROETHYLENE, 1,1-	4.3E+00	4.3E+00	2.5E+01
DICHLOROETHYLENE, Cis 1,2-	1.2E+00	3.6E+00	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	2.1E+00	6.2E+00	5.9E+02
DICHLOROPHENOL, 2,4-	3.6E-01	3.6E-01	3.0E+00
DICHLOROPHENOXYACETIC ACID (2,4-D)	2.0E-01	2.0E-01	4.0E+01
DICHLOROPROPANE, 1,2-	4.1E-02	1.5E-01	1.0E+02
DICHLOROPROPENE, 1,3-	1.0E-01	3.6E-01	1.2E+02
DIELDRIN	3.3E-03	3.3E-03	1.9E-03
DIETHYLPHTHALATE	3.1E-02	3.1E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	1.3E+01	1.3E+01	1.1E+02
DIMETHYLPHTHALATE	3.5E-02	3.5E-02	1.5E+00
DINITROBENZENE, 1,3-	1.1E+00	1.1E+00	3.0E+01
DINITROPHENOL, 2,4-	4.5E+00	4.5E+00	7.5E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	2.7E+00	2.7E+00	4.4E+01
DINITROTOLUENE, 2,6- (2,6-DNT)	2.7E+00	2.7E+00	4.4E+01
DIOXANE, 1,4-	9.8E+00	9.8E+00	5.0E+04
DIOXIN (2,3,7,8-TCDD)	4.5E-06	1.8E-05	5.0E-06
DIURON	1.4E+00	1.4E+00	6.0E+01
ENDOSULFAN	3.2E-02	3.2E-02	8.7E-03
ENDRIN	4.0E-03	4.0E-03	2.3E-03
ETHANOL	4.5E+00	4.5E+00	5.0E+04
ETHYLBENZENE	1.6E+00	5.8E+00	2.9E+02
FLUORANTHENE	4.0E+01	4.0E+01	8.0E+00
FLUORENE	7.3E+00	7.3E+00	3.9E+00
GLYPHOSATE	2.0E-01	2.0E-01	6.5E+01
HEPTACHLOR	1.1E-01	3.8E-01	3.6E-03
HEPTACHLOR EPOXIDE	3.1E-03	3.1E-03	3.6E-03
HEXACHLOROBENZENE	3.0E-01	1.1E+00	3.1E+00
HEXACHLOROBUTADIENE	1.1E+00	1.1E+00	4.7E+00
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.5E-02	4.5E-02	8.0E-02
HEXACHLOROETHANE	7.4E-01	7.4E-01	1.2E+01
HEXAZINONE	4.0E+02	5.1E+02	5.0E+03
INDENO(1,2,3-cd)PYRENE	1.5E+00	2.1E+01	9.2E-02
ISOPHORONE	1.3E+00	1.3E+00	1.3E+02
LEAD	2.0E+02	8.0E+02	2.5E+00
MERCURY	4.7E+00	1.0E+01	7.7E-01
METHOXYCHLOR	2.6E+01	2.6E+01	1.9E-02
METHYL ETHYL KETONE	1.4E+01	1.4E+01	1.4E+04

TABLE B. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (≤3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Shallow Soil [2]Unrestricted Land Use (mg/kg)	Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
METHYL ISOBUTYL KETONE	4.5E-01	4.5E-01	1.7E+02
METHYL MERCURY	1.6E+00	1.0E+01	3.0E-03
METHYL TERT BUTYL ETHER	1.6E+00	5.6E+00	1.8E+03
METHYLENE CHLORIDE	8.8E-01	3.1E+00	2.2E+03
METHYLNAPHTHALENE, 1-	1.1E+00	1.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	1.0E+00	1.0E+00	2.1E+00
MOLYBDENUM	4.0E+01	4.0E+01	2.4E+02
NAPHTHALENE	4.6E-01	1.9E+00	2.4E+01
NICKEL	1.5E+02	1.5E+02	8.2E+00
NITROBENZENE	1.9E+00	1.9E+00	6.0E+01
NITROGLYCERIN	1.2E+00	3.0E+00	1.4E+02
NITROTOLUENE, 2-	1.9E+00	8.8E+00	1.0E+03
NITROTOLUENE, 3-	2.1E+01	2.1E+01	3.8E+02
NITROTOLUENE, 4-	3.0E+01	8.2E+01	1.6E+03
PENTACHLOROPHENOL	3.0E+00	4.4E+00	7.9E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	4.4E+00	1.6E+01	2.2E+04
PERCHLORATE	1.2E+00	1.2E+00	6.0E+02
PHENANTHRENE	1.1E+01	1.1E+01	4.6E+00
PHENOL	4.0E+01	4.0E+01	1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	1.1E+00	7.4E+00	1.4E-02
PROPICONAZOLE	2.4E+01	2.4E+01	2.6E+01
PYRENE	5.6E+01	5.6E+01	2.0E+00
SELENIUM	1.0E+01	1.0E+01	5.0E+00
SILVER	2.0E+01	4.0E+01	1.9E-01
SIMAZINE	4.9E-02	4.9E-02	2.0E+00
STYRENE	1.0E+01	1.0E+01	1.0E+02
TERBACIL	3.0E+01	3.0E+01	2.3E+03
tert-BUTYL ALCOHOL	8.1E+01	1.1E+02	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	2.0E+00	9.9E+00	9.3E+02
TETRACHLOROETHANE, 1,1,2,2-	7.1E-03	2.5E-02	1.6E+02
TETRACHLOROETHYLENE	7.0E-02	2.5E-01	1.2E+02
TETRACHLOROPHENOL, 2,3,4,6-	4.0E-01	4.0E-01	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	1.0E+02	1.0E+02	3.3E+02
THALLIUM	1.0E+00	1.3E+01	2.0E+01
TOLUENE	1.1E+01	1.1E+01	1.3E+02
TOXAPHENE	4.4E-01	1.6E+00	2.0E-04
TPH (gasolines)	1.0E+02	4.0E+02	5.0E+02
TPH (middle distillates)	5.0E+02	5.0E+02	6.4E+02
TPH (residual fuels)	5.0E+02	1.0E+03	6.4E+02
TRICHLOROBENZENE, 1,2,4-	1.5E-01	4.9E-01	2.5E+01
TRICHLOROETHANE, 1,1,1-	7.1E+00	7.1E+00	6.2E+01
TRICHLOROETHANE, 1,1,2-	2.6E-02	9.1E-02	3.0E+02
TRICHLOROETHYLENE	2.1E-01	7.3E-01	3.6E+02
TRICHLOROPHENOL, 2,4,5-	2.2E+00	2.2E+00	1.1E+01
TRICHLOROPHENOL, 2,4,6-	1.0E+01	1.0E+01	4.9E+02
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	5.5E+00	5.5E+00	6.9E+02

TABLE B. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Shallow Soils (≤3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Shallow Soil: [2]Unrestricted Land Use (mg/kg)	[1]Shallow Soil: Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	4.0E-01	4.0E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	1.8E-02	8.7E-02	1.4E+01
TRICHLOROPROPENE, 1,2,3-	4.0E-01	4.0E-01	2.2E+00
TRIFLURALIN	3.2E+01	3.2E+01	2.0E+01
TRINITROBENZENE, 1,3,5-	5.4E+00	5.4E+00	3.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	4.9E+01	1.3E+02	3.7E+02
TRINITROTOLUENE, 2,4,6- (TNT)	7.2E+00	4.0E+01	1.3E+02
VANADIUM	1.1E+02	2.0E+02	1.9E+01
VINYL CHLORIDE	4.0E-02	3.3E-01	2.1E+01
XYLENES	1.2E+01	1.2E+01	1.0E+02
ZINC	6.0E+02	6.0E+02	8.1E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	4.0	0.0E+00
Sodium Adsorption Ratio	5.0	12	0.0E+00

Notes:

1. Shallow soils defined as soils less than or equal to 3 meters (approximately 10 feet) below ground surface for residential/unrestricted land use and less than one meter (approximately three feet) for commercial/industrial sites.

2. Category "Unrestricted Land Use" generally considered adequate for residential and other sensitive uses (e.g., schools, day-care centers, hospitals, etc.)

3. Assumes potential discharge of groundwater into marine or estuary surface water system.

Source of soil ESLs: Refer to Appendix 1, Tables A-1 and A-2.

Source of groundwater ESLs: Refer to Appendix 1, Table F-1b.

Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).

Soil ESLs intended to address direct-exposure, groundwater protection, ecologic (urban areas) and nuisance concerns under noted land-use scenarios. **Soil gas data should be collected for additional evaluation of potential indoor-air impacts at at sites with significant areas of VOC-impacted soil. See Section 2.6 and Table E.**

Groundwater ESLs intended to address surface water, indoor-air and nuisance concerns. **Use in conjunction with soil gas screening levels to more closely evaluate potential impacts to indoor-air if groundwater screening levels for this concern approached or exceeded (refer to Section 2.6 and Appendix 1, Table F-1a).**

Aquatic habitat goals for bioaccumulation concerns not considered in selection of groundwater goals (refer to Section 2.7).

Refer to appendices for summary of ESL components.

Soil and water ESLs for ethanol based on gross contamination concerns (see Appendix 1, Chapter 5 and related tables).

TPH -Total Petroleum Hydrocarbons. TPH ESLs must be used in conjunction with ESLs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2 and Appendix 1, Chapter 5.

TABLE C: DEEP SOIL (>3M BGS) - WATER <u>IS</u> A CURRENT OR POTENTIAL SOURCE OF DRINKING WATER

Notes:

- Always compare final soil data for commercial/industrial sites to residential ESLs and evaluate need for formal land-use restrictions (see Section 2.7).
- ESLs for deep soils may be applicable to soils <3m below ground surface at commercial/industrial sites provided institutional controls are put in place to maintain an adequate cap and provide proper management of soil if exposed in future (see Section 2.2 and Section 2.7).

TABLE C. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	Deep Soil[1] [2]Unrestricted Land Use (mg/kg)	Deep Soil[1] Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
ACENAPHTHENE	2.0E+01	2.0E+01	2.0E+01
ACENAPHTHYLENE	1.3E+01	1.3E+01	3.0E+01
ACETONE	8.6E-01	8.6E-01	1.5E+03
ALDRIN	8.4E+00	8.4E+00	4.0E-03
AMETRYN	1.1E+00	1.1E+00	1.5E+01
AMINO,2- DINITROTOLUENE,3,6-	6.5E-01	6.5E-01	3.9E+01
AMINO,4- DINITROTOLUENE,2,6-	2.5E-01	2.5E-01	1.5E+01
ANTHRACENE	2.5E+00	2.5E+00	7.3E-01
ANTIMONY	1.8E+02	1.8E+02	6.0E+00
ARSENIC	8.9E+01	8.9E+01	1.0E+01
ATRAZINE	1.1E-02	1.1E-02	2.9E-01
BARIUM	2.5E+03	4.3E+03	2.0E+03
BENZENE	3.1E-01	3.1E-01	5.0E+00
BENZO(a)ANTHRACENE	1.3E+01	1.3E+01	2.7E-02
BENZO(a)PYRENE	7.6E+00	7.6E+00	1.4E-02
BENZO(b)FLUORANTHENE	1.2E+01	1.2E+01	9.2E-02
BENZO(g,h,i)PERYLENE	2.7E+01	2.7E+01	1.0E-01
BENZO(k)FLUORANTHENE	5.2E+01	5.2E+01	4.0E-01
BERYLLIUM	1.5E+02	1.5E+02	2.7E+00
BIPHENYL, 1,1-	5.2E-01	5.2E-01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	3.1E-05	3.1E-05	1.2E-02
BIS(2-CHLOROISOPROPYL)ETHER	3.5E-03	3.5E-03	3.2E-01
BIS(2-ETHYLHEXYL)PHTHALATE	1.6E+02	1.6E+02	6.0E+00
BORON	5.0E+02	1.0E+03	7.3E+03
BROMODICHLOROMETHANE	4.2E-03	4.2E-03	2.2E-01
BROMOFORM	9.1E-01	9.1E-01	1.0E+02
BROMOMETHANE	1.8E-01	3.6E-01	8.7E+00
CADMIUM	3.7E+02	3.7E+02	2.5E-01
CARBON TETRACHLORIDE	2.7E-02	9.7E-02	5.0E+00
CHLORDANE (TECHNICAL)	2.9E+01	2.9E+01	4.0E-03
CHLOROANILINE, p-	1.5E-02	1.5E-02	1.2E+00
CHLOROBENZENE	1.6E+00	1.6E+00	2.5E+01
CHLOROETHANE	2.8E-01	2.8E-01	3.9E+00
CHLOROFORM	1.8E-02	6.3E-02	7.4E+01
CHLOROMETHANE	1.0E-01	1.0E-01	1.8E+00
CHLOROPHENOL, 2-	1.3E-02	1.3E-02	1.8E-01
CHROMIUM (Total)	6.5E+01	6.5E+01	7.4E+01
CHROMIUM III	2.5E+03	5.0E+03	7.4E+01
CHROMIUM VI	5.4E+01	5.4E+01	1.1E+01
CHRYSENE	1.4E+01	1.4E+01	3.5E-01
COBALT	1.8E+02	1.8E+02	3.0E+00
COPPER	2.5E+03	5.0E+03	3.1E+00
CYANIDE (Free)	5.0E+02	1.0E+03	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	2.0E-02	2.0E-02	6.1E-01
DALAPON	1.4E-01	1.4E-01	3.0E+02
DIBENZO(a,h)ANTHTRACENE	1.6E+01	1.6E+01	9.2E-03
DIBROMO,1,2- CHLOROPROPANE,3-	4.5E-03	4.7E-04	2.0E-01
DIBROMOCHLOROMETHANE	1.7E-03	1.7E-03	1.6E-01

TABLE C. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Deep Soil [2]Unrestricted Land Use (mg/kg)	[1]Deep Soil Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
DIBROMOETHANE, 1,2-	5.7E-04	5.7E-04	5.0E-02
DICHLOROBENZENE, 1,2-	8.5E-01	8.5E-01	1.0E+01
DICHLOROBENZENE, 1,3-	7.4E+00	7.4E+00	6.5E+01
DICHLOROBENZENE, 1,4-	3.7E-02	1.3E-01	5.0E+00
DICHLOROBENZIDINE, 3,3-	1.9E-01	1.9E-01	1.5E-01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.2E+01	8.2E+01	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	3.7E+01	3.7E+01	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	7.3E+00	7.3E+00	1.0E-03
DICHLOROETHANE, 1,1-	9.8E-02	9.8E-02	2.4E+00
DICHLOROETHANE, 1,2-	1.6E-02	5.6E-02	5.0E+00
DICHLOROETHYLENE, 1,1-	1.2E+00	1.2E+00	7.0E+00
DICHLOROETHYLENE, Cis 1,2-	1.2E+00	2.3E+00	7.0E+01
DICHLOROETHYLENE, Trans 1,2-	2.1E+00	6.2E+00	1.0E+02
DICHLOROPHENOL, 2,4-	3.6E-02	3.6E-02	3.0E-01
DICHLOROPHENOXYACETIC ACID (2,4-D)	2.0E-01	2.0E-01	4.0E+01
DICHLOROPROPANE, 1,2-	4.1E-02	1.5E-01	5.0E+00
DICHLOROPROPENE, 1,3-	1.6E-02	1.6E-02	4.3E-01
DIELDRIN	3.3E-03	3.3E-03	1.9E-03
DIETHYLPHTHALATE	3.1E-02	3.1E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	1.3E+01	1.3E+01	1.1E+02
DIMETHYLPHTHALATE	3.5E-02	3.5E-02	1.5E+00
DINITROBENZENE, 1,3-	1.3E-01	1.3E-01	3.7E+00
DINITROPHENOL, 2,4-	4.4E+00	4.4E+00	7.3E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	2.7E+00	2.7E+00	4.4E+01
DINITROTOLUENE, 2,6- (2,6-DNT)	2.3E+00	2.3E+00	3.7E+01
DIOXANE, 1,4-	1.2E-03	1.2E-03	6.1E+00
DIOXIN (2,3,7,8-TCDD)	1.5E-03	1.5E-03	3.0E-08
DIURON	1.4E+00	1.4E+00	6.0E+01
ENDOSULFAN	3.2E-02	3.2E-02	8.7E-03
ENDRIN	4.0E-03	4.0E-03	2.3E-03
ETHANOL	4.5E+00	4.5E+00	5.0E+04
ETHYLBENZENE	1.6E+00	4.0E+00	3.0E+01
FLUORANTHENE	1.1E+02	1.1E+02	8.0E+00
FLUORENE	7.3E+00	7.3E+00	3.9E+00
GLYPHOSATE	2.0E-01	2.0E-01	6.5E+01
HEPTACHLOR	3.2E+01	3.2E+01	3.6E-03
HEPTACHLOR EPOXIDE	3.1E-03	3.1E-03	3.6E-03
HEXACHLOROBENZENE	5.7E-01	5.7E-01	1.0E+00
HEXACHLOROBUTADIENE	2.0E-01	2.0E-01	8.6E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.5E-02	4.5E-02	8.0E-02
HEXACHLOROETHANE	3.0E-01	3.0E-01	4.8E+00
HEXAZINONE	1.2E+02	1.2E+02	1.2E+03
INDENO(1,2,3-cd)PYRENE	4.1E+01	4.1E+01	9.2E-02
ISOPHORONE	6.9E-01	6.9E-01	7.1E+01
LEAD	8.0E+02	8.0E+02	2.5E+00
MERCURY	1.3E+02	1.3E+02	7.7E-01
METHOXYCHLOR	2.6E+01	2.6E+01	1.9E-02

TABLE C. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS a Current or Potential Source of Drinking Water

	[1]Deep Soil		
CHEMICAL PARAMETER	[2]Unrestricted Land Use (mg/kg)	Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
METHYL ETHYL KETONE	6.9E+00	6.9E+00	7.1E+03
METHYL ISOBUTYL KETONE	4.5E-01	4.5E-01	1.7E+02
METHYL MERCURY	4.4E+01	4.4E+01	3.0E-03
METHYL TERT BUTYL ETHER	2.3E-02	2.3E-02	5.0E+00
METHYLENE CHLORIDE	1.1E-01	1.1E-01	4.8E+00
METHYLNAPHTHALENE, 1-	1.1E+00	1.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	1.0E+00	1.0E+00	2.1E+00
MOLYBDENUM	2.2E+03	2.2E+03	1.8E+02
NAPHTHALENE	4.6E-01	1.9E+00	1.7E+01
NICKEL	2.5E+03	5.0E+03	8.2E+00
NITROBENZENE	1.1E-01	1.1E-01	3.4E+00
NITROGLYCERIN	7.9E-02	7.9E-02	3.7E+00
NITROTOLUENE, 2-	3.2E-03	3.2E-03	6.2E-02
NITROTOLUENE, 3-	6.7E+00	6.7E+00	1.2E+02
NITROTOLUENE, 4-	2.2E-01	2.2E-01	4.2E+00
PENTACHLOROPHENOL	5.6E-01	5.6E-01	1.0E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	1.5E-02	1.5E-02	6.1E-01
PERCHLORATE	7.0E-03	7.0E-03	2.6E+01
PHENANTHRENE	1.1E+01	1.1E+01	4.6E+00
PHENOL	2.2E-01	2.2E-01	5.0E+00
POLYCHLORINATED BIPHENYLS (PCBs)	1.5E+01	1.5E+01	1.4E-02
PROPICONAZOLE	2.4E+01	2.4E+01	2.6E+01
PYRENE	5.6E+01	5.6E+01	2.0E+00
SELENIUM	2.2E+03	2.2E+03	5.0E+00
SILVER	2.2E+03	2.2E+03	1.9E-01
SIMAZINE	1.4E-02	1.4E-02	5.6E-01
STYRENE	1.0E+00	1.0E+00	1.0E+01
TERBACIL	6.1E+00	6.1E+00	4.7E+02
tert-BUTYL ALCOHOL	2.8E-02	2.8E-02	4.5E+00
TETRACHLOROETHANE, 1,1,1,2-	1.6E-02	1.6E-02	5.2E-01
TETRACHLOROETHANE, 1,1,2,2-	1.3E-03	1.3E-03	6.7E-02
TETRACHLOROETHYLENE	7.0E-02	2.5E-01	5.0E+00
TETRACHLOROPHENOL, 2,3,4,6-	4.0E-01	4.0E-01	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	1.0E+02	1.0E+02	3.3E+02
THALLIUM	2.9E+01	2.9E+01	2.0E+00
TOLUENE	3.4E+00	3.4E+00	4.0E+01
TOXAPHENE	1.3E+02	1.3E+02	2.0E-04
TPH (gasolines)	1.0E+02	1.0E+02	1.0E+02
TPH (middle distillates)	1.0E+02	1.0E+02	1.0E+02
TPH (residual fuels)	1.0E+03	1.0E+03	1.0E+02
TRICHLOROBENZENE, 1,2,4-	1.5E-01	4.9E-01	2.5E+01
TRICHLOROETHANE, 1,1,1-	7.1E+00	7.1E+00	6.2E+01
TRICHLOROETHANE, 1,1,2-	2.6E-02	8.2E-02	5.0E+00
TRICHLOROETHYLENE	2.1E-01	3.6E-01	5.0E+00
TRICHLOROPHENOL, 2,4,5-	2.2E+00	2.2E+00	1.1E+01
TRICHLOROPHENOL, 2,4,6-	1.2E+00	1.2E+00	6.1E+00
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	2.9E+00	2.9E+00	3.7E+02

TABLE C. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Deep Soil [2]Unrestricted Land Use (mg/kg)	[1]Deep Soil Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	4.0E-01	4.0E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	4.6E-05	4.6E-05	1.9E-03
TRICHLOROPROPENE, 1,2,3-	4.0E-01	4.0E-01	2.2E+00
TRIFLURALIN	1.4E+01	1.4E+01	8.7E+00
TRINITROBENZENE, 1,3,5-	5.4E+00	5.4E+00	3.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	5.2E+01	5.2E+01	1.5E+02
TRINITROTOLUENE, 2,4,6- (TNT)	6.8E-01	6.8E-01	2.2E+00
VANADIUM	2.5E+03	3.1E+03	1.9E+01
VINYL CHLORIDE	4.0E-02	3.3E-01	2.0E+00
XYLENES	2.3E+00	2.3E+00	2.0E+01
ZINC	2.5E+03	5.0E+03	8.1E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	not applicable	0.0E+00
Sodium Adsorption Ratio	not applcable	not applcable	0.0E+00

Notes:

1. Deep soils defined as soils greater than to 3 meters (approximately 10 feet) below ground surface for residential/unrestricted land use and more than one meter (approximately three feet) for commercial/industrial sites.

2. Category "Unrestricted Land Use" generally considered adequate for residential and other sensitive uses (e.g., schools, day-care centers, hospitals, etc.)

3. Assumes potential discharge of groundwater into a freshwater, marine or estuary surface water system.

Source of soil ESLs: Refer to Appendix 1, Tables C-1 and C-2.

Source of groundwater ESLs: Refer to Appendix 1, Table F-1a.

Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).

Soil ESLs intended to address human health, groundwater protection and nuisance concerns under a construction/trench worker exposure scenario and noted land-use scenarios. **Soil gas data should be collected for additional evaluation of potential indoor-air impacts at sites with significant areas of VOC-impacted soil. See Section 2.6 and Table E.**

Groundwater ESLs intended to be address drinking water, surface water, indoor-air and nuisance concerns. **Use in conjunction with soil gas screening levels to more closely evaluate potential impacts to indoor-air if groundwater screening levels for this concern approached or exceeded (refer to Section 2.6 and Appendix 1, Table F-1a).**

Aquatic habitat goals for bioaccumulation concerns not considered in selection of groundwater goals (refer to Section 2.7).

Refer to appendices for summary of ESL components.

Soil and water ESLs for ethanol based on gross contamination concerns (see Appendix 1, Chapter 5 and related tables).

TPH -Total Petroleum Hydrocarbons. TPH ESLs must be used in conjunction with ESLs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2 and Appendix 1, Chapter 5.

TABLE D: DEEP SOIL (>3M BGS) - WATER IS NOT A CURRENT OR POTENTIAL SOURCE OF DRINKING WATER

Notes:

- Always compare final soil data for commercial/industrial sites to residential ESLs and evaluate need for formal land-use restrictions (see Section 2.7).
- Assumption that groundwater is not a current or potential source of drinking water should be approved by overseeing regulatory agency prior to use of this table (see Section 2.2).
- ESLs for deep soils may be applicable to soils <3m below ground surface at commercial/industrial sites provided institutional controls are put in place to maintain an adequate cap and provide proper management of soil if exposed in future (see Section 2.2 and Section 2.7).

TABLE D. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Deep Soil [2]Unrestricted Land Use (mg/kg)	[1]Deep Soil Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
ACENAPHTHENE	2.3E+01	2.3E+01	2.3E+01
ACENAPHTHYLENE	1.3E+01	1.3E+01	3.0E+01
ACETONE	8.6E-01	8.6E-01	1.5E+03
ALDRIN	8.4E+00	8.4E+00	1.3E-01
AMETRYN	1.1E+00	1.1E+00	1.5E+01
AMINO,2- DINITROTOLUENE,3,6-	6.5E-01	6.5E-01	3.9E+01
AMINO,4- DINITROTOLUENE,2,6-	2.5E-01	2.5E-01	1.5E+01
ANTHRACENE	2.5E+00	2.5E+00	7.3E-01
ANTIMONY	1.8E+02	1.8E+02	3.0E+01
ARSENIC	8.9E+01	8.9E+01	3.6E+01
ATRAZINE	4.6E-01	4.6E-01	1.2E+01
BARIUM	2.5E+03	4.3E+03	2.0E+03
BENZENE	5.3E-01	1.9E+00	4.6E+01
BENZO(a)ANTHRACENE	1.3E+01	1.3E+01	2.7E-02
BENZO(a)PYRENE	7.6E+00	7.6E+00	1.4E-02
BENZO(b)FLUORANTHENE	1.2E+01	1.2E+01	9.2E-02
BENZO(g,h,i)PERYLENE	2.7E+01	2.7E+01	1.0E-01
BENZO(k)FLUORANTHENE	5.2E+01	5.2E+01	4.0E-01
BERYLLIUM	1.5E+02	1.5E+02	2.7E+00
BIPHENYL, 1,1-	5.2E+00	5.2E+00	5.0E+00
BIS(2-CHLOROETHYL)ETHER	2.6E-03	1.1E-02	6.1E+01
BIS(2-CHLOROISOPROPYL)ETHER	6.6E-01	6.6E-01	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	8.8E+02	8.8E+02	3.2E+01
BORON	5.0E+02	1.0E+03	7.3E+03
BROMODICHLOROMETHANE	2.3E-02	8.2E-02	1.6E+02
BROMOFORM	2.9E+01	2.9E+01	3.2E+03
BROMOMETHANE	1.8E-01	5.2E-01	1.6E+02
CADMIUM	3.7E+02	3.7E+02	2.5E-01
CARBON TETRACHLORIDE	2.7E-02	9.7E-02	9.8E+00
CHLORDANE (TECHNICAL)	2.9E+01	2.9E+01	4.0E-03
CHLOROANILINE, p-	6.0E-02	6.0E-02	5.0E+00
CHLOROBENZENE	1.6E+00	1.6E+00	2.5E+01
CHLOROETHANE	2.8E-01	2.8E-01	3.9E+00
CHLOROFORM	1.8E-02	6.3E-02	7.4E+01
CHLOROMETHANE	2.3E-01	8.1E-01	2.9E+02
CHLOROPHENOL, 2-	1.3E-01	1.3E-01	1.8E+00
CHROMIUM (Total)	6.5E+01	6.5E+01	7.4E+01
CHROMIUM III	2.5E+03	5.0E+03	7.4E+01
CHROMIUM VI	5.4E+01	5.4E+01	1.1E+01
CHRYSENE	1.4E+01	1.4E+01	3.5E-01
COBALT	1.8E+02	1.8E+02	3.0E+00
COPPER	2.5E+03	5.0E+03	3.1E+00
CYANIDE (Free)	5.0E+02	1.0E+03	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	6.2E+00	6.2E+00	1.9E+02
DALAPON	1.4E-01	1.4E-01	3.0E+02
DIBENZO(a,h)ANTHTRACENE	1.8E+01	1.8E+01	5.2E-01
DIBROMO,1,2- CHLOROPROPANE,3-	4.5E-03	4.7E-04	2.0E-01
DIBROMOCHLOROMETHANE	1.7E-02	2.8E+00	2.7E+02

TABLE D. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Deep Soil: [2]Unrestricted Land Use (mg/kg)	[1]Deep Soil: Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
DIBROMOETHANE, 1,2-	6.9E-04	2.4E-03	1.2E+01
DICHLOROBENZENE, 1,2-	1.2E+00	1.2E+00	1.4E+01
DICHLOROBENZENE, 1,3-	7.4E+00	7.4E+00	6.5E+01
DICHLOROBENZENE, 1,4-	3.7E-02	1.3E-01	1.5E+01
DICHLOROBENZIDINE, 3,3-	3.1E+02	3.1E+02	2.5E+02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.2E+01	8.2E+01	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	3.7E+01	3.7E+01	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	7.3E+00	7.3E+00	1.0E-03
DICHLOROETHANE, 1,1-	2.6E-01	9.1E-01	4.7E+01
DICHLOROETHANE, 1,2-	1.6E-02	5.6E-02	1.2E+02
DICHLOROETHYLENE, 1,1-	4.3E+00	4.3E+00	2.5E+01
DICHLOROETHYLENE, Cis 1,2-	1.2E+00	3.6E+00	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	2.1E+00	6.2E+00	5.9E+02
DICHLOROPHENOL, 2,4-	3.6E-01	3.6E-01	3.0E+00
DICHLOROPHENOXYACETIC ACID (2,4-D)	2.0E-01	2.0E-01	4.0E+01
DICHLOROPROPANE, 1,2-	4.1E-02	1.5E-01	1.0E+02
DICHLOROPROPENE, 1,3-	1.0E-01	3.6E-01	1.2E+02
DIELDRIN	3.3E-03	3.3E-03	1.9E-03
DIETHYLPHTHALATE	3.1E-02	3.1E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	1.3E+01	1.3E+01	1.1E+02
DIMETHYLPHTHALATE	3.5E-02	3.5E-02	1.5E+00
DINITROBENZENE, 1,3-	1.1E+00	1.1E+00	3.0E+01
DINITROPHENOL, 2,4-	4.5E+00	4.5E+00	7.5E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	2.7E+00	2.7E+00	4.4E+01
DINITROTOLUENE, 2,6- (2,6-DNT)	2.7E+00	2.7E+00	4.4E+01
DIOXANE, 1,4-	9.8E+00	9.8E+00	5.0E+04
DIOXIN (2,3,7,8-TCDD)	1.5E-03	1.5E-03	5.0E-06
DIURON	1.4E+00	1.4E+00	6.0E+01
ENDOSULFAN	3.2E-02	3.2E-02	8.7E-03
ENDRIN	4.0E-03	4.0E-03	2.3E-03
ETHANOL	4.5E+00	4.5E+00	5.0E+04
ETHYLBENZENE	1.6E+00	5.8E+00	2.9E+02
FLUORANTHENE	1.1E+02	1.1E+02	8.0E+00
FLUORENE	7.3E+00	7.3E+00	3.9E+00
GLYPHOSATE	2.0E-01	2.0E-01	6.5E+01
HEPTACHLOR	3.2E+01	3.2E+01	3.6E-03
HEPTACHLOR EPOXIDE	3.1E-03	3.1E-03	3.6E-03
HEXACHLOROBENZENE	1.8E+00	1.8E+00	3.1E+00
HEXACHLOROBUTADIENE	1.1E+00	1.1E+00	4.7E+00
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.5E-02	4.5E-02	8.0E-02
HEXACHLOROETHANE	7.4E-01	7.4E-01	1.2E+01
HEXAZINONE	5.1E+02	5.1E+02	5.0E+03
INDENO(1,2,3-cd)PYRENE	4.1E+01	4.1E+01	9.2E-02
ISOPHORONE	1.3E+00	1.3E+00	1.3E+02
LEAD	8.0E+02	8.0E+02	2.5E+00
MERCURY	1.3E+02	1.3E+02	7.7E-01
METHOXYCHLOR	2.6E+01	2.6E+01	1.9E-02

TABLE D. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

	[1]Deep Soil		
CHEMICAL PARAMETER	[2]Unrestricted Land Use (mg/kg)	Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
METHYL ETHYL KETONE	1.4E+01	1.4E+01	1.4E+04
METHYL ISOBUTYL KETONE	4.5E-01	4.5E-01	1.7E+02
METHYL MERCURY	4.4E+01	4.4E+01	3.0E-03
METHYL TERT BUTYL ETHER	1.6E+00	5.6E+00	1.8E+03
METHYLENE CHLORIDE	8.8E-01	3.1E+00	2.2E+03
METHYLNAPHTHALENE, 1-	1.1E+00	1.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	1.0E+00	1.0E+00	2.1E+00
MOLYBDENUM	2.2E+03	2.2E+03	2.4E+02
NAPHTHALENE	4.6E-01	1.9E+00	2.4E+01
NICKEL	2.5E+03	5.0E+03	8.2E+00
NITROBENZENE	1.9E+00	1.9E+00	6.0E+01
NITROGLYCERIN	3.0E+00	3.0E+00	1.4E+02
NITROTOLUENE, 2-	5.2E+01	5.2E+01	1.0E+03
NITROTOLUENE, 3-	2.1E+01	2.1E+01	3.8E+02
NITROTOLUENE, 4-	8.2E+01	8.2E+01	1.6E+03
PENTACHLOROPHENOL	4.4E+00	4.4E+00	7.9E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	5.4E+02	5.4E+02	2.2E+04
PERCHLORATE	1.2E+00	1.2E+00	6.0E+02
PHENANTHRENE	1.1E+01	1.1E+01	4.6E+00
PHENOL	5.7E+01	5.7E+01	1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	1.5E+01	1.5E+01	1.4E-02
PROPICONAZOLE	2.4E+01	2.4E+01	2.6E+01
PYRENE	5.6E+01	5.6E+01	2.0E+00
SELENIUM	2.2E+03	2.2E+03	5.0E+00
SILVER	2.2E+03	2.2E+03	1.9E-01
SIMAZINE	4.9E-02	4.9E-02	2.0E+00
STYRENE	1.0E+01	1.0E+01	1.0E+02
TERBACIL	3.0E+01	3.0E+01	2.3E+03
tert-BUTYL ALCOHOL	1.1E+02	1.1E+02	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	2.9E+01	2.9E+01	9.3E+02
TETRACHLOROETHANE, 1,1,2,2-	7.1E-03	2.5E-02	1.6E+02
TETRACHLOROETHYLENE	7.0E-02	2.5E-01	1.2E+02
TETRACHLOROPHENOL, 2,3,4,6-	4.0E-01	4.0E-01	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	1.0E+02	1.0E+02	3.3E+02
THALLIUM	2.9E+01	2.9E+01	2.0E+01
TOLUENE	1.1E+01	1.1E+01	1.3E+02
TOXAPHENE	1.3E+02	1.3E+02	2.0E-04
TPH (gasolines)	4.0E+02	4.0E+02	5.0E+02
TPH (middle distillates)	5.0E+02	5.0E+02	6.4E+02
TPH (residual fuels)	1.0E+03	1.0E+03	6.4E+02
TRICHLOROBENZENE, 1,2,4-	1.5E-01	4.9E-01	2.5E+01
TRICHLOROETHANE, 1,1,1-	7.1E+00	7.1E+00	6.2E+01
TRICHLOROETHANE, 1,1,2-	2.6E-02	9.1E-02	3.0E+02
TRICHLOROETHYLENE	2.1E-01	7.3E-01	3.6E+02
TRICHLOROPHENOL, 2,4,5-	2.2E+00	2.2E+00	1.1E+01
TRICHLOROPHENOL, 2,4,6-	9.5E+01	9.5E+01	4.9E+02
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	5.5E+00	5.5E+00	6.9E+02

TABLE D. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Deep Soils (>3m bgs)
Groundwater IS NOT a Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	[1]Deep Soil: [2]Unrestricted Land Use (mg/kg)	[1]Deep Soil: Commercial/ Industrial Land Use Only (mg/kg)	[3]Groundwater (ug/L)
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	4.0E-01	4.0E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	3.3E-01	3.3E-01	1.4E+01
TRICHLOROPROPENE, 1,2,3-	4.0E-01	4.0E-01	2.2E+00
TRIFLURALIN	3.2E+01	3.2E+01	2.0E+01
TRINITROBENZENE, 1,3,5-	5.4E+00	5.4E+00	3.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	1.3E+02	1.3E+02	3.7E+02
TRINITROTOLUENE, 2,4,6- (TNT)	4.0E+01	4.0E+01	1.3E+02
VANADIUM	2.5E+03	3.1E+03	1.9E+01
VINYL CHLORIDE	4.0E-02	3.3E-01	2.1E+01
XYLENES	1.2E+01	1.2E+01	1.0E+02
ZINC	2.5E+03	5.0E+03	8.1E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	not applicable	0.0E+00
Sodium Adsorption Ratio	not applicable	not applicable	0.0E+00

Notes:

1. Deep soils defined as soils greater than to 3 meters (approximately 10 feet) below ground surface for residential/unrestricted land use and more than one meter (approximately three feet) for commercial/industrial sites.

2. Category "Unrestricted Land Use" generally considered adequate for residential and other sensitive uses (e.g., schools, day-care centers, hospitals, etc.)

3. Assumes potential discharge of groundwater into marine or estuary surface water system.

Source of soil ESLs: Refer to Appendix 1, Tables D-1 and D-2.

Source of groundwater ESLs: Refer to Appendix 1, Table F-1b.

Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).

Soil ESLs intended to address human health, groundwater protection and nuisance concerns under a construction/trench worker exposure scenario and noted land-use scenarios. **Soil gas data should be collected for additional evaluation of potential indoor-air impacts at sites with significant areas of VOC-impacted soil. See Section 2.6 and Table E.**

Groundwater ESLs intended to address surface water, indoor-air and nuisance concerns. **Use in conjunction with soil gas screening levels to more closely evaluate potential impacts to indoor-air if groundwater screening levels for this concern approached or exceeded (refer to Section 2.6 and Appendix 1, Table F-1a).**

Aquatic habitat goals for bioaccumulation concerns not considered in selection of groundwater goals (refer to Section 2.7).

Refer to appendices for summary of ESL components.

Soil and water ESLs for ethanol based on gross contamination concerns (see Appendix 1, Chapter 5 and related tables).

TPH -Total Petroleum Hydrocarbons. TPH ESLs must be used in conjunction with ESLs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2 and Appendix 1, Chapter 5.

TABLE E: SHALLOW SOIL GAS AND INDOOR AIR

Notes:

- Shallow soil gas intended to reflect soil gas zero to five feet below ground surface or the foundation of a building. Collection of soil gas data from depths <3 feet below ground surface in open areas is generally not practical (see Section 4.4).

TABLE E. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Indoor Air and Soil Gas
(Vapor Intrusion Concerns)

CHEMICAL PARAMETER	Physical State		INDOOR AIR SCREENING LEVELS [1]Residential (ug/m3)	INDOOR AIR SCREENING LEVELS Commercial/ Industrial (ug/m^3)	[2]SHALLOW SOIL GAS SCREENING LEVELS [1]Residential (ug/m3)	[2]SHALLOW SOIL GAS SCREENING LEVELS Commercial/ Industrial (ug/m^3)
ACENAPHTHENE	V	S	4.4E+01	6.1E+01	4.4E+04	1.2E+05
ACENAPHTHYLENE	V	S	2.9E+01	4.1E+01	2.9E+04	8.2E+04
ACETONE	V	L	6.5E+03	9.1E+03	6.5E+06	1.8E+07
ALDRIN	NV	S				
AMETRYN	NV	S				
AMINO,2- DINITROTOLUENE,4,6-	NV	S				
AMINO,4- DINITROTOLUENE,2,6-	NV	S				
ANTHRACENE	V	S	2.2E+02	3.1E+02	2.2E+05	6.1E+05
ANTIMONY	NV	S				
ARSENIC	NV	S				
ATRAZINE	NV	S				
BARIUM	NV	S				
BENZENE	V	L	2.5E-01	5.2E-01	2.5E+02	1.0E+03
BENZO(a)ANTHRACENE	NV	S				
BENZO(a)PYRENE	NV	S				
BENZO(b)FLUORANTHENE	NV	S				
BENZO(g,h,i)PERYLENE	NV	S				
BENZO(k)FLUORANTHENE	NV	S				
BERYLLIUM	NV	S				
BIPHENYL, 1,1-	V	S	3.7E+01	5.1E+01	3.7E+04	1.0E+05
BIS(2-CHLOROETHYL)ETHER	V	L	5.8E-03	1.2E-02	5.8E+00	2.5E+01
BIS(2-CHLOROISOPROPYL)ETHER	V	L	1.9E-01	4.1E-01	1.9E+02	8.2E+02
BIS(2-ETHYLHEXYL)PHTHALATE	NV	S				
BORON	NV	S				
BROMODICHLOROMETHANE	V	L	1.1E-01	2.3E-01	1.1E+02	4.6E+02
BROMOFORM	NV	S				
BROMOMETHANE	V	G	1.0E+00	1.5E+00	1.0E+03	2.9E+03
CADMIUM	NV	S				
CARBON TETRACHLORIDE	V	L	1.3E-01	2.7E-01	1.3E+02	5.5E+02
CHLORDANE (TECHNICAL)	NV	S				
CHLOROANILINE, p-	NV	S				
CHLOROBENZENE	V	L	1.0E+01	1.5E+01	1.0E+04	2.9E+04
CHLOROETHANE	V	G	2.1E+03	2.9E+03	2.1E+06	5.8E+06
CHLOROFORM	V	L	8.4E-02	1.8E-01	8.4E+01	3.6E+02
CHLOROMETHANE	V	G	1.1E+00	2.3E+00	1.1E+03	4.5E+03
CHLOROPHENOL, 2-	V	L	3.7E+00	5.1E+00	3.7E+03	1.0E+04
CHROMIUM (Total)	NV	S				
CHROMIUM III	NV	S				
CHROMIUM VI	NV	S				
CHRYSENE	NV	S				
COBALT	NV	S				
COPPER	NV	S				
CYANIDE (Free)	V	S				
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	NV	S				
DALAPON	NV	L				
DIBENZO(a,h)ANTHTRACENE	NV	S				
DIBROMO,1,2- CHLOROPROPANE,3-	V	L	3.2E-04	6.8E-04	3.2E-01	1.4E+00
DIBROMOCHLOROMETHANE	V	S	8.0E-02	1.7E-01	8.0E+01	3.4E+02
DIBROMOETHANE, 1,2-	V	S	3.2E-03	6.8E-03	3.2E+00	1.4E+01
DICHLOROBENZENE, 1,2-	V	L	4.2E+01	5.8E+01	4.2E+04	1.2E+05
DICHLOROBENZENE, 1,3-	V	L	2.2E+01	3.1E+01	2.2E+04	6.1E+04
DICHLOROBENZENE, 1,4-	V	S	1.7E-01	3.7E-01	1.7E+02	7.4E+02
DICHLOROBENZIDINE, 3,3-	NV	S				
DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV	S				
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	NV	S				
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV	S				
DICHLOROETHANE, 1,1-	V	L	1.2E+00	2.6E+00	1.2E+03	5.1E+03
DICHLOROETHANE, 1,2-	V	L	7.4E-02	1.6E-01	7.4E+01	3.1E+02

TABLE E. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Indoor Air and Soil Gas
(Vapor Intrusion Concerns)

CHEMICAL PARAMETER	Physical State		INDOOR AIR SCREENING LEVELS		[2]SHALLOW SOIL GAS SCREENING LEVELS	
			[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)	[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)
DICHLOROETHYLENE, 1,1-	V	L	4.2E+01	5.8E+01	4.2E+04	1.2E+05
DICHLOROETHYLENE, Cis 1,2-	V	L	7.3E+00	1.0E+01	7.3E+03	2.0E+04
DICHLOROETHYLENE, Trans 1,2-	V	L	1.3E+01	1.8E+01	1.3E+04	3.5E+04
DICHLOROPHENOL, 2,4-	NV	S				
DICHLOROPHENOXYACETIC ACID (2,4-D)	NV	S				
DICHLOROPROPANE, 1,2-	V	L	1.9E-01	4.1E-01	1.9E+02	8.2E+02
DICHLOROPROPENE, 1,3-	V	L	4.8E-01	1.0E+00	4.8E+02	2.0E+03
DIELDRIN	NV	S				
DIETHYLPHTHALATE	NV	S				
DIMETHYLPHENOL, 2,4-	V	S	1.5E+01	2.0E+01	1.5E+04	4.1E+04
DIMETHYLPHTHALATE	NV	S				
DINITROBENZENE, 1,3-	NV	S				
DINITROPHENOL, 2,4-	NV	S				
DINITROTOLUENE, 2,4- (2,4-DNT)	NV	S				
DINITROTOLUENE, 2,6- (2,6-DNT)	NV	S				
DIOXANE, 1,4-	NV	L				
DIOXINS (TEQ)	NV	S				
DIURON	NV	S				
ENDOSULFAN	NV	S				
ENDRIN	NV	S				
ETHANOL	NV	L				
ETHYLBENZENE	V	L	7.7E-01	1.6E+00	7.7E+02	3.3E+03
FLUORANTHENE	NV	S				
FLUORENE	V	S	2.9E+01	4.1E+01	2.9E+04	8.2E+04
GLYPHOSATE	NV	S				
HEPTACHLOR	NV	S				
HEPTACHLOR EPOXIDE	NV	S				
HEXACHLOROBENZENE	NV	S				
HEXACHLOROBUTADIENE	NV	S				
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV	S				
HEXACHLOROETHANE	NV	S				
HEXAZINONE	NV	S				
INDENO(1,2,3-cd)PYRENE	NV	S				
ISOPHORONE	NV	L				
LEAD	NV	S				
MERCURY	V	S				
METHOXYCHLOR	NV	S				
METHYL ETHYL KETONE	V	L	1.0E+03	1.5E+03	1.0E+06	2.9E+06
METHYL ISOBUTYL KETONE	V	L	6.3E+02	8.8E+02	6.3E+05	1.8E+06
METHYL MERCURY	NV	S				
METHYL TERT BUTYL ETHER	V	L	7.4E+00	1.6E+01	7.4E+03	3.1E+04
METHYLENE CHLORIDE	V	L	4.1E+00	8.7E+00	4.1E+03	1.7E+04
METHYLNAPHTHALENE, 1-	V	S	2.3E-01	4.9E-01	2.3E+02	9.9E+02
METHYLNAPHTHALENE, 2-	V	S	2.9E+00	4.1E+00	2.9E+03	8.2E+03
MOLYBDENUM	NV	S				
NAPHTHALENE	V	S	5.7E-02	1.2E-01	5.7E+01	2.4E+02
NICKEL	NV	S				
NITROBENZENE	V	L	4.2E-01	5.8E-01	4.2E+02	1.2E+03
NITROGLYCERIN	NV	L				
NITROTOLUENE, 2-	V	S	3.1E-02	6.5E-02	3.1E+01	1.3E+02
NITROTOLUENE, 3-	V	S	1.5E+01	2.0E+01	1.5E+04	4.1E+04
NITROTOLUENE, 4-	NV	S				
PENTACHLOROPHENOL	NV	S				

TABLE E. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Indoor Air and Soil Gas
(Vapor Intrusion Concerns)

			INDOOR AIR SCREENING LEVELS		[2]SHALLOW SOIL GAS SCREENING LEVELS	
CHEMICAL PARAMETER	Physical State		[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)	[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)
PENTAERYTHRITOLTETRANITRATE (PETN)	NV	S				
PERCHLORATE	NV	S				
PHENANTHRENE	V	S	2.9E+01	4.1E+01	2.9E+04	8.2E+04
PHENOL	NV	S				
POLYCHLORINATED BIPHENYLS (PCBs)	NV	S				
PROPICONAZOLE	NV	L				
PYRENE	V	S	2.2E+01	3.1E+01	2.2E+04	6.1E+04
SELENIUM	NV	S				
SILVER	NV	S				
SIMAZINE	NV	S				
STYRENE	V	L	2.1E+02	2.9E+02	2.1E+05	5.8E+05
TERBACIL	NV	S				
tert-BUTYL ALCOHOL	V	L	2.2E+00	4.8E+00	2.2E+03	9.5E+03
TETRACHLOROETHANE, 1,1,1,2-	V	L	2.6E-01	5.5E-01	2.6E+02	1.1E+03
TETRACHLOROETHANE, 1,1,2,2-	V	L	3.3E-02	7.0E-02	3.3E+01	1.4E+02
TETRACHLOROETHYLENE	V	L	3.3E-01	6.9E-01	3.3E+02	1.4E+03
TETRACHLOROPHENOL, 2,3,4,6-	NV	S				
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	NV	S				
THALLIUM	NV	S				
TOLUENE	V	L	1.0E+03	1.5E+03	1.0E+06	2.9E+06
TOXAPHENE	NV	S				
TPH (gasolines)	V	L	2.6E+01	3.7E+01	2.6E+04	7.3E+04
TPH (middle distillates)	V	L	5.7E+01	8.0E+01	5.7E+04	1.6E+05
TPH (residual fuels)	NV	L				
TRICHLOROBENZENE, 1,2,4-	V	S	8.3E-01	1.2E+00	8.3E+02	2.3E+03
TRICHLOROETHANE, 1,1,1-	V	L	1.0E+03	1.5E+03	1.0E+06	2.9E+06
TRICHLOROETHANE, 1,1,2-	V	L	1.2E-01	2.6E-01	1.2E+02	5.1E+02
TRICHLOROETHYLENE	V	L	9.6E-01	2.0E+00	9.6E+02	4.1E+03
TRICHLOROPHENOL, 2,4,5-	NV	S				
TRICHLOROPHENOL, 2,4,6-	NV	S				
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	NV	S				
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	NV	S				
TRICHLOROPROPANE, 1,2,3-	V	L	9.6E-04	2.0E-03	9.6E-01	4.1E+00
TRICHLOROPROPENE, 1,2,3-	V	L	7.3E+00	1.0E+01	7.3E+03	2.0E+04
TRIFLURALIN	NV	S				
TRINITROBENZENE, 1,3,5-	NV	S				
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	NV	S				
TRINITROTOLUENE, 2,4,6- (TNT)	NV	S				
VANADIUM	NV	S				

TABLE E. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Indoor Air and Soil Gas
(Vapor Intrusion Concerns)

CHEMICAL PARAMETER	Physical State		INDOOR AIR SCREENING LEVELS [1]Residential (ug/m3)	INDOOR AIR SCREENING LEVELS Commercial/ Industrial (ug/m^3)	[2]SHALLOW SOIL GAS SCREENING LEVELS [1]Residential (ug/m3)	[2]SHALLOW SOIL GAS SCREENING LEVELS Commercial/ Industrial (ug/m^3)
VINYL CHLORIDE	V	G	4.4E-01	9.3E-01	4.4E+02	1.9E+03
XYLENES	V	L	1.5E+02	2.0E+02	1.5E+05	4.1E+05
ZINC	NV	S				
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)			not applicable	not applicable	not apploicable	not applicable
Sodium Adsorption Ratio			not applicable	not applicable	not applicable	not applicable

Notes:
1. Category "Residential Land Use" generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.)
2. Soil Gas: Screening levels based on soil gas data collected within 1.5 meters (five feet) below a building foundation or the ground surface. Intended for evaluation of potential indoor-air impacts.

Screening levels also apply to areas over both contaminated soil and contaminated groundwater.

Source of soil ESLs: Refer to Tables E-2 and E-3 in Appendix 1.

TPH -Total Petroleum Hydrocarbons. TPH ESLs must be used in conjunction with ESLs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Volume 1, Section 2.2 and Appendix 1, Chapter 5.

TABLE F: SURFACE WATER

TABLE F. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Surface Water Bodies

CHEMICAL PARAMETER	[2]Freshwater (ug/L)	[3]Marine (ug/L)	[4]Estuarine (ug/L)
ACENAPHTHENE	2.0E+01	2.0E+01	2.0E+01
ACENAPHTHYLENE	3.0E+01	3.0E+01	3.0E+01
ACETONE	1.5E+03	1.5E+03	1.5E+03
ALDRIN	5.0E-05	5.0E-05	5.0E-05
AMETRYN	1.5E+01	1.5E+01	1.5E+01
AMINO,2- DINITROTOLUENE,4,6-	3.9E+01	3.9E+01	3.9E+01
AMINO,4- DINITROTOLUENE,2,6-	1.5E+01	1.5E+01	1.5E+01
ANTHRACENE	7.3E-01	7.3E-01	7.3E-01
ANTIMONY	6.0E+00	5.0E+02	3.0E+01
ARSENIC	1.4E-01	1.4E-01	1.4E-01
ATRAZINE	2.9E-01	2.6E+01	1.2E+01
BARIUM	2.0E+03	2.0E+03	2.0E+03
BENZENE	5.0E+00	5.1E+01	4.6E+01
BENZO(a)ANTHRACENE	1.8E-02	1.8E-02	1.8E-02
BENZO(a)PYRENE	1.4E-02	1.4E-02	1.4E-02
BENZO(b)FLUORANTHENE	1.8E-02	1.8E-02	1.8E-02
BENZO(g,h,i)PERYLENE	1.0E-01	1.0E-01	1.0E-01
BENZO(k)FLUORANTHENE	1.8E-02	1.8E-02	1.8E-02
BERYLLIUM	2.7E+00	2.7E+00	2.7E+00
BIPHENYL, 1,1-	5.0E-01	5.0E-01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	1.2E-02	5.3E-01	5.3E-01
BIS(2-CHLOROISOPROPYL)ETHER	3.2E-01	6.1E+01	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	2.2E+00	2.2E+00	2.2E+00
BORON	7.3E+03	7.3E+03	7.3E+03
BROMODICHLOROMETHANE	2.2E-01	3.2E+03	3.2E+03
BROMOFORM	1.0E+02	1.4E+02	1.4E+02
BROMOMETHANE	8.7E+00	1.5E+03	1.6E+02
CADMIUM	2.5E-01	8.8E+00	2.5E-01
CARBON TETRACHLORIDE	1.6E+00	1.6E+00	1.6E+00
CHLORDANE (TECHNICAL)	8.1E-04	8.1E-04	8.1E-04
CHLOROANILINE, p-	1.2E+00	5.0E+00	5.0E+00
CHLOROBENZENE	2.5E+01	5.0E+01	2.5E+01
CHLOROETHANE	3.9E+00	3.9E+00	3.9E+00
CHLOROFORM	1.0E+02	4.7E+02	4.7E+02
CHLOROMETHANE	1.8E+00	3.2E+03	3.2E+03
CHLOROPHENOL, 2-	1.8E-01	1.8E-01	1.8E-01
CHROMIUM (Total)	7.4E+01	1.0E+04	7.4E+01
CHROMIUM III	7.4E+01	7.4E+01	7.4E+01
CHROMIUM VI	1.1E+01	5.0E+01	1.1E+01
CHRYSENE	1.8E-02	1.8E-02	1.8E-02
COBALT	3.0E+00	3.0E+00	3.0E+00
COPPER	9.0E+00	3.1E+00	3.1E+00
CYANIDE (Free)	5.2E+00	1.0E+00	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	6.1E-01	1.9E+02	1.9E+02
DALAPON	3.0E+02	3.0E+02	3.0E+02
DIBENZO(a,h)ANTHTRACENE	9.2E-03	1.8E-02	1.8E-02
DIBROMO,1,2- CHLOROPROPANE,3-	2.0E-01	2.0E-01	2.0E-01
DIBROMOCHLOROMETHANE	1.6E-01	1.3E+01	1.3E+01
DIBROMOETHANE, 1,2-	5.0E-02	1.4E+03	1.4E+03

TABLE F. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Surface Water Bodies

CHEMICAL PARAMETER	[2]Freshwater (ug/L)	[3]Marine (ug/L)	[4]Estuarine (ug/L)
DICHLOROBENZENE, 1,2-	1.0E+01	1.0E+01	1.0E+01
DICHLOROBENZENE, 1,3-	7.1E+01	6.5E+01	6.5E+01
DICHLOROBENZENE, 1,4-	5.0E+00	1.1E+01	1.1E+01
DICHLOROBENZIDINE, 3,3-	2.8E-02	2.8E-02	2.8E-02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	3.1E-04	3.1E-04	3.1E-04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.2E-04	2.2E-04	2.2E-04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	2.2E-04	2.2E-04	2.2E-04
DICHLOROETHANE, 1,1-	2.4E+00	4.7E+01	4.7E+01
DICHLOROETHANE, 1,2-	5.0E+00	3.7E+01	3.7E+01
DICHLOROETHYLENE, 1,1-	3.2E+00	3.2E+00	3.2E+00
DICHLOROETHYLENE, Cis 1,2-	7.0E+01	5.9E+02	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	1.0E+02	2.6E+02	2.6E+02
DICHLOROPHENOL, 2,4-	3.0E-01	3.0E-01	3.0E-01
DICHLOROPHENOXYACETIC ACID (2,4-D)	2.2E+02	4.0E+01	4.0E+01
DICHLOROPROPANE, 1,2-	5.0E+00	1.0E+01	1.0E+01
DICHLOROPROPENE, 1,3-	4.3E-01	1.2E+02	1.2E+02
DIELDRIN	5.4E-05	5.4E-05	5.4E-05
DIETHYLPHTHALATE	1.5E+00	1.7E+00	1.5E+00
DIMETHYLPHENOL, 2,4-	1.2E+02	1.1E+02	1.1E+02
DIMETHYLPHTHALATE	1.5E+00	1.7E+00	1.5E+00
DINITROBENZENE, 1,3-	3.7E+00	3.0E+01	3.0E+01
DINITROPHENOL, 2,4-	7.3E+01	7.5E+01	7.5E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	3.4E+00	3.4E+00	3.4E+00
DINITROTOLUENE, 2,6- (2,6-DNT)	3.7E+01	6.7E+01	4.4E+01
DIOXANE, 1,4-	6.1E+00	5.0E+04	5.0E+04
DIOXINS (TEQ)	5.1E-09	5.1E-09	5.1E-09
DIURON	6.0E+01	6.0E+01	6.0E+01
ENDOSULFAN	5.6E-02	8.7E-03	8.7E-03
ENDRIN	3.6E-02	2.3E-03	2.3E-03
ETHANOL	5.0E+04	5.0E+04	5.0E+04
ETHYLBENZENE	3.0E+01	3.0E+01	3.0E+01
FLUORANTHENE	8.1E+00	8.0E+00	8.0E+00
FLUORENE	3.9E+00	3.9E+00	3.9E+00
GLYPHOSATE	6.5E+01	6.5E+01	6.5E+01
HEPTACHLOR	7.9E-05	7.9E-05	7.9E-05
HEPTACHLOR EPOXIDE	3.9E-05	3.9E-05	3.9E-05
HEXACHLOROBENZENE	2.9E-04	2.9E-04	2.9E-04
HEXACHLOROBUTADIENE	8.6E-01	4.7E+00	4.7E+00
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	6.3E-02	6.3E-02	6.3E-02
HEXACHLOROETHANE	3.3E+00	3.3E+00	3.3E+00
HEXAZINONE	1.2E+03	5.0E+03	5.0E+03
INDENO(1,2,3-cd)PYRENE	1.8E-02	1.8E-02	1.8E-02
ISOPHORONE	7.1E+01	1.3E+02	1.3E+02
LEAD	2.5E+00	8.1E+00	2.5E+00
MERCURY	3.0E-01	3.0E-01	3.0E-01
METHOXYCHLOR	1.9E-02	1.9E-02	1.9E-02
METHYL ETHYL KETONE	7.1E+03	8.4E+03	8.4E+03
METHYL ISOBUTYL KETONE	1.7E+02	1.7E+02	1.7E+02
METHYL MERCURY	3.0E-03	3.0E-03	3.0E-03

TABLE F. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Surface Water Bodies

CHEMICAL PARAMETER	[2]Freshwater (ug/L)	[3]Marine (ug/L)	[4]Estuarine (ug/L)
METHYL TERT BUTYL ETHER	5.0E+00	1.8E+02	1.8E+02
METHYLENE CHLORIDE	4.8E+00	5.9E+02	5.9E+02
METHYLNAPHTHALENE, 1-	2.1E+00	2.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	2.1E+00	2.1E+00	2.1E+00
MOLYBDENUM	1.8E+02	2.4E+02	2.4E+02
NAPHTHALENE	1.7E+01	2.1E+01	2.1E+01
NICKEL	5.2E+01	8.2E+00	8.2E+00
NITROBENZENE	3.4E+00	6.0E+01	6.0E+01
NITROGLYCERIN	3.7E+00	1.4E+02	1.4E+02
NITROTOLUENE, 2-	6.2E-02	1.0E+03	1.0E+03
NITROTOLUENE, 3-	1.2E+02	3.8E+02	3.8E+02
NITROTOLUENE, 4-	4.2E+00	1.6E+03	1.6E+03
PENTACHLOROPHENOL	1.0E+00	3.0E+00	3.0E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	6.1E-01	2.2E+04	2.2E+04
PERCHLORATE	2.6E+01	6.0E+02	6.0E+02
PHENANTHRENE	6.3E+00	4.6E+00	4.6E+00
PHENOL	5.0E+00	1.3E+03	1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	6.4E-05	6.4E-05	6.4E-05
PROPICONAZOLE	4.2E+01	2.6E+01	2.6E+01
PYRENE	2.0E+00	2.0E+00	2.0E+00
SELENIUM	5.0E+00	7.1E+01	5.0E+00
SILVER	3.2E-01	1.9E-01	1.9E-01
SIMAZINE	5.6E-01	2.0E+00	2.0E+00
STYRENE	1.0E+01	1.1E+01	1.1E+01
TERBACIL	4.7E+02	2.3E+03	2.3E+03
tert-BUTYL ALCOHOL	4.5E+00	1.8E+04	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	5.2E-01	9.3E+02	9.3E+02
TETRACHLOROETHANE, 1,1,2,2-	6.7E-02	4.0E+00	4.0E+00
TETRACHLOROETHYLENE	3.3E+00	3.3E+00	3.3E+00
TETRACHLOROPHENOL, 2,3,4,6-	1.2E+00	4.0E+00	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	3.3E+02	3.3E+02	3.3E+02
THALLIUM	2.0E+00	6.3E+00	6.3E+00
TOLUENE	4.0E+01	4.0E+01	4.0E+01
TOXAPHENE	2.0E-04	2.0E-04	2.0E-04
TPH (gasolines)	1.0E+02	3.7E+03	5.0E+02
TPH (middle distillates)	1.0E+02	6.4E+02	6.4E+02
TPH (residual fuels)	1.0E+02	6.4E+02	6.4E+02
TRICHLOROBENZENE, 1,2,4-	2.5E+01	6.5E+01	2.5E+01
TRICHLOROETHANE, 1,1,1-	6.2E+01	6.2E+01	6.2E+01
TRICHLOROETHANE, 1,1,2-	5.0E+00	1.6E+01	1.6E+01
TRICHLOROETHYLENE	5.0E+00	3.0E+01	3.0E+01
TRICHLOROPHENOL, 2,4,5-	6.3E+01	1.1E+01	1.1E+01
TRICHLOROPHENOL, 2,4,6-	6.1E+00	1.0E+02	1.0E+02
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	3.7E+02	6.9E+02	6.9E+02
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	3.0E+01	3.0E+01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	1.9E-03	1.4E+01	1.4E+01
TRICHLOROPROPENE, 1,2,3-	2.2E+00	2.2E+00	2.2E+00
TRIFLURALIN	8.7E+00	2.0E+01	2.0E+01
TRINITROBENZENE, 1,3,5-	3.0E+01	3.0E+01	3.0E+01

TABLE F. ENVIRONMENTAL SCREENING LEVELS (ESLs)
Surface Water Bodies

CHEMICAL PARAMETER	[2]Freshwater (ug/L)	[3]Marine (ug/L)	[4]Estuarine (ug/L)
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	1.5E+02	3.7E+02	3.7E+02
TRINITROTOLUENE, 2,4,6- (TNT)	2.2E+00	2.0E+01	2.0E+01
VANADIUM	1.9E+01	1.9E+01	1.9E+01
VINYL CHLORIDE	2.0E+00	5.3E+02	5.3E+02
XYLENES	2.0E+01	1.0E+02	1.0E+02
ZINC	1.2E+02	8.1E+01	8.1E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	not applicable	not applicable
Sodium Adsorption Ratio	not applicable	not applicable	not applicable

Notes:

1. Source of Freshwater ESLs: Refer to Appendix 1, Table F-2a for basis.
2. Source of Marine ESLs: Refer to Appendix 1, Table F-2b for basis.
3. Source of Estuarine ESLs: Refer to Appendix 1, Table F-2c for basis.

Surface water screening levels lowest of drinking water goal (freshwater only), chronic aquatic habitat goal, goal to address bioaccumulation in aquatic organisms and subsequent consumption by humans, and general nuisance goal (odors, etc.). Refer to Section 2.7 of text for discussion.

Estuarine screening levels lowest of freshwater and marine screening levels.

Water ESLs for ethanol based on gross contamination concerns (see Appendix 1, Chapter 5 and related tables).

TPH -Total Petroleum Hydrocarbons. TPH ESLs must be used in conjunction with ESLs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Section 2.2 and Appendix 1, Chapter 5.