Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater

Volume 1: User’s Guide

Hawai‘i Edition

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DISCLAIMER

This document, *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (Draft Spring 2024), is a technical report prepared by staff of the Hawai'i Department of Health (HDOH), Environmental Management Division. The document updates and replaces the Fall 2017 edition of the same document. A summary of the Spring 2024 updates is provided in Appendix 9.

The document provides guidance for identification and evaluation of environmental hazards associated with contaminated soil and groundwater. The Environmental Action Levels (EALs) 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 a baseline environmental risk assessment, 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 HDOH.

The information presented in this document is not final action. HDOH reserves the right to change this information at any time without public notice. This document is not intended, nor can it be relied upon, to create any rights enforceable by any party in litigation in areas associated with HDOH. HDOH may elect to follow the information provided herein or act at a variance with the information, based on an analysis of site-specific circumstances.

This document will be periodically updated. Please send comments, edits, etc. in writing to the above contacts. This document is not copyrighted. Copies may be freely made and distributed. It is cautioned, however, that reference to the action levels presented in this document without adequate review of the accompanying narrative could result in misinterpretation and misuse of the information.

ACKNOWLEDGEMENTS

This guidance represents the most recent edition of the original *Risk-Based Corrective Action* document originally published by the Hawai’i Department of Health in 1995. Other editions of this document were prepared by the same author for use as a consultant with Dames and Moore in the mid-1990s and with the California Environmental Protection Agency from 1999 to 2005, followed by periodic updates to the HDOH guidance since returning to Hawai‘i in 2005. The author is deeply indebted to the countless consultants, regulators and private individuals who provided their expertise on thousands of individual projects during this time and continue to do so today. The guidance is an attempt to present their collective expertise in a manner that improves the efficiency and effectiveness of the work we undertake for the mutual benefit of all parties involved.

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Executive Summary

This document presents guidance for the expedited identification of environmental hazards associated with contaminated soil and groundwater and the preparation of *Environmental Hazard Evaluation* (EHE) reports. This guidance should be used in conjunction with the Hawai‘i Department of Health (HDOH) HEER Office *Technical Guidance Manual* (HDOH 2023 and updates). The use of *Decision Unit* (DU) and *Multiple-Increment Sample* (MIS) investigation approaches is required for comparison of site data to *Environmental Action Levels* (EALs) and final decision making presented in this guidance. A companion, “Tropical Pacific” edition of this guidance has been prepared for use in the Commonwealth of the Northern Mariana Islands and Guam (TPEHE 2017 and updates; check with the local, overseeing regulatory agency for concurrence to use the guidance).

Refer to the HDOH *Technical Guidance Manual* (TGM) for guidance on the collection and analysis of samples for comparison to EALs (HDOH 2023). The EALs apply to the *mean* concentration of the contaminant for the targeted “Decision Unit (DU)” area and volume of media investigated, in the same manner as if the entire DU could be submitted to the laboratory and tested as a single sample. The EALs are not intended for direct comparison to individual, “discrete” sample data collected within a subarea or volume of a targeted DU beyond simple screening purposes. This is a fundamental principal of sampling theory. This approach is well developed for soil, as discussed in Sections 3, 4 and 5 of the TGM, with final decisions to be based on Multi Increment sample rather than discrete sample data. Development of methods to better apply the concept of DUs to soil vapor are currently underway. The concept is already well developed for testing of indoor air (refer to Section 7 of the HDOH TGM).

An 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 referred to as an environmental “risk assessment.” An important part of the EHE is the use of pre-approved EALs included in the lookup tables and *EAL Surfer* included with the EHE guidance (referred to as *Environmental Screening Levels* or *ESLs* in the Tropical Pacific edition of the guidance). The EALs are used to rapidly screen soil, soil vapor, 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 vapor, or groundwater at concentrations below the corresponding Tier 1 EAL 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.

Site-specific risk assessments for contaminants in soil were reasonable in the 1980s when only a small number of cases were being investigated. The caseload exploded in the late 1980s and early 1990s, however, and agencies were overwhelmed with case work. This was highly detrimental to the regulated community from a legal and financial perspective, with the average time required to prepare, review and accept a risk assessment exceeding a year. This spurred the publication of conservative, but usually optional, soil action (screening) levels in the early 1990s by the U.S. Environmental Protection Agency (USEPA) and a progressively increasing number of states, with HDOH publishing the first edition of action levels in 1995.

The EALs 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 EALs in order to use them. As potential environmental hazards are identified, additional expertise can be brought in as deemed necessary and cost-beneficial for remediation of the contamination.

Exceeding the Tier 1 EAL 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 and preparation of alternative action levels can be carried out at the discretion of the responsible party if time- and cost-beneficial (or as otherwise required by the HEER Office). This can include the preparation of a detailed, human health or ecological risk assessment, 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. The site investigation can be modified to ensure that adequate types and amounts of data are collected as potential environmental hazards are identified. For example, soil vapor should be collected if a comparison of initial soil or groundwater data to action levels indicates a potential vapor intrusion hazard. 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 vapor and/or groundwater above Tier 1 EALs, 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 vapor and/or groundwater data to Tier 1 EALs as well as action levels for specific hazards (latter especially important at sites where full cleanup to the Tier 1 EALs will not take place or alternative action 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 HDOH.
6. **Conclusions and Recommendations:** Provides a summary of EHE findings and recommendations for follow-up 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 follow-up 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* (EHMP) that describes ongoing measures to be taken to ensure that the contamination is properly managed in the future.

The Tier 1 EALs presented in the lookup tables are NOT regulatory "cleanup standards". Site-specific action levels and cleanup levels are, however, subject to the approval of HDOH. EALs 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 EALs 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 EALs (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 EALs 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 EHE 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 Response, Compensation, and Liability 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.

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Introduction

1.1 Environmental Hazard Evaluation

Environmental Hazard Evaluation (EHE) 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 significance of potential environmental hazards associated with the contamination is determined. This is carried out initially by comparison of soil, groundwater and/or soil vapor data to pre-approved, Environmental Action Levels (EALs) presented in Tables A through E 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* (EHMP) 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 use in this document, the term "soil" refers to any unconsolidated material found in the subsurface, including actual soil, saprolite, sediment, fill material, etc. Soil data should be reported on dry-weight basis (see Appendix 1, Section 7.3). Tier 1 Environmental Action Levels (EALs 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. This is because the leaching models assume that the soil is not in direct contact with groundwater and the direct-exposure models assume the soils are or could be exposed at the ground surface and are relatively dry (latter increases assumed vapor emissions; refer to following section and Section 2.4).

The soil screening levels are also not applicable to samples of rock or other solid media. If little to no soil is present within a targeted area then no further action with regards to soil contamination is required (e.g., contaminated soil removed down to bedrock to the extent practicable, with less than a few cubic yards/meters of soil left in place in isolated low areas or fractures).

For comparison, the minimum Decision Unit volume of soil recommended for characterization is 20 cubic yards (HDOH 2023). Although proper management might still be required, for example disposal of grossly contaminated soil disturbed during construction projects, smaller volumes of contaminated soil are not anticipated to pose a significant, long-term risk to human health and the environment under typical site scenarios and no further action under direct, HDOH oversight is warranted. Potential exceptions include the use of contaminated soil in small play areas used by young children. This does not necessarily imply that small volumes of heavily impacted soil do not pose a potential environmental concern, since the presence of isolated “hot areas” within a larger DU can cause the DU as a whole to fail EALs.

A brief description of each hazard is provided in Figure 1-2a. A schematic of common, potential environmental hazards associated with contaminated soil and groundwater is depicted in Figure 1-2b. Detailed discussions of each hazard are provided in Chapters 4 and 5 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 vapor. 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, polychlorinated biphenyls [PCBs], etc.) will usually be flagged for potential direct exposure hazards. Soil contaminated with chlorinated, volatile chemicals that are potential carcinogens (e.g., tetrachloroethylene [PCE] or TCE) or soil contaminated with gasoline or diesel fuel is typically flagged for potential vapor intrusion hazards. Soil contaminated with petroleum, solvents or highly mobile pesticides (e.g., total petroleum hydrocarbon [TPH] gasoline or diesel, benzene, toluene, ethylbenzene and xylenes [BTEX], PCE, atrazine, etc.) will often be flagged for 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 and an ecological risk assessment might be require is sensitive habitat have been impacted.

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, methyl tertiary butyl ether [MTBE]).

1.3 Tier 1 Environmental Action levels

Tier 1 *Environmental Action levels* (Tier 1 EALs are concentrations of contaminants in soil, soil vapor 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 EALs. Exceeding the Tier 1 EAL 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 action 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 EALs is provided in Chapter 2. A detailed discussion of the compilation and development of the EALs is provided in Appendix 1.

1.3.1 EAL Surfer

The EAL Surfer, an Excel-based version of the lookup up tables, makes use of the EALs and the identification of potential environmental hazards at contaminated sites especially easy. The EALs should be rounded to two significant digits for comparison to site data. The EAL Surfer is available for download from the HDOH web page (refer to contact information at beginning of guidance). Use of the EAL Surfer in EHE reports is recommended. Guidance on use of the Surfer and example printouts are provided in Chapter 3.

1.3.2 Use of EALs in Site Investigations

One of the most basic uses of the EALs 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 EALs. Further consideration of contaminants that do not exceed Tier 1 EALs is not necessary. This assumes of course that existing data are representative of overall site conditions.

The EALs presented in Tables A and B reflect unrestricted land use (e.g., residential allowed) under four scenario where underlying groundwater is or is not a potential source of drinking water and the site is situated >150m or <150m from a surface water body (originally developed for petroleum plumes; Shih et al. 2004). These scenarios are discussed in Section 2.4. The EAL Surfer allows for modification of land use from unrestricted to commercial/industrial only. The resulting EALs are no longer considered Tier 1, however, since a restriction on use of the property might then be required. This can include a restriction on the excavation and offsite reuse of soil impacted the most stringent, Tier 1 EALs (i.e., unrestricted landuse, situated over groundwater that is a source of drinking water and <150 meter from surface water). Refer to the HDOH document *Guidance for Soil Stockpile Characterization and Evaluation of Imported and Exported Fill Materia*l (HDOH 2017a) for additional information.

The lateral and vertical extent of contamination should be determined for COPCs that exceed the Tier 1 EALs (or approved, alternative action 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 EALs (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 24 mg/kg then laboratory bioaccessibility tests should be run on the same sample (refer to Chapter 4). If the reported concentrations of volatile contaminants exceed action levels for vapor intrusion concerns then soil vapor data should be collected. Incorporating these decision 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 EALs in Environmental Hazard Evaluations

The most important use of the Tier 1 EALs is the rapid identification of potential environmental hazards associated with contaminated soil and groundwater (refer to Section 2.1). 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 EALs provided in Tables A through E will only indicate if a potential hazard is present (i.e., “yes” or “no”). If the Tier 1 EAL is exceeded, site data should be compared to the detailed action levels used to develop the Tier 1 EAL. 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 EAL Surfer will significantly expedite this process.

Potential environmental hazards identified in a Tier 1, action level EHE 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 be 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 volatile organic chemicals (VOCs) contaminated sites where occupied structures are present (or proposed). The collection of soil vapor data at these sites can be highly useful and in some cases required. A detailed review of groundwater data can replace soil action 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 EALs 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 EALs. The Tier 1 EALs 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 EALs presented in Appendix 1 of this guidance and, in particular, use of the accompanying *EAL 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 action 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 as identify 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 and in the HEER office *Technical Guidance Manual* (HDOH 2023).

1.4 Decision Unit and Multi Increment Investigation Strategies

The use of *Decision Unit (DU)* and *Multi Increment (MI) sampling* methods is strongly recommended for the investigation of contaminated sites. Refer to the Sections 3-5 of the HEER Office *Technical Guidance Manual* for a detailed discussion of DU-MI investigation methods (HDOH 2023). A brief overview is provided below.

1.4.1 Decision Units

A DU is an area over which a decision is to be made regarding the need to address contamination within that area. Strictly speaking, a DU is a volume of soil rather than simply an area, since the thickness of the DU is often a key factor. A DU can be an identified spill area or “hot spot,” a residential yard, a playground or schoolyard, a garden, a commercial/industrial property or other specific area of interest. “Perimeter DUs” are designated to characterize the lateral and vertical extent of contamination.

The location, size, and shape of a DU depend on the nature of the decision that will be made using the data to be collected. For example, if a site is being sampled to decide whether contaminants pose potential direct exposure hazards, then the size of the DU is based on the size of the area over which average exposure is assumed to take place (i.e., a 5,000 ft^2 house lot). The consideration of individual spill areas as separate DUs is generally necessary to assess leaching, vapor intrusion and gross contamination hazards posed by highly mobile and volatile chemicals. Examples include releases from pipelines or storage tanks, as well as heavily contaminated portions of pesticide mixing areas.

Discrete samples can sometimes be useful for initial delineation of spill area boundaries but are not reliable for final decision making. Multi Increment sample data should be collected for more detailed characterization. These methods are amenable to both volatile and non-volatile contaminants and in both surface and subsurface soils, as well as sediments.

When using a DU strategy, the entire area of a DU is acted upon as a single entity based on the data collected from that unit, regardless of internal variation. If the data suggest that remediation is required, then this applies to the entire DU. This makes it important during the selection of DUs to isolate areas of obvious, heavy contamination in order to reduce the volume of soil or groundwater that must be treated. The isolation of heavily contaminated areas can be based on previous sampling data or other relevant indicators such as variations in soil type across the site, the presence of visible soil stains or stressed vegetation, knowledge of past use of chemicals at the site, site topography, etc.

1.4.2 Multi Increment Samples

The MI samples should be collected from selected DUs whenever practicable. This approach involves the collection of thirty to seventy-five small *increments* of soil (typically 10 to 50 grams per increment) within a designated DU area, depending on the nature of the contaminant released. A larger number of increments is collected from DUs where the contamination might be present as small nuggets or clumps (e.g, lead-based paint, PCBs).

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 DU. The MI sampling data typically have low variability and high reproducibility, which results in a high level of confidence for decision-making. Multiple MI samples collected from the same DU are referred to as *replicates*. Data for replicate samples can be statistically analyzed to help evaluate the precision of the field sampling methodology. HDOH recommends that three replicate samples, referred to as *triplicates*, be collected in 10% of the DUs to be investigated (minimum one set of triplicate samples per site).

The MI 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. 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 sectoral splitter or by collecting an MI sample using the same approach as used to collect the field sample but with smaller tools and increment masses. A minimum subsample mass of 10 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.

The MI 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. Alternative methods are also allowable. Refer to Section 4 of the HDOH Technical Guidance Manual for addition information on the collection of MI samples to be tested for VOCs (HDOH 2023).

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 EALs is summarized in Chapter 2. Chapter 3 discusses the preparation of basic *Environmental Hazard Evaluations*. Chapter 4 presents more 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 EALs are discussed in a series of appendices presented in Volume 2. The EAL Surfer and advanced models that accompany this guidance document are available for download from the HDOH HEER Office website (see contact information at the front of the document).

1.6 Limitations

The EALs presented in the lookup tables are NOT required, regulatory "cleanup standards". Use of the EALs 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 EALs 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 10 known or suspected carcinogens or more than 5 chemicals with similar noncarcinogenic health effects have been identified (potential cumulative risk concerns even if no individual EAL exceeded;; see section 2.10 and Appendix 1, section 4.2);

- 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 HDOH on a site-by-site basis. Consideration of cumulative risk for petroleum-contaminated soil or groundwater is not required unless specifically requested by HDOH, since cumulative risk is directly incorporated into action levels for TPH.

Soil EALs 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. Action levels for leaching of metals in soil are not considered reliable and are not included in the Tier 1 EALs. Lab-based methods to evaluate this potential hazard are discussed in Chapter 4.

It is conceivable that soil, groundwater and soil vapor action levels developed to address the emission of chlorinated VOCs 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 action 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., polynuclear aromatic hydrocarbons [PAHs] and other heavy petroleum compounds).

Direct-exposure action levels for construction and utility trench workers are presented in Appendix 1, Table I-3.. The action levels consider ingestion and dermal contact with contaminated soil as well as the inhalation of vapors and dust for 120 days a year over several years (see Appendix 1, Section 4.2 and Appendix 2). Construction/Trench Worker action levels are consistently higher than direct-exposure action levels for unrestricted land use, which consider long-term exposure of young children to contaminants in soil (see Appendix 1, Table I-1). Action levels for numerous metals and in some cases VOCs are lower than comparative action levels for commercial/industrial land use and take precedence over the latter for screening of commercial/industrial sites (see Appendix 1, Table I-2). This is due to an assumed greater exposure to dust and vapors posed to construction and trench workers during work activities, even though exposure is assumed to occur over a fewer number of days per year In addition, *the model used to evaluate inhalation of vapors may not fully consider soil that is being disturbed during excavation or exposed in trenches, however.* The HDOH is investigating the use of alternative models to make the action levels more applicable to these circumstances. **In the interim, exposure of workers to volatile contaminants in soil during construction or trench-related activities should be minimized and discussed in a properly prepared health and safety plan.**

2

Environmental Action Levels

2.1 Introduction

Environmental Hazard Evaluations, as described in Chapter 3, are based on the use of *Environmental Action Levels* (EALs) to quickly screen soil, soil vapor and groundwater data for potential environmental hazards. As reviewed below, individual action levels were developed to address each of the environmental hazards described in Section 1.2 for each contaminant listed in the lookup tables, as available and applicable (refer to Figures 1-1 and 1-2). The lowest action level represents the concentration of the contaminant in the respective media where the threat to human health or the environment is considered to be insignificant under any site condition. This is selected as that contaminants Tier 1 EAL. Soil and groundwater Tier 1 EALs for approximately 150 common contaminants are summarized in Tables A through D. Vapor intrusion action levels for indoor air and subslab soil vapor r are presented in Table C. Table D presents action levels for marine, freshwater and estuarine aquatic habitats. Table E presents an additional set of soil vapor action levels than can be used to assess potential leaching impacts to groundwater. A detailed discussion of the development of the Tier 1 EALs is provided in Appendix 1.

The presence or absence of potential environmental hazards at a contaminated site is determined by the direct comparison of soil, groundwater and/or soil vapor data to Tier 1 EALs for targeted contaminants of concern. Exceeding the Tier 1 EAL 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 EALs 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 EHEs.

The EAL Surfer included with this guidance and available for download on the EHE webpage provides a quick and easy method to screen site data and, as needed, identify specific, potential environmental hazards (refer to Chapter 3). Sample printouts from the Surfer can be included in the appendices of an EHE report for reference. **Use of the EAL Surfer to prepare EHEs is strongly recommended.**

2.2 Organization of Lookup Tables

The Tier 1 EAL lookup tables are organized to reflect four default *conceptual site models* for contaminated sites in Hawai‘i, based on groundwater utility and proximity to a surface water body (Figure 2.1):

	Drinking Water Resource Threatened	Drinking Water Resource NOT Threatened
≤150m to surface water	A-1	B-1
>150m to surface water	A-2	B-2

The first table presents soil and groundwater action levels for sites that directly overlie a current or potential source of drinking water (Table A). Two sets of action levels are provided, one for sites within 150m (500 feet) of a surface water body and one for sites located more than 150m (500 feet) from a surface water body. A second table presents a similar set of action levels for sites that do not directly overlie a current or potential source of drinking water (Table B).

The Tier 1 EALs for soil assume that contaminated soil is exposed at the ground surface or could be excavated and spread out at the ground surface at some time in the future. The Tier 1 EALs 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, including the export of soil for reuse in offsite areas, and highlight soils that must be properly managed if complete remediation to unrestricted future use is not feasible (refer to HDOH 2017a). Alternative soil action levels for sites that will be restricted to commercial/industrial use only are included in Appendix 1 and included in the EAL Surfer (refer to Chapter 3). Use of these action levels for final site closure should be discussed with HDOH 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 default, conceptual site models and Tier 1 EAL lookup tables is presented in the following sections. Compilation of the Tier 1 EALs is discussed in more detail in Appendix 1.

2.3 Use of Lookup Tables

The step-by-step use of the Tier 1 EAL lookup tables and preparation of an EHE is summarized below and in Figure 1-3. A detailed discussion of EHE reports is provided in Chapter 3.

Step 1: EAL Updates and Applicability

Check the HDOH web page listed at the beginning of this guidance to ensure that the most up-to-date version of this document is being used. Review the limitations discussed in Section 1.6 to determine if the EALs are applicable to the subject site.

Step 2: Identify All Chemicals of Potential Concern

An EHE must be based on the results of a thorough site investigation, where all chemicals of potential concern have been identified. A summary of the site investigation results should be included in the EHE in order for it to be reviewed as a "stand alone" document. An outline of the information that should be included in an EHE is provided in Section 9.

Step 3: Select Lookup Table(s)

Determine the beneficial use of impacted or threatened groundwater beneath the site and the distance to the nearest surfaced water body from the downgradient edge of the release site (refer to Figure 2.1). In general, all groundwater inland of the Underground Injection Control (UIC) lines should initially be treated as a current or potential source of drinking water (see Section 2.4.3, Appendix 7).

Reference can be made to the Water Resources Research *Center Aquifer Identification and Classification* reports, however, to evaluate the utility of the groundwater on a more site-specific basis. This information is then used to select soil and groundwater action levels in Table A (potential source of drinking water) or Table B (not a potential source of drinking water). Tier 1 EALs for unrestricted landuse, situated over groundwater that is a source of drinking water and <150 meter from surface water) must be considered for offsite reuse of soil excavated from the property (HDOH 2017a).

Step 4: Select Soil and/or Groundwater EALs

Select appropriate soil EALs from the appropriate lookup table. EALs for groundwater are provided in the adjacent column of each table and are not dependent on land use or depth to impacted soil. Replace EALs with naturally occurring, background concentrations of chemicals of concern (e.g., assumed background arsenic = 24 mg/kg) or laboratory method reporting levels if higher (see Section 2.8).

Step 5: Determine Extent of Impacted Soil and/or Groundwater

Using the selected EALs, determine the extent of impacted soil or groundwater and areas of potential environmental hazard at the site and offsite, as required. (Soil data should be reported on a dry-weight basis. While this is not likely to affect final cleanup decisions, it is more in line with assumptions used to develop direct-exposure action levels for human health concerns. See also Appendix 1, Section 7.3.) If a groundwater plume originating from an inland release site is suspected to have migrated to within 150m of a surface water body, then additional downgradient investigation may be necessary, using more conservative action levels for this zone.

Step 6: Evaluate the Need for Additional Investigation or Corrective Actions; Submit EHE Report

A detailed discussion of EHE reports is provided in Chapter 3. Based on a comparison of available site data to the EALs, evaluate the need for additional action at the site (e.g. additional site investigation, remedial action, preparation of a more site-specific risk assessment, etc.). The collection of Multi Increment sample data is recommended for site characterization (refer to Section 1.4). Detailed guidance on collection and use of MI samples as well as the use of discrete sample data is provided in the HEER Office *Technical Guidance Manual* (HDOH 2023).

This evaluation should be summarized in the EHE report and workplans for additional actions prepared as needed (see Section 3). Decisions for or against additional actions should be made in conjunction with guidance from HDOH. Adjustment of Tier 1 action levels in a more advanced, environmental hazard evaluation is discussed in Chapter 4.

2.4 Default Conceptual Site Models

2.4.1 Land Use

The Tier 1 EALs for soil listed in Tables A and B were developed to allow unrestricted current and future use of a property. This includes consideration of direct exposure action levels suitable for use of the site as residences, hospitals, day-care centers, and other sensitive purposes (refer to CalEPA 2002). Action levels for unrestricted land use incorporate conservative assumptions with respect to long-term, continuous exposure of children and adults to impacted soils in a residential setting (see Appendices 1 and 2). As discussed in Chapter 3, alternative (and potentially less stringent) soil action levels for site that will be restricted to commercial/industrial land use only can be considered on a case-by-case basis.

2.4.2 Exposed versus Isolated Contaminated Soil

The Tier 1 EALs are based on an assumption that contaminated soil is currently exposed at the ground surface or could be excavated and exposed at the surface in the future. This assumption eliminates the need to consider long-term management of soil that is not currently exposed. As discussed in Chapter 4, the potential for deep or otherwise isolated contaminated soil to be exposed at the ground surface can be reviewed on a site-specific basis as needed.

2.4.3 Groundwater Utility

Groundwater utility is determined based on the location of the site with respect to the Underground Injection Control (UIC) Line and the state *Aquifer Identification and Classification* technical reports prepared by the University of Hawai‘i (refer to Figure 2.1). The UIC line is used to designate areas where industrial wastewater injection can be injected into the subsurface under permitted conditions (HAR Chapter 23, Title 11). The procedure for determination of groundwater utility is summarized below and described in more detail in an HDOH policy dated September 19, 1995, provided in Appendix 7. .

The UIC lines established for each island in most cases closely follow the shoreline and delineate areas of fresh versus brackish, groundwater. First-encountered groundwater in areas situated makai (oceanward) of the UIC line is by regulation not considered to be a potential source of drinking water (Hawai'i Administrative Rules Title 11, Chapter 23). Environmental Action Levels for nondrinking water scenarios apply to both soil and groundwater situated in these areas (Scenarios B-1 and B-2 in Figure 2-1). The groundwater is typically very shallow (e.g., <25 feet below ground surface [ft bgs]), unconfined and highly vulnerable to contamination. Exclusion from consideration as a potential source of drinking water might be due to high salinity, low permeability and production, historic contamination or the need to permit the injection of industrial wastewater in these areas.

Groundwater situated mauka (inland) of the UIC line is in most cases classified as a current or potential source of drinking water. Soil and groundwater action levels applicable to drinking water impact scenarios apply to these areas (Scenarios A-1 and A-2 in Figure 2-1). Some areas of groundwater situated mauka of the UIC line are not considered to be viable sources of drinking water, however, for similar reasons as noted above. Refer to the *Aquifer Identification and Classification* reports prepared for individual islands by the Water Resources Research Center (WRRC) at the University of Hawai'i at Manoa for information on specific areas (see Appendix 7). Environmental Action Levels for nondrinking water scenarios again apply to these areas. This determination can be made without consultation with the HDOH but should be documented in the site investigation report. A copy of the WRRC map that includes the area in question should be included. If the report will be reviewed by HDOH then is useful to point this consideration out to the project manager prior to submittal of a final report.

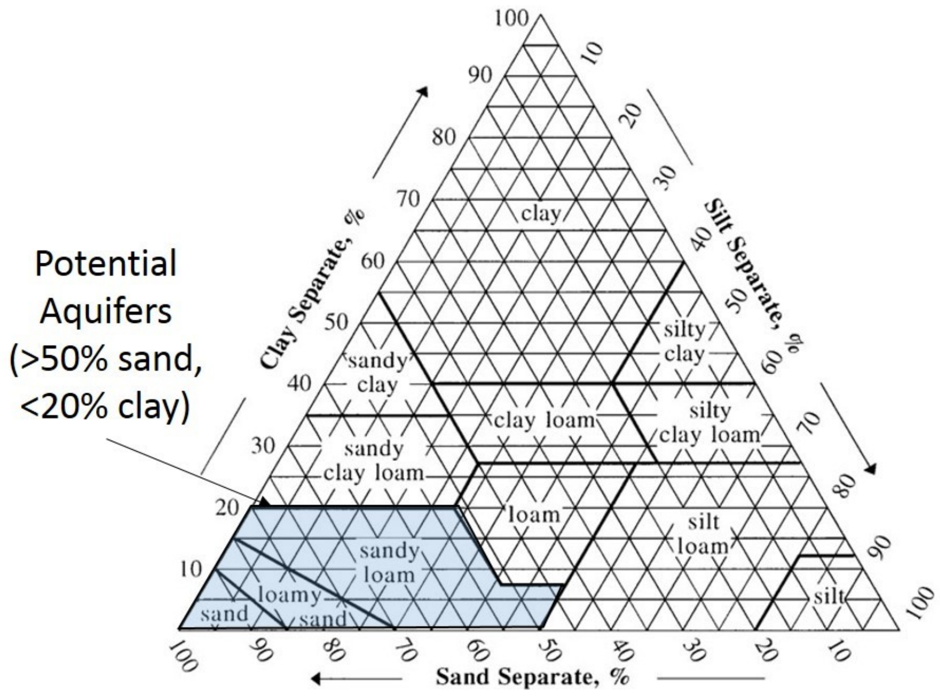
Note that shallow groundwater situated makai of the UIC is not considered to be a potential source of drinking water, even if the aquifer is classified as such in the WRRC reports. The groundwater in these areas has been formally designated for underground injection of wastewater by the state and use of the water for drinking water is not allowed.

Deeper, confined aquifers in areas makai of the UIC line might, however, be classified as a potential source of drinking water. This is common in areas where deep, basal aquifers in basaltic bedrock are overlain by a thick sequence of unconfined, coastal “caprock” sediment (refer to WWRC reports in Appendix 7). Groundwater action levels for nondrinking water resource scenarios apply to the uppermost groundwater. Groundwater action levels applicable to drinking water apply to the deeper zone. Action levels for leaching of contaminants from vadose-zone soil should be based on the utility of the uppermost, first-encountered groundwater, since the deeper aquifer is presumed to be confined and not susceptible to surface releases.

Additional hydrogeologic criteria for potential exclusion of a given occurrence of groundwater from consideration as a potential source of drinking water include (after CalEPA 2013):

- Total dissolved solids in groundwater is greater than or equal to 3,000 mg/L; OR
- Water bearing unit is not sufficiently permeable to produce an average, sustained yield of 200 gallons of water per day.

Such considerations should be carried out in coordination with the HDOH. Groundwater in coastal areas, geothermal fields, etc., can contain levels of dissolved solids that make the water unsuitable as a potential source of drinking water. The hydraulic conductivity of coastal, caprock sediments that lack a significant amount of coarse-grained material can be too low to allow for an adequate, sustained yield of groundwater. The hydraulic conductivity of an unconsolidated formation must in general be greater than 10^{-6} to 10^{-7} meters per second for the formation to be considered a potential aquifer (Freeze and Cherry 1979). This is equivalent to a “silty sand” under the Unified Soil Classification System (ASTM 1985) and similar to a “sandy loam” under the US Department of Agriculture soil classification (USDA 1987). In combination, unconsolidated geologic units that are comprised of less than 50% sand-size ($\leq$2mm) material or more than 20% clay-size material ($\leq$0.002 mm) are typically not considered to be viable "aquifers" or potential sources of useable groundwater. The relation of soil (or more likely sediment) type versus potential aquifer potential is summarized in the following diagram (after USDA 1987):



Potential Aquifers (>50% sand, <20% clay)

The potential for a given unit of bedrock to serve as a viable source of groundwater similarly depends on the primary and secondary porosity in the rock and the quality of the groundwater. Consideration must also be made for the potential migration of groundwater out of a geologic unit that is insufficiently permeable to be considered an aquifer and into a more permeable unit that could serve as a viable source of drinking water.

In general, soil and groundwater action 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. This requires that soil to be excavated from a property and used in an offsite area be screened against Tier 1 action levels applicable to areas that overlie a source of drinking water, even if groundwater beneath the site of origin is not considered as such (refer to HDOH 2017a). For chemicals that are especially toxic to aquatic life, however, Tier 1 action 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, D-series lookup tables in Appendix 1 or use the EAL Surfer for individual contaminants.

Note that apparent background levels of relatively mobile, heavy metals in groundwater can marginally exceed the groundwater action levels in some areas, especially in areas of clay-rich, caprock sediments (e.g., lead; sometimes reported above the action level with no apparent anthropogenic source). A detailed study of background metals in groundwater has not been carried out by the HEER Office. Natural, trace levels of hexavalent chromium in basalt aquifers can also exceed highly conservative, risk-based screening levels for drinking water. As discussed in a technical memorandum included in Appendix 8, however, the hexavalent chromium does not pose a significant risk to human health.

Groundwater action levels should be compared to dissolved-phase chemical concentrations unless instructed by the overseeing regulatory agency. This may require filtering of turbid samples (refer to Section 6 of the HEER Office *Technical Guidance Manual*). Filtering should not be carried out on samples to be tested for volatile chemicals.

2.4.4 Threat to Surface Water Habitats

The conceptual site models used to develop the Tier 1 EALs assume that contaminated groundwater at all sites could at some time migrate offsite and discharge into a body of surface water (refer to Section 1.2). This could occur due to the natural, downgradient migration of groundwater or to human activities such as dewatering of construction sites. To address this concern, Tier 1 groundwater EALs for both drinking water sources (Table A) and non-drinking water sources (Table B) include consideration of surface water goals for aquatic toxicity (refer to Chapter 5 of Appendix 1).

Promulgated water quality standards and correlative action levels for contaminants that lack promulgated standards are presented in Table D. The selection of action 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 EALs (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 EAL Surfer).

Concentrations of contaminants in groundwater should meet chronic surface water goals at the point that the groundwater discharges into a sensitive aquatic habitat. Chronic surface water goals are therefore included in development of action levels for groundwater situated within 150m of a surface water body (Zones A-2 and B-2 in Figure 2.1; refer to Appendix 1). This is likely to be overly conservative for many petroleum-contaminated sites but is appropriate under a Tier 1 evaluation. If long-term monitoring of groundwater (e.g., two-plus years) adequately demonstrates that a plume if not likely to discharge into a surface water body above chronic goals even though it is within 150m of the body, then acute surface water goals can be used as final cleanup and closure levels.

Acute surface water goals are included in development of groundwater action levels for sites located more than 150m from a surface water body (Zones A-1 and B-1 in Figure 2.1; refer to Appendix 1). An argument could be made that plumes of petroleum-contaminated groundwater beyond this distance will never naturally migrate to a surface water body and that this concern does not need to be addressed. Plumes of heavily contaminated groundwater in inland areas pose potential concerns for future construction or utility maintenance related activities, however. It is important that the presence of these plumes is identified ahead of time and actions taken to ensure that contaminated groundwater is not inadvertently discharged to storm sewers without adequate testing and treatment. Documenting the nature and location of inland plumes that do not otherwise pose a threat to human health and the environment is especially important for contaminants that do not readily biodegrade, such as chlorinated solvents and MTBE. Additional characterization and monitoring of groundwater impacted with these contaminants may be needed if it is suspected that the plumes could move to within 150m of a surface water body at levels above chronic surface water goals.

The groundwater action levels 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 action levels with respect to dilution of groundwater upon discharge to surface water was therefore not considered. Consideration of dilution/attenuation factor and alternative groundwater action levels for the protection of surface water quality may, however, be appropriate on a limited basis in highly developed, industrial waterfront areas.

The soil and groundwater action levels presented in the lookup tables do not directly address the protection of sediment quality. Site-specific concerns could include the accumulation and magnification of concentrations 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 highly sorptive (lipophilic) chemicals, including heavy petroleum products.

Potential erosion and runoff of surface soils from impacted sites may also need to be considered, particularly at sites impacted with metals and pesticides that are situated near a sensitive body of surface water. 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 Department of Health.

2.5 Compilation of Environmental Action Levels

2.5.1 Tier 1 EALs

A detailed discussion of the compilation of all action levels is provided in Appendix 1. Approximately 150 chemicals are listed in the lookup tables. For each chemical, an action level was compiled to address each of the environmental hazards noted above, as applicable and available. The lowest of the individual action levels for each hazard was selected for inclusion in the summary lookup tables. This ensures that the Tier 1 EALs are protective of all potential environmental concerns and provides a tool for rapid screening of site data. Where EALs 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 action levels for individual environmental hazards is provided in Figure 2-2. A detailed discussion of each source and associated models is provided in Appendix 1. In most cases, the action levels were drawn from published references (e.g., published drinking water and surface water standards). In other cases, published models were used to develop action levels for the subject environmental hazard (e.g., vapor intrusion action levels).

An example of the selection of summary, Tier 1 EALs for benzene is presented in Figure 2-3 for unrestricted ("residential") land use, drinking water resource threatened, site ≤150m from a surface water body. For soil, the action level for leaching hazards (0.22 mg/kg) is lower than the action levels for each of the other environmental hazards. This action level is therefore selected as the Tier 1 EAL presented in Table A of the summary lookup tables. For groundwater, the action level for drinking water toxicity concerns drives environmental hazards and is selected as the Tier 1 EAL presented in Table A (5 µg/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 be seen by a review of the detailed lookup tables in Appendix 1 or by using the EAL Surfer to browse through various chemicals under different site scenarios. Tier 1 EALs 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 EAL in Figure 2-3). Tier 1 EALs 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 EALs 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 EALs 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 4.6).

Driving environmental hazards are similar for groundwater. Tier 1 EALs 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). Action levels for taste and odor concerns drive the selection of Tier 1 EALs for several, less toxic chemicals in drinking water supplies (e.g., xylenes and ethylbenzene). Tier 1 EALs 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., dichlorodiphenyltrichloroethane [DDT] and dieldrin). Vapor intrusion into buildings drives the selection of Tier 1 EALs for carcinogenic, highly volatile contaminants for groundwater that is not used as a source of drinking water (e.g., PCE and vinyl chloride).

2.5.2 Comparison of Organochlorine Pesticide Data to EALs

Toxicity factors and associated action levels for several organochlorine pesticides are based on "technical" products that can include mixtures of multiple chemicals or multiple isomers of the same chemical. Reported concentrations of the mixtures and isomers must be summed for comparison to the EALs. Examples are provided below.

Technical Chlordane

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 (refer also to the HEER *Technical Guidance Manual;* HDOH 2023). 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 its relatively strong sorption to organic carbon and clay particles (koc >5,000 cm^3/g; refer to Section 4.4 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 29 mg/kg. Refer to Section 4.3.3 for additional information.

Other Organochlorine Pesticides

Individual isomers of organochlorine pesticides and related compounds tested using USEPA Method 8081a or similar method should be summed for comparison to action levels unless listed separately in the lookup tables. Examples of groupings include:

- Total Dichlorodiphenyltrichloroethane (DDT): Isomers of DDT (similar for DDE and DDD);
- Total Endosulfan: Endosulfan I, Endosulfan II, Endosulfan Sulfate;
- Total Endrin: Endrin, Endrin Aldehyde, Endrin Keytone; and

- Total Hexachlorobenzene (BHC): alpha, beta and gamma BHC (Lindane).

Alpha and beta BHC are assumed to be minor components of Lindane and do not need to be assessed separately, even if reported separately by the laboratory. Heptachlor and heptachlor epoxide should be evaluated separately if not associated with mixtures of Technical Chlordane (see above).

2.6 Contaminants of Potential Concern at Petroleum Release Sites

2.6.1 TPH and Targeted Individual Compounds

Refer to Section 6 of Appendix 1 for a detailed review of the chemistry and toxicity of petroleum compounds. Staff from the HDOH HEER Office assisted in preparation of a document prepared by the Interstate Technical and Regulatory Council (ITRC) that discusses risk-based approaches for the evaluation of “Total Petroleum Hydrocarbons (TPH)” in soil, water and air (ITRC 2018). Case studies included in the document are based on large part on experience gained from Hawaii’s ten-plus years of experience with risk-based approaches for TPH.

Recommended, target analytes for petroleum contaminated soil and groundwater are provided in Figure 2-4. This table was originally published in the HDOH technical memorandum *Long-Term Management of Petroleum-Contaminated Soil and Groundwater* (HDOH 2007b). Slight modifications have been made in subsequent updates and reflected in the figure (e.g., methylnaphthalene no longer recommended for soil vapor samples). Information from the memorandum has been incorporated into this guidance document. Refer also to Section 9 of the HEER office *Technical Guidance Manual* (HDOH 2023).

Petroleum is a complex mixture of hundreds of different compounds composed of hydrogen and carbon or “petroleum hydrocarbon” compounds (API 1994). The bulk of these compounds are evaluated collectively under the all-inclusive category of “Total Petroleum Hydrocarbons (TPH).” The term “TPH” is defined for use in this guidance as the sum total of parent petroleum hydrocarbons as well as petroleum hydrocarbon-related metabolites and other degradants. The latter includes alcohols, phenols, ketones, aldehydes and organic acids (Mohler et al. 2013; Zemo et al. 2013, 2016). The toxicity of parent, petroleum hydrocarbon compounds and related degradants is assumed to be similar for initial screening purposes. A detailed overview of the chemistry and toxicity of petroleum-related metabolites is provided in the document *Petroleum Metabolites Literature Review and Assessment Framework* (CalEPA 2016b). This issue will be reviewed in the

ITRC document noted above, with examples provided in the Case Studies appendix to that document (ITRC 2018). Methane, a product of anaerobic, biologic respiration that is commonly identified at petroleum-release sites, is assessed separately and is not included under the definition and measurement of TPH.

Laboratory analytical methods for TPH were designed to report the total concentration of petroleum hydrocarbons in a sample with respect to a gasoline, diesel or residual fuel standard (e.g., Method 8015; USEPA 2007). It has traditionally been assumed that these test methods are also adequate to quantify petroleum-related, degradation compounds in the samples. This assumption has recently been called into question, however, and the need for analytical methods more specific to degradation compounds is currently under review (Bekins 2016; ITRC 2018). Silica gel cleanup methods can be used to separate and quantify non-polar, parent compounds from polar, degradation compounds (see HEER TGM Section 9; HDOH 2023; see also Mohler et al. 2013; Zemo et al. 2013, 2016). Petroleum-related, polar compounds are considered to have similar toxicities as the parent compounds, however, and TPH action levels are applicable to both the nonpolar and polar fractions for initial screening. The use of alternative toxicity factors and physiochemical constants for metabolites can be proposed in a site-specific Environmental Hazard Evaluation.

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). Vapor-phase compounds are typically dominated by C5-C8 aliphatics (Brewer et al, 2013).

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 methylnaphthalenes), and heterocyclic compounds with carbon ranges of C5 to C25. Liquid fuels are characterized by a dominance of C9-C25 aliphatics with a lesser amount of C9-C10+ aromatics. Vapor-phase compounds are characterized by a mixture of C5-C8 aliphatics and C9-C12+ aliphatics with only minor amounts of aromatics (see Section 6 of Appendix 1). Although still potentially significant, vapor emissions from middle distillate release sites tends to be an order of magnitude lower than for gasoline-contaminated for the same volume and magnitude of contamination.

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. With the exception of waste associated with manufactured gas plants, vapor emissions associated with residual fuels releases are significantly lower than emission associated with middle distillate or gasoline releases and generally do not pose significant vapor intrusion hazards. Soil vapor data may be warranted to document a lack of vapor problems, however, as well as to evaluate potential methane buildup.

Due to the complex nature of petroleum mixtures, petroleum contamination should be evaluated in terms of both TPH and target "indicator chemicals" for the specific type of petroleum product released (e.g., BTEX, MTBE, 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.

Eighteen priority pollutant PAHs are listed in the USEPA Regional Screening Level (RSL) guidance (USEPA 2023):

- 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 & 2)
- naphthalene
- phenanthrene
- pyrene

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). As indicated in the Figure 2-4, only naphthalene needs to be tested for at gasoline release sites. Soils impacted with middle distillates should be tested or both methylnaphthalenes and naphthalene (e.g., diesel, JP-8 jet fuel, etc.). The full suite of PAHs should be considered at sites with releases of heavier petroleum fuels and waste oil, unless site-specific information on the product released can be used to justify elimination of specific PAHs.

Understanding the potential source of PAHs in soil is important for decision making. Anthropogenic, background concentrations of PAHs in urban area soils due to auto exhaust and other sources can easily exceed risk-based screening levels based on a conservative, excess cancer risk of 10^{-6} (e.g., MADEP 2002b). Samples of soils impacted with waste oil can have concentrations of benzo(a)pyrene and related PAHs in the range of one to ten-plus parts-per-million - well above Tier 1 EALs for potential direct-exposure concerns. Correlative concentrations of TPH up to approximately C40 are usually in the thousands of parts-per-million range. Soils impacted with asphalt can express similar concentrations of PAHs. An asphalt source of the PAHs is usually readily identifiable by relatively low concentrations of TPH, usually in the low hundreds of parts-per-million range, however. The bioavailability of PAHs in asphalt is relatively low and their presence at these levels does not pose a significant health risk. Asphalt is also usually regulated as an inert waste that can be used for fill material. Relatively low concentrations of TPH are also often reported for soils impacted with coal tar, including petroleum-based patching material for roads or roofing. The concentration of PAHs associated with these materials is often in the hundreds of parts-per-million range, however, highlighting coal tar or similar material as the likely source of the PAHs. Concentrations of PAHs in soil at these levels could pose potential direct-exposure concerns, even if the bioavailability of the PAHs is relatively low.

Volatile components of petroleum that are not specifically identified as target indicator compounds in Figure 2-4 but reported as separate compounds by the laboratory using Method 8260 or similar methods can in general be ignored (e.g., hexane, methylbenzenes, alkanes, alkenes, alkyl benzenes and other aromatics not specifically identified as target indicator compounds; refer to Section 2.11 and NEIWPCC 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 2-4 (refer to Appendix 1, Chapter 6).

Soil, groundwater and soil vapor samples must always be tested for TPH (or equivalent) 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). Refer to the HEER office *Technical Guidance Manual* for additional information on laboratory methods. 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. Analysis of soil vapor for TPH is commonly reported as *Total Volatile Hydrocarbons* or *TVH*. Consult a laboratory with expertise in analysis of total hydrocarbon fractions in soil vapor for additional information.

Environmental action 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). The following carbon range fractions were targeted:

- C5-C8 aliphatics;
- C9-C18 aliphatics;
- C19+ aliphatics; and
- C9+ aromatics.

Note that the lower end of reported light aliphatics can range from C3 to C6, depending on the laboratory. This is unlikely to make a significant difference to the total TPH reported. Any starting point within this range is acceptable for comparison to the EALs. A more in-depth analysis of the specific carbon range makeup of TPH can be carried out in a site-specific environmental hazard assessment as needed. This may especially be useful for cases where the reported concentration of TPH in soil vapor exceeds the Tier 1 action level. Carbon range data are less useful for soil, since gross contamination concerns generally outweigh direct-exposure concerns under residential or commercial scenarios for exposed soil.

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 moderately more volatile and mobile than 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 2-4). 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 recommended for the same reason (refer to Figure 2-4).

The chemical composition of gasolines and middle distillates can be presumed with reasonable confidence (see Section 6 in Appendix 1). In 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.

2.6.2 Ethanol

Ethanol should be tested for at release sites where it is a known or suspected fuel additive or where it was stored or transferred. Toxicity factors are not available for ethanol (refer to Appendix, Table H). Ethanol is not believed to be significantly toxic at concentrations likely to be found in contaminated soil or groundwater. It is also readily biodegradable under both aerobic and anaerobic conditions and not anticipated to persist in the environment for long periods of time. Tier 1 soil, groundwater and indoor air action levels presented in this guidance are therefore based on gross contamination hazards only (odors in soil, taste and odor in drinking water supplies, generation of explosive vapors, etc., refer to Appendix 1).

In addition to gross contamination hazards, ethanol's high rate of biodegradability may result in additional adverse impacts, including (after MADEP 2002a):

- Increased levels of gasoline constituents in groundwater due to co-solvency effects in the presence of high concentrations of ethanol; and
- Longer plumes of petroleum-contaminated groundwater and other dissolved gasoline hydrocarbons due to the high biochemical oxygen demand exerted by ethanol and the depletion of oxygen and nutrients available for the degradation of other constituents. This has implications for natural attenuation considerations as a long-term cleanup remedy.

2.7 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 4.3).

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).

The types and persistence of pesticides commonly used in agricultural lands across Hawai'i are discussed in Section 9 of the HEER office *Technical Guidance Manual* (HDOH 2023). The list chemicals provided in that guidance 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 EALs. Soil and groundwater action levels for the majority of commonly used, persistent pesticides in are included in this document. To obtain action levels for pesticides not listed in the lookup tables, contact HDOH or follow the guidelines used to develop the Tier 1 EALs in Appendix 1.

Refer to Section 9 of the HEER TGM for guidance on testing of pesticides in former agricultural lands. 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. . 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 vapor data (e.g., 3-5 ft bgs) in additional to soil data is recommended if fumigant contamination is suspected (refer to Section 4.5). Areas of past fumigant storage, mixing and distribution points should be targeted. Testing of large field areas for fumigants more than a year after the last application is generally considered unnecessary.

2.8 Laboratory Reporting Limits and Ambient Background

In cases where an EAL for a specific chemical is less than the standard, method reporting limit for a commercial laboratory (as agreed upon by HDOH), it is generally acceptable to consider the method reporting limit in place of the action level. Potential examples include groundwater action 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 µg/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.

A summary of typical, background concentrations of trace metals in soils from Hawaiʻi is provide in Table K of Appendix 1 (see HDOH 2011). The upperbound, naturally occurring concentration of a trace metal in soil is selected as the final, Tier 1 EAL if higher than risk-based or other action levels for the metal. A

"Background Threshold Value" that represents the maximum-reported concentration of the trace metal assumed to be naturally occurring in the samples evaluated is also noted in the Appendix 1 table.

Understanding the presence and nature of background metals in soil is important. Trace metals are a natural constituent in the volcanic soils of Hawaiʻi and even in soils associated with coastal, coralline sands. The metals are tightly bound to the soil matrix and have a very low bioavailability. They do not pose a health risk to people. This is particularly an issue for arsenic (HDOH 2011). Background concentrations of arsenic in soils typically range from 1 mg/kg to 24 mg/kg, with some soils containing in excess of 40 mg/kg (see Appendix 1). This is well above theoretical, risk-based, direct-exposure action levels for arsenic in soil which can be less than 1 mg/kg (e.g., USEPA 2023). These action levels assume that the arsenic is 100% bioavailable, however, and are also based on a target risk that is well below the natural background risk posed by arsenic in soil and in particular our diet (see HDOH 2011).

In order to address this issue on a site-specific basis, bioaccessibility tests are recommended when a total arsenic concentration of 24 mg/kg is exceeded (upperbound background level in soil, refer to Chapter 4). Based on bioaccessibility data reviewed by HDOH, pesticide-related arsenic present in soil below this concentration is likely to be strongly bound to soil particles and not significantly toxic.

Other trace metals that could be naturally present in soils above theoretical, risk-based action levels include antimony, cadmium, chromium, cobalt, nickel, thallium and vanadium. Refer to the HEER Office document *Hawaiian Islands Soil Metal Background Evaluation Report* for information on naturally occurring background metals in soil across the islands (HDOH 2011).

2.9 Land-Use Restrictions Inherent in Tier 1 EALs

The Tier 1 EALs presented in Tables A and B are based on an assumed current or potential unrestricted ("residential") land use (refer to Section 2.4.1). This allows sites to be initially screened for unrestricted land use. Risk-based action levels for commercial/industrial land use scenarios are included in Appendix 1. An option to screen data based on assumed commercial/industrial land use is also incorporated into the EAL Surfer (refer to Chapter 3).

Allowing the option to tie action 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 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 EALs (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. This will normally require that a formal covenant to the deed be recorded to restrict future use of the property to commercial/industrial only. 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 action levels for deep or otherwise isolated soils assumes that the impacted soil will remain isolated below the ground surface "for eternity" (refer to Section 4.6). 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 EALs for soil located below this depth is reasonable (see Section 4.3). For commercial/industrial sites, soils situated below a depth of one meter are assumed be “isolated” and not likely to be exposed during authorized subsurface activities. For persistent contaminants, preparation of an EHMP and 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 feet 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.

Land-use restrictions inherent in the selection of EALs from the Tier 1 lookup tables or assumptions used in site-specific risk assessments (e.g., commercial/industrial land use, current isolation of soil at depth, etc.) 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.** 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 when possible in order to minimize future land-use restrictions and controls. 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.

2.10 Cumulative Risks at Sites with Multiple Chemicals of Concern

Risks posed by direct exposure to multiple chemicals with similar health effects 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 noncarcinogenic health effects. A summary of example target health effects for the chemicals listed in the lookup tables is provided in Appendix 1 (Table K).

With the exceptions noted in Appendix 1, the Tier 1 EALs conservatively assume that the presence of multiple carcinogens COPCs (ten or more) and up to five noncarcinogenic COPCs could be present at a site. This is incorporated into the EALs through a combination of conservative exposure assumptions (e.g., years of continuous, daily exposure) and target risk (e.g., one-in-a-million excess cancer risk) in direct-exposure models. Refer to Chapter 4 and Appendix 1 for additional discussion of this subject. Cumulative health risk may need to be calculated for sites where additional contaminants are present (see also USEPA 2023).

2.11 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 6).

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) should not be used as stand-alone criteria for screening of contaminated soil or water (USEPA 2023;** 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 leaching, vapor intrusion, ecotoxicity and gross contamination hazards. Proposals for use of alternative, site-specific action levels must be inclusive of all potential environmental concerns incorporated in the HDOH EALs unless otherwise supported and presented for review.

2.12 Comparison to Other Published Screening Levels

The *HDOH EHE guidance and EALs have been updated multiple timessince the* first edition of the document was published in 1995 (HIDOH 1995). Similar guidance documents have been prepared by the same author for the California Environmental Protection Agency (CalEPA 2016a), the Commonwealth of the

Northern Mariana Islands and the Guam Environmental Protection Agency (TPEHE 2017). Staff from the HDOH HEER office assisted in preparation of earlier versions of the California guidance and coordinate with that agency on updates. Each of these guidance documents represent a progressive compilation and expansion of approaches developed by various environmental agencies in the USA, Canada and other countries. As discussed below, the documents incorporate and significantly expand on the USEPA *Regional Screening Levels* (USEPA 2023). Differences and similarities between this guidance document and guidance prepared by the other agencies are summarized below.

2.12.1 USEPA RSLs and PRGs

The USEPA *Regional Screening Levels* (RSLs; USEPA 2023) replace *Preliminary Remediation Goals* (PRGs) previously published by individual USEPA regional offices. This includes PRGs published by USEPA Region IX (USEPA 2004a) and referenced in earlier editions of the HDOH environmental action level guidance. 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 are essentially identical, with the exception that the 2008 and later 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 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 HDOH EALs.

The HDOH EALs 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 (exceptions noted in Appendix 1);
- 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 action levels for construction and trench worker exposure to contaminated soils;
- Addition of soil, groundwater and soil vapor action levels for vapor intrusion (indoor-air impact) hazards;
- Addition of groundwater action 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 action levels for protection of groundwater quality (soil leaching hazards);
- Addition of soil and groundwater "ceiling levels" to address gross contamination hazards, including explosion hazards, odors, sheens and general nuisance and resource degradation concerns;
- Consideration of natural background levels for trace metals (and dioxins) in soil; and
- Inclusion of soil, soil vapor and groundwater action levels for TPH.

Use of the USEPA RSL models in the HDOH EALs is discussed further in Appendix 1, Chapter 4, and Appendix 2**. As previously stated, 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 and includes sites that fall under Federal rather than State jurisdiction in Hawai‘i. The RSLs can be referred to assess direct-exposure concerns, as they are intended. Cumulative risk should be evaluated is RSLs based on a noncancer Hazard Quotient of 1.0 are referred to (consideration of cumulative risk directly incorporated into ESLs). An additional, comprehensive assessment of potential environmental hazards must be included, however, including leaching, vapor intrusion and gross contamination concerns. Refer to Section 4 for additional guidance.

2.12.2 Tropical Pacific ESLs

Guidance very similar to the HDOH EALs has been prepared by the same author for use in the Commonwealth of the Northern Mariana Islands (CNMI) the Guam, as well as other areas of the Pacific with direct ties to the United States (TPEHE 2017). This guidance, referred to as the “Tropical Pacific” edition (formerly “Pacific Basin” edition), is for the most part identical to the Hawai‘i guidance. The Tropical Pacific edition of the guidance uses the term *Environmental*

Screening Levels (ESLs) rather than *Environmental Action Levels* (EALs), as preferred in Hawai‘i. The guidance was originally prepared for the Commonwealth of the Mariana Islands in 2005 (CNMI 2005) and later expanded for use in Guam.

Unlike the Hawai’i guidance, the Tropical Pacific Edition provides a separate set of Tier 1 action levels for commercial or industrial properties in the summary Tier 1 lookup tables. This was included based on the preference of the environmental agencies in CNMI and Guam. The Hawai‘i guidance, in contrast, only presents Tier 1 EALs for unrestricted/residential land use scenarios. This was done to minimize restrictions on the future use of properties, as well as due to limited resources within the HEER Office for the review of site-specific, human health risk assessments based on alternative land use scenarios. An alternative to select EALs for commercial/industrial land use only is, however, built into the Hawai‘i EAL Surfer and can be proposed in a site-specific EHE.

The Tropical Pacific Tier 1 lookup tables also include alternative soil screening levels for deep or otherwise isolated soils versus soils that are currently exposed at the ground surface or could be exposed at some time in the future. This reflects an assumption that residents and workers are not likely to come into regular contact with contaminated soils located more than three to four meters below the ground surface. While this option is not directly incorporated in the HDOH Tier 1 EAL lookup tables, the isolation of contaminated soils can be considered under a more advanced EHE (refer to Chapter 4).

The HDOH guidance incorporates alternative, less stringent groundwater action levels for threats to aquatic habitats for sites situated greater than 150m from a surface water body (acute versus chronic surface water goals, refer to Section 2.4.4 and Figure 2.1). This recognizes the presence of lower permeability, “caprock” sediments over much of the low lying areas of the islands. The low permeability of the caprock sediments significantly impedes groundwater flows and the spread of contaminants away from the original release areas. This decreases the threat posed by the potential discharge of contaminated groundwater into streams and the ocean. These geologic conditions do not apply to Guam or CNMI and alternative, less stringent groundwater screening levels for inland areas are not considered in the Tropical Pacific Edition of the guidance.

2.12.3 TSCA PCB Standards

Risk-based soil screening for PCBs are included in the lookup tables of this guidance (refer to Table K series in Appendix 1). The action levels are calculated based on the same approach used to develop the USEPA Region IX PRGs and more recent USEPA RSLs, 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 1.4 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 (CFR). 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 parts per million (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 action level for PCBs in soil of 1.1 mg/kg presented in the EALs (refer to Table K-1 in Appendix 1), *the TSCA cleanup level of 1.0 mg/kg should not be referred to in soil cleanup actions for unrestricted (e.g., residential) land use.*

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 EALs 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.*

2.12.4 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 be sent to a Class I, hazardous waste landfill (see HDOH 2017a). Collection of TCLP data is not required for soil that meets Tier 1 EALs, provided that samples were collected in accordance with the HEER TGM (HDOH 2023).

The TCLP leachate standards **cannot** be used to screen soils for potential environmental hazards, including potential leaching hazards. The leachate standards, 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 standards do not apply to potential leaching hazards outside of a regulated landfill.

The TCLP test itself is, however, very similar to the Synthetic Precipitation Leaching Procedure (SPLP) test recommended by HDOH for a more site-specific evaluation of leaching hazards (HDOH 2007b, see Section 4.3.3). Refer to Section 4.4.3 and Appendix 1 for guidance on appropriate methods for screening of contaminated soil and approaches for evaluation of potential leaching hazards.

2.12.5 OSHA Permissible Exposure Limits

The National Institute for Occupational Safety and Health (NIOSH) is a 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 PCE is 678,000 $\mu g/m^3$ (100 ppmv; NIOSH 2007). Comparable risk-based action 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 action 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 EALs and in particular by use of the EAL 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, naphthalene, lead and fuel oxygenates (refer to Figure 2-4). 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 HDOH Tier 1 EALs (refer to Chapter 2). If the representative concentration of a contaminant does not exceed the corresponding Tier 1 EAL then it can be reasonably assumed the contaminant does not pose a significant environmental hazard. If the Tier 1 EAL *is* exceeded, then additional evaluation of that contaminant is warranted. Contaminants that exceed the Tier 1 EALs should continue to be considered COPCs and carried through the EHE 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 Figures 1-1 and 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 EALs offers a relatively rapid and cost-effective alternative to detailed EHEs and related risk assessments. Use of the EAL Surfer included with this guidance to identify potential environmental hazards and expedite Tier 1 EHEs is highly recommended.

Example printouts of the EAL 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 action 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 action 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 EALs 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 EALs. The input concentrations are compared to action levels for specific environmental hazards in the second worksheet (Figure 3-2b). The Surfer flags hazards where the action level is exceeded. A separate, summary report is generated that can be printed and included in the EHE 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. The site is situated within 150m of a surface water body. In the example, the input concentrations of benzene in soil (5.1 mg/kg), groundwater (150 µg/L) and soil vapor (8000 µg/m^3) each cause the Tier 1 EALs for both media to flagged (Figure 3-2a). A look at the detailed action 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. Potential vapor intrusion hazards are confirmed by the input soil vapor data. 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 follow-up 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 EALs is determined. In some cases (e.g., investigation of commercial/industrial areas with land use restrictions), the delineation of contamination to higher action 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 EALs 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 Unit 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 (refer to HEER Office TGM; HDOH 2023).

If soil leaching hazards are identified then specific spill areas should be identified and treated as separate DUs. Unlike direct exposure hazards, data collected outside of contaminated areas should *not* be considered when estimating representative soil concentrations to assess leaching hazards. This is because the DU 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 action 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 vapor samples should be collected at the site. The model used to develop the soil and groundwater actions levels for vapor intrusion estimate soil vapor concentrations of the target contaminants based on assumed default soil properties and are considered to be conservative. Actual soil vapor 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 EALs (or approved alternative action levels) may or may not in fact exist at the site. The EALs 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, action 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 EALs 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 EAL 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 5 above 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 preparation of post-cleanup, “as-built” *environmental hazard maps* is especially important. As discussed in the previous sections, this can be accomplished by comparison of site data to HDOH action levels (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 action 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 action levels (e.g., refer to HDOH EAL 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 action levels (e.g., refer to HDOH EAL Surfer). The site was to be redeveloped for residential use. Soil vapor 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 hot spots, in situ treatment of remaining groundwater contamination, long-term monitoring, institutional and engineering controls, etc.).

3.1.7 Recommend Follow-up 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 EHE 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 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 actions 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, EHMP. The preparation of EHMPs is discussed in more detail in Chapter 5 and in Section 19 the HEER Office TGM (HDOH 2023).

3.2 Preparation of Environmental Hazard Evaluation Reports

The *Environmental Hazard Evaluation* (EHE) should serve as a "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 EALs for unrestricted ("residential") land use to evaluate need for formal land use restrictions and other institutional and engineered controls; see Section 2.9).
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 EALs 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 EALs or alternative action levels:
    - Do Tier 1 EALs 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 10 carcinogens or 5 chemicals with similar noncarcinogenic health effects been identified (excluding petroleum, see Section 2.10)?
    - 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 EALs and comparison to site data.

- Summarize how Tier 1 EALs were selected with respect to the information provided above and additional assumptions as applicable.
- Compare site data to the selected summary Tier 1 EALs (see Tables A-E or use EAL Surfer) 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 EALs or approved, alternative action levels for individual hazards (use the EAL Surfer; detailed tables presented in Volume 2, Appendix 1).
   - Identify any additional, potential environmental hazards not specifically addressed by the EALs (refer to Section 3.1.5).
   - Include environmental hazard maps in the EHE to help guide follow-up remedial actions and long-term site management plans.
7. Conclusions and recommendations for follow-up actions, possibly including (see also Section 3.1.7):
   - Recommendation for no further action;
   - Recommendation for the collection of additional soil, groundwater and/or soil vapor data to complete the site investigation and delineation of environmental hazards;
   - Recommendation for more advanced evaluation of specific, environmental hazards, including (refer to Chapter 4):
     - Use of SPLP batch tests to evaluate potential leaching hazards;
     - Collection of soil vapor data to better evaluate vapor intrusion hazards;
     - Testing of soil for bioaccessible arsenic data to better evaluate risk to human health;

    - Preparation of a tradition human health and ecological risk assessments to quantify risks to human and/or ecological receptors;
    - Field evaluation of potential gross contamination hazards;
    - Evaluation of free product mobility.
- Recommendation for preparation of a remedial action plan to address the identified environmental hazards;
- Recommendation for land-use restrictions and/or institutional controls to address the identified environmental hazards in the absence of full cleanup to unrestricted land use (e.g., requirements for caps, land use restrictions, etc.).
- Recommendation for preparation of an *Environmental Hazard Management Plan* (required for all sites where contamination above Tier 1 EALs left in place).

The conclusions and recommendations of the EHE should be referenced in and used to develop the remedial action plan. For example, air sparging and soil vapor extraction could be the most appropriate remedy to address vapor intrusion hazards. *In situ* chemical oxidation may be effective in reducing non-urgent hazards associated with the contamination of marginal drinking water resources or potential discharges of contaminated groundwater to nearby aquatic habitats. Excavation could be the most cost-effective approach to address gross contamination hazards in soil within five meters of the ground surface. *In situ* free product recovery could be appropriate to address deeper, gross contamination hazards at the groundwater interface. Capping with clean soil may be appropriate to address direct exposure hazards at sites where the soil cannot be removed. Capping with pavement or some other type of impermeable barrier would be required for soil that poses potential leaching hazards.

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 at individual sites. For relatively simple sites, the EHE can be included as a separate chapter in the post-remediation report with EAL Surfer printouts for target COPCs included in the appendices. Preparation of a separate EHE that serves as a stand-alone summary of site conditions may be more appropriate for complicated sites. 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 EHMPs 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.

The approach described in this chapter was referred to as Environmental "Risk Assessment" and in previous editions of this guidance (e.g., HDOH 2005). The term "risk assessment" is replaced with the term "hazard evaluation" in this edition of the guidance document. This was done in part to reflect the fact that the guidance was prepared by the EHE section of the HDOH HEER Office. This was also done to help distinguish an EHE from a traditional human health and ecological risk assessments. Human health and ecological risk assessments can of course be included as one component of an EHE, 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 Site-Specific Environmental Action Levels

4.1.1 Tier 1 Action Level Assumptions and Flexibility

The Tier 1 EALs presented in this guidance incorporate a large number of conservative assumptions about the toxicity of a chemical and the potential exposure to that chemical. These assumptions can be reviewed on a site-specific basis as needed. This will be most common (though still rare) for soil action levels in general and for soil, soil vapor and groundwater action levels intended to flag potential vapor intrusion hazards.

The Tier 1 soil action levels are based on an assumed current or future unrestricted land use (e.g., residential) and an assumption that the soil is currently exposed at the ground surface, or could be in the future (see Section 1.2 and Appendix 1, Chapter 4). Alternative action levels for commercial/industrial land use versus residential land use and subsurface versus surface or near surface soils are provided in Appendix 1. These action levels can be referred to in a site-specific Environmental Hazard Evaluation if desired. This allows for more flexible use of the EHE guidance without the time and cost of independently developing similar, alternative action levels on a case-by-case basis. Note that use of alternative site assumptions could, however, impose land use restrictions on the property (e.g., commercial use only and/or long-term management of subsurface contaminated soil).

It is important to understand that the action levels presented in this guidance are optional for use and intentionally conservative for the majority of sites where investigations are carried out. As discussed in the previous sections, concentrations of chemicals above the action levels do not necessarily indicate that the chemicals pose a potential risk to human health and the environment, only that additional evaluation is warranted. The HEER action levels in general denote the *lowermost concentration* of a range of potentially acceptable contaminant concentrations in the targeted media (i.e., indoor air, soil vapor, soil and groundwater). Potentially acceptable contaminant concentrations in soil could be significantly higher than the Tier 1 EALs and still be protective human health and the environment. In most cases it will be more time- and cost-beneficial to simply refer to the HEER Office action levels for final decision making purposes, however, rather than develop site-specific action levels. In other cases, adjustment of the action levels on a site-specific basis may be desirable or even required by HODH (e.g., to address cumulative risk at sites with a large number of contaminants).

Site-specific action levels for indoor air and groundwater that is a source of drinking water are the least flexible, discounting consideration of natural background. This is because there are relatively few site-specific variables for these media, other than target risk (see Appendix 2). For example, exposure models assume that the average person inhales 10 to 20 m^3 of air and drinks 1 to 2 liters of water a day. Many of the drinking water action levels are also promulgated standards that cannot be adjusted. With the exception of target risk for indoor air, these assumptions cannot be significantly altered on a site-specific basis.

Groundwater action levels for potential discharges into an aquatic habitat or for vapor intrusion hazards could, in theory, be adjusted on a more site-specific basis. This will rarely be practical or beneficial, however (see Section 4.4). For the former the next step is more likely to be characterization and monitoring of the groundwater plume and a closer look at potential groundwater-surface water interactions if an aquatic habitat is indeed threatened. The next step for potential vapor intrusion hazards will be the collection of soil vapor data, rather than additional modeling.

Development of site-specific soil action levels will be more common. Soil action levels are much more complicated and dependent on a long list of site-specific and chemical-specific factors. This is reflected by a wide range of potentially acceptable action levels and one reason why the USEPA and individual states rarely promulgate soil action levels as legally required, “cleanup standards.” When they do, allowances are almost always made for development of more site-specific action levels when necessary. Factors considered to generate the Tier 1 soil action levels presented in this guidance include (see Appendix 1):

- Land use;
- Area, thickness and volume of impacted soil;
- Number of contaminants present;
- Chemical bioavailability/bioaccessibility;

- Biodegradation;
- Groundcover (e.g., pavement vs grass vs barren soil);
- Depth to contaminated soil;
- Distance from slab of building to top of impacted soil (VOCs);
- Fraction organic carbon in soil;
- Soil density;
- Particle density;
- Soil porosity;
- Soil air-filled porosity;
- Soil water-filled porosity;
- Soil temperature;
- Rainfall;
- Evapotranspiration;
- Soil pH and Redox potential; and
- Groundwater depth, utility, flow rate and proximity to a surface water body.

Conservative assumptions about these site characteristics are incorporated into the models used to generate the soil action levels (described in the appendices). Each of these parameters could in theory be evaluated in an advanced, site-specific EHE, although in most cases this will have only a minor effect on the original action level and not be time- or cost-beneficial. Potential common exceptions include a consideration of land use, area and volume of contaminated soil, potential exposure at the ground surface, bioaccessibility of arsenic in contaminated soil and the use of laboratory batch tests to provide a more accurate evaluation of potential soil leaching hazards.

The range of potentially acceptable cancer and noncancer health risks that could be used to develop soil action levels is also a very important controlling factor. Target risks used to develop the Tier 1 soil action levels generally assume the presence of multiple contaminants with similar, potential health effects at a site (see Appendix 1). This is done in order to ensure that potential cumulative health effects are taken into account upfront and minimize the time and cost required to do this on a site-by-site basis. For example, a target, excess cancer risk of one-in-a-million is used to generate action levels for most carcinogens. This is the most stringent of the potentially acceptable excess cancer risk range of one-in-a-million (10^{-6}) to one-in-a-ten-thousand (10^{-4}). This in itself reflects a potential upward adjustment of site-specific soil action levels by up to two orders of magnitude. Action levels for noncarcinogens similarly incorporate a default, conservative assumption that up to four other chemicals with similar health effects could be present in the soil (see Appendix 1). If only a single chemical were present then based on this factor alone the soil action level could be safely increased five-fold and still be protective of direct-exposure concerns.

As discussed in Section 4.2 and Appendix 1, adjustment of target cancer and noncancer risks to more reasonable levels was made upfront for several chemicals, based on a better understanding of the occurrence and nature of the chemicals at sites investigated in Hawaiʻi as well as a more detailed review of toxicological studies. This includes chemicals that are ubiquitous in trace amount in soil, such as arsenic, PAHs and dioxins. This also includes chemicals that do not usually co-occur with other chemicals in significant amounts, such as organochlorine pesticides in termite-treated soils around and under buildings (e.g., Technical Chlordane and aldrin, with its breakdown product dieldrin). In these cases less stringent, but still protective, target health risks were used to develop Tier 1 soil action levels upfront in order to minimize the need to so on a site-by-site basis. Cumulative risks may need to be evaluated in more detail if multiple contaminants are indeed present at a site, however.

Site-specific exposure assumptions such as exposure duration and frequency and soil ingestion rates can likewise be evaluated on a case-by-case basis, although this could lead to a requirement for land use restrictions or engineered controls. Potential variations in these assumptions generally affect soil action levels by less than a factor of three to five. Published toxicity factors used to develop the soil action levels incorporate another host of assumptions and safety factors that can be reviewed on a case-by-case basis if warranted. As described in the next section, however, this process is much more time consuming and will require significant input from an experienced toxicologist and approval by HDOH.

4.1.2 Safety Factors Incorporated into Direct-Exposure Soil Action Levels

It is important to understand the significance of safety factors incorporated into direct-exposure action levels for soil (and other media). The majority of these built-in safety factors are left untouched in a site-specific EHE or risk assessment.

Screening levels presented in this document are, for example, presented to two significant digits (see Appendix 1). Calculation of site-specific cancer risk noncancer hazard is rounded to the nearest, whole number, however, due in part to uncertainty already built into the toxicity factors (e.g., see USEPA 1989a). This implies that a concentration of 149 mg/kg of Chemical X in soil adequately satisfies a target screening level of 100 mg/kg, since the ratio of the two is less than 1.5 and thus rounds to the target, acceptable hazard quotient of 1 (cumulative risk not considered in this example). While it is still useful to remediate a contaminated site to the target screening level, these types of risk-based considerations should be taken into account in terms of feasibility and the cost-benefit of additional remediation.

Table 4-1 and Figure 4-1 illustrate an example of the development of soil action levels for typical chemical, modeled after dieldrin (see USEPA 1990c; for example only and not intended to be comprehensive). (The toxicity factors referenced in this example are out-of-date. Dieldrin toxicity factors were updated in 2016. Refer to Appendix 1, Section 4.2.2.) The process begins with the development of noncancer toxicity factors and selection of a *Lowest Observed Adverse Effects Level* (LOAEL), usually from animal studies. In the case of dieldrin the selected LOAEL is 0.05 mg/kg-day (i.e., 0.05 milligram of dieldrin ingested per kilogram of body weight per day) (USEPA 1990c). Health effects were identified in the laboratory animals after long-term, chronic (e.g. several years) exposure this level of dieldrin. Much higher levels would have been required to see acute health effects within days or weeks (or even minutes).

Next, a *No Observed Adverse Effects Level* (NOAEL) is estimated. As the name implies, this is the level where no adverse health effects were observed in laboratory studies. A NOAEL of 0.005 mg/kg-day was selected for dieldrin, in this case assumed to be 1/10th of the LOAEL since a clear threshold was not identified in the studies (i.e., the lower the noncancer toxicity factor the more conservative; USEPA 1990c).

For the purpose of this example, the LOAEL and NOAEL are converted to equivalent dieldrin concentrations in soil, following the same models and exposure assumptions used to develop the residential, direct exposure soil action levels presented in Appendix 1 (see Table 4-1 and Figure 4-1). A LOAEL of 0.05 mg/kg-day corresponds to an equivalent, risk-based concentration in soil of 3,100 mg/kg (based on target noncancer Hazard Quotient of 1.0). The more conservative NOAEL of 0.005 mg/kg-day equates to a correspondingly lower, equivalent concentration in soil of 310 mg/kg.

Laboratory-based LOAELs and NOAELs are almost always further adjusted downwards (i.e., made more conservative) before use in human health risk assessment. The NOAEL is then further adjusted downwards (i.e, made more stringent) by a series of safety and uncertainty factors in order to generate a noncancer Reference Dose (RfD) for use in human health risk assessments or for the development of risk-based action levels. In the example, the NOAEL is first divided by an uncertainty factor of 10 to take into account the extrapolation of laboratory animal data to human exposure. This is then divided by an additional uncertainty factor of 10 to take into account the lack of a reliable threshold dose below which no adverse health effects will occur. The initial NOAEL based on animal studies is therefore divided by a total uncertainty factor of 100 in order to generate an RfD for use in human health risk assessment. This generates a final RfD of 0.00005 mg/kg-day (see Table 4-1). This similarly reduces the equivalent soil action level by a factor of 100, to 3.1 mg/kg (see Figure 4-1).

For development of an initial, Tier 1 action level, the soil action level for noncancer health risk is further reduced by a factor of up to five (i.e., reduction in target Hazard Quotient from 1.0 to 0.2) to take into account the potential presence of other chemicals in the soil with similar health effects and associated cumulative health risks (see Figure 4-1; see also Section 2.10). This generates a final, residential soil action level for potential noncancer, direct-exposure hazards of 0.60 mg/kg. Note that this step is not considered in the USEPA RSLs (USEPA 2023). The USEPA guidance instead recommends that cumulative risk be evaluated at sites with multiple contaminants, although in practice this is rarely done (see Section 2.12.1).

Additional considerations such as potential cancer risks (if applicable) are then taken into account to determine if further reduction of the soil action level is warranted. In the case of dieldrin, potentially acceptable, cancer-based soil action levels range from 0.03 mg/kg to 3.0 mg/kg, reflecting the potentially acceptable excess cancer risk (ECR) range of 10^{-4} to 10^{-6} (see Table 4-1 and Figure 4-1; see also Appendix 1, Table I-1).

The final, Tier 1 soil action level for dieldrin could therefore be set anywhere between 0.03 mg/kg and 3.0 mg/kg in order to address both cancer and noncancer risk (see Figure 4-1). Where the level is ultimately set depends on the target risks used and the assumed number of other chemicals present. In the case of dieldrin, a final, Tier 1 action level for unrestricted land use of 1.5 mg/kg was selected, based on a target noncancer Hazard Quotient of 0.5 (see Figure 4-1; see also Appendix 1, Section 4.2.2). The target Hazard Quotient takes into consideration the likely co-occurrence of dieldrin with its parent chemical, aldrin. This action level also takes into consideration weaker evidence of carcinogenicity for dieldrin and meets the upper limit to the acceptable excess cancer risk of 10^{-4}. Cumulative health risks would need to be evaluated if other chemicals with similar health effects were identified in soil at concentrations that approach their respective, direct-exposure action levels.

Consideration of alternative exposure assumptions in a site-specific EHE could further increase the maximum-acceptable concentration of a chemical in soil (e.g., commercial/industrial use, exposure duration, assumed soil ingestion rate, etc.). Doing so may impose land use restrictions and even engineered controls on the property, however. A closer evaluation of the studies and assumptions used to develop toxicity factors could also be carried out in a more formal, human health risk assessment. This would be more time consuming and require input from an experienced toxicologist, as well as approval by HDOH. In the case of dieldrin, leaching concerns and other potential environmental hazards would also need to be evaluated in more detail (e.g., by SPLP batch tests; see Section 4.3.3).

This example is intended to demonstrate the range of potentially acceptable soil action levels that could be developed on a site-specific basis. The actual range of acceptable levels will vary from chemical to chemical. Again note that the large safety factors built into the conversion of the dieldrin LOAEL to the final RfD are not affected by the site-specific adjustment of target risk or exposure assumptions (see Table 4-1 and Figure 4-1).

4.2 Tentatively Identified Environmental Hazards

Use of the Tier 1 EALs allows for the expedited identification of contaminated soil and groundwater that could, under some site conditions, pose a significant threat to human health and the environment. This approach allows sites with minimal contamination to be quickly investigated and remediated as needed, without the need for costly and time consuming risk assessments and other evaluations of potential environmental hazards.

A more advanced evaluation of potential environmental hazards should be considered as the cost of remedial actions or the imposition of engineered or institutional controls begins to pose a significant burden on the responsible party or property owner. A summary of possible approaches is provided in Figures 4-2a (soil) and 4-2b (groundwater). Examples include:

- Use of bioaccessibility tests to estimate the potentially toxic fraction of total arsenic in soil (see HDOH 2010a). Bioaccessibility tests carried out on soils from former agricultural areas in Hawaiʻi typically indicate that 80-90% of the arsenic 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. (Note that much higher bioaccessibility has been identified in non-agricultural soils that lack high concentrations of iron, including soils developed over calcareous, coastal sediments.)

- The necessity and practicability of removing gross contamination in areas where access is limited and no other environmental hazards are posed should be evaluated on a site-by-site basis. Targeted removal of free product can be based on an evaluation of the stability, potential mobility and recoverability of the product (e.g., ASTM 2006).

- 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 vapor data provide a much more realistic idea of vapor intrusion hazards initially flagged by a comparison or soil or groundwater data to Tier 1 action levels for this concern. Collection of soil vapor data and comparison to action 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 EHE 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 vapor 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 EHE. 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). Action levels specifically developed to screen for potential direct exposure concerns are incorporated in the Tier 1 EALs (based on USEPA RSLs, 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 action 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 4.3.1.3). In some cases, legal needs on the part of the responsible party could also require preparation of a detailed human health risk assessment.

4.3 Advanced Evaluations of Contaminated Soil

Example approaches for advanced evaluation of environmental hazards posed by contaminated soil are presented in Figure 4-2a. A brief discussion of highlighted topics is provided below.

4.3.1 Direct Exposure

4.3.1.1 Tier 2 Direct Exposure Model

This guidance document includes an easy-to-use, Excel-based spreadsheet model (available for download from HDOH HEER Office EAL webpage; http://eha-web.doh.hawaii.gov/) that calculates site-specific, Tier 2 direct-exposure action levels for soil based modifications to default site conditions and human exposure assumptions. The model uses the same equations used to develop the USEPA Regional Screening Levels (RSLs) and the Tier 1 action levels for direct exposure hazards (refer to Appendix 1). Printouts of the model input pages (first two worksheets, two pages) should be included in the EHE. 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 4-3. 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 action 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, 2016). 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 action levels simply input the site-specific thickness of soil above Tier 1 EALs. The spreadsheet automatically generates an adjusted, Tier 2, direct-exposure action level for the selected land use. An action level is also generated for construction worker exposure. If the latter is lower than the Tier 2 action level for the selected exposure scenario then it is selected as the final, action level. Risk-based soil action 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 action 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 action 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.

4.3.1.2 Tier 2 Action levels for Arsenic, TEQ Dioxin and Lead

The HDOH published a series of technical memorandums between 2005 and 2011 that provide alternative, Tier 2 direct exposure action levels for arsenic and TEQ dioxin in soil (HDOH 2006a, 2006b and 2007a, 2010a, 2010b). Copies of the technical memorandums are provided in Appendix 8. The information in these memorandums is restated and updated below. Use of the alternative approaches presented is recommended. The action levels are based on modifications to the USEPA RSLs used to develop Tier 1 action levels for direct exposure hazards (USEPA 2023; refer also to Appendix 1).

The alternative action levels can be used in place of the Tier 1 EALs provided that other contaminants are not present above their respective Tier 1 (or Tier 2) action 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 use of soil contaminated with arsenic and dioxins 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 should be evaluated using laboratory batch tests (Section 4.3.3). 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 Tier 2 action levels and guidance for arsenic is provided in Appendix 8 (HDOH 2010a). A summary of the HDOH Tier 2 action levels and guidance for arsenic is provided in Figure 4-4. Total arsenic analyses should be used to initially screen soils for potential contamination concerns. If the reported total concentration of arsenic exceeds 24 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. USEPA guidance for lead-contaminated soil calls for use of the <250 micron soil fraction in bioaccessibility tests (USEPA 2000). This also applies for bioaccessibility tests carried out on arsenic-contaminated soils.

The arsenic action level for unrestricted/residential land used presented in Figure 4-4 reflects a noncancer Hazard Quotient of 1.0 (see HDOH 2010a). The action level for commercial/industrial land use reflects an excess cancer risk of $5x10^{-5}$

(lower than C/I action level for a target HQ of 1.0) Note that action levels presented in Tables I-1 (unrestricted/residential) and I-2 (commercial/industrial) of the updated EALs are slightly different due to minor changes in exposure assumptions used in the 2016 update of the USEPA RSLs (USEPA 2023; see Appendix 2).

Use of the Solubility/Bioavailability Research Council (SBRC) gastric-phase bioaccessibility method is recommended (Drexler and Brattin 2007; refer to Section 9 of the HEER office Technical *Guidance Manual*, HDOH 2023). As an alternative, the USEPA default bioaccessibility for arsenic in soil of 0.6 (60%) can be applied to total arsenic reported for the <250 micron soil fraction (USEPA 2012a). If the adjusted concentration of arsenic is less than the target action level then no further action is necessary. Use of an algorithm proposed for adjustment of bioaccessible arsenic data based on comparisons to bioavailability data from multiple databases in lieu of site-specific, bioaccessibility data *is not recommended* for soils in Hawaiʻi (Diamond et al. 2016). Bioaccessible and bioavailable data for soil samples from Hawaiʻi have indicated consistently strong correlation (refer to Section 9 of the HEER TGM).

The 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 4.3.3 for additional information.

Dioxins and Furans

A detailed discussion of Tier 2 action levels and guidance for dioxins and furans is provided in Appendix 8 (HDOH 2010b). A summary of HDOH Tier 2 action levels for dioxins is provided in Figure 4-5. **Remediation of sites to the HDOH default soil background level of 20 ng/kg TEQ dioxins should be considered to the extent practicable for residential sites where contamination in excess of 240 ng/kg is initially identified (refer to HDOH 2010b).** Note that the Reference Dose used to develop the dioxin action levels incorporates an assumed bioavailability of 50%. The residential action level therefore reflects an equivalent concentration of bioavailable TEQ dioxin in soil of 120 ng/kg.

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 (see Section 9 of the HEER office *Technical Guidance Manual*; HDOH 2023 and updates). 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 action levels presented in the HDOH guidance are applicable to adjusted TEQ dioxin data. A value of ½ of the laboratory Method Detection Limit (MDL) should be used for calculation of a TEQ dioxin concentration if the subject isomer was detected above the MDL in one or more samples from the same area.

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, with CALUX currently in most use. Laboratory method procedures for CALUX have also been formalized (USEPA 2008). A 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 (default koc 250,000 cm^3/g; refer to Section 4.4 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.

Note that the HDOH action levels for TEQ dioxins are based on a review of dioxin toxicity published by the World Health Organization, with a focus on noncancer risk (WHO 2001, 2002; refer to Appendix 6). The USEPA published a final review of dioxin toxicity in 2012 (USEPA 2012b; see also ATSDR 2007). Drafts of this document, which were consistent with the final, were reviewed for preparation of the 2010 HDOH technical memorandum. A detailed comparison of the WHO and USEPA toxicity factors is included in the memorandum. As discussed in the 2010 HDOH technical memorandum, reference to the WHO study was based in part on preference for the body burden approach to evaluate potential health risks posed by chronic exposure to dioxins. The WHO

“Permissible Tolerable Intake (PTI)” of 3.3 pg/kg-day) used to develop soil action levels is somewhat higher (less conservative) than the equivalent “Reference Dose” of 0.7 pg/kg-day selected by USEPA for development of RSLs (USEPA 2023). This is used to generate a noncancer-based screening level of 51 ng/kg for residential exposure. This compares to a USEPA RSL cancer-based screening level of 480 ng/kg, assuming a target 10^{-4} risk. Noncancer risk to young children thus takes precedence, under this scenario. Similar studies were reviewed by both organizations. The toxicity factors selected represent a range of potential values from those studies. The WHO PTI includes an assumed bioavailability of 50%. This is consistent with studies carried out for dioxins in soil, as discussed in the HDOH memorandum.

The USEPA toxicity factor does not considered bioavailability. Consideration of a similar bioavailability in the USEPA toxicity factor would generate a noncancer, residential soil screening level of 102 ng/kg (51 ng/kg divided by 0.5). This compares to the HDOH action level of 240 ng/kg. Both USEPA and HDOH soil levels assume a conservative, soil ingestion rate for children of 200 mg/day. This likely overestimates actual soil ingestion rates by a factor of at least four (NZME 2011). Assuming a soil ingestion rate of 50 mg/kg would increase the HDOH residential soil action level to a 960 ng/kg (240 ng/kg times four). The latter is coincident with a soil screening level of 1,000 ng/kg originally utilized to by USEPA for residential properties (ATSDR 1998) and should be considered an upperbound value in terms of risk to human health under a residential exposure scenario.

A residential action level of 240 ng/kg is thus considered adequately conservative for initial screening purposes and the identification of impacted areas that will likely require remediation. **As noted above and in Figure 4-5, , in absence of a more site-specific risk assessment, remediation of sites to background (default 20 ng/kg) should be considered to the extent practicable for residential sites when TEQ dioxin concentrations above this level are identified.**

Lead

The HDOH action level of 200 mg/kg in part reflects recommendations to reduce the target blood level to 5 µg/dl (USEPA 2011a; USCDC 2012a,b). The model used to calculate soil screening levels for lead is not linear, however (USEPA 2007). The former USEPA residential RSL for lead of 400 mg/kg was revised to 200 mg/kg in 2024 (USEAPA 2024). A reduction in the soil action level for lead below 200 mg/kg is not practical for heavily developed, urban areas, however. Background, anthropogenic levels of lead in urban soils from past auto exhaust and other sources is estimated to average 75-200 mg/kg and in places far exceed these values (USEPA 1994, 1998). In HDOH’s experience, the use of an action level below 200 mg/kg can complicate the identification and characterization of localized contamination that could conceivable be remediated.

The HEER Office does, however, recommend the inclusion of soil that exceeds the natural background action level for lead of 73 mg/kg (HDOH 2012) in remediation plans when practicable and when the contamination can be attributed to a specific release. Capping, landscaping (including a well-maintained lawn) or other efforts to minimize exposure of young children should be considered where area-wide impacts above 200 mg/kg lead are identified, regardless of the suspected source.

4.3.1.3 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 Regional Screening Levels: (USEPA 2023).
- Standard Provisional Guide for Risk-Based Corrective Action (ASTM 1995); 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. Sample data to be utilized in a site-specific risk assessment must be collected in accordance with the HEER Office Technical Guidance Manual (HDOH 2023). This includes the use of “Decision Unit” and “Multi Increment Sample” (DU-MIS) investigation methods. **Discrete sample data are not reliable for determination of the extent and magnitude of contamination or for use in assessment of risk and will not be accepted by HDOH for final decision making (refer to HDOH 2023).**

4.3.2 Vapor Intrusion into Buildings

Detailed guidance on advanced approaches for evaluation of vapor intrusion hazards is provided in Section 4.5. A more site-specific evaluation usually begins with the collection of soil vapor data once concentrations of volatile contaminants in soil or groundwater exceed Tier 1 action levels for this potential hazard. The use of site-specific vapor intrusion models in the absence of soil vapor data is strongly discouraged.

4.3.3 Use of Batch Tests to Evaluate Leaching from Soil

Soil leaching hazards drive the selection of final Tier 1 EALs for the majority of organic contaminants presented in the lookup tables. That is, action levels for leaching hazards are lower than action 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, action levels for leaching hazards are not incorporated into the Tier 1 EAL 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 HDOH guidance document *Use of laboratory batch tests to evaluate potential leaching of contaminants from soil* (HDOH 2017b). 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, DUs 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 action 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 (after Fetter 1988; refer HDOH 2017b). A Kd of 20 is equivalent to a Retardation Factor of approximately 100, where: Retardation Factor = 1 + [(soil density/effective porosity) x Kd], assuming a soil density of 1.5 g/cm3 and an effective porosity of 0.30 or 30%. This implies that the contaminant in the soil will be carried downwards in leachate at $1/100^{th}$ of the rate that the leachate itself is migrating. Chemicals with a Kd of greater than 20 in soil rarely if ever cause significant groundwater contamination, unless the soil is sitting directly in groundwater (refer to 2007 memo in Appendix 8). This is in turn a useful tool to screen sites for potential leaching hazards. Potential direct exposure hazards instead typically drive risk at sites impacted by these chemicals (e.g., DDT, PAHs, PCBs, etc.).

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 action levels and the need for further action is evaluated. Note that direct comparison of SPLP data to target groundwater action levels is not technically correct or appropriate in most cases; see 2017 HDOH memo in Appendix 8. If the Kd value is very high, ever, then the measured concentration of the chemical in the SPLP solution will indeed be very close to the predicted concentration in leachate.

A detailed discussion of the approach is provided in the referenced HDOH guidance (HDOH 2017b, included in Appendix 8). 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 HDOH HEER Office 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 action 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).

4.3.4 Use of Soil Vapor to Evaluate Vadose-Zone Leachate

Soil vapor screening levels for potential leaching hazards posed by volatile organic chemicals (VOCs) in vadose-zone soil or bedrock are presented in Table E (see Appendix 1, Section 4.4.2). The screening levels are calculated based on target concentration of the chemical in groundwater times the chemicals Henry's Law constant and a default, dilution/attenuation factor of twenty. The screening levels focus on potential impacts to immediately unconfined, drinking water aquifers by volatile hydrocarbons, solvents, explosives and fumigants. The evaluation of leachate associated with petroleum fuels focuses on TPHg, TPHmd, BTEX, MTBE and naphthalene. Testing for additional, semi-volatile, PAHs in soil vapors is not necessary to evaluate potential leachate conditions (e.g., acenaphthene or methylnaphthalenes).

The presence of a VOC in soil vapors above its respective screening level suggests that the concentration of the VOC in soil moisture or leachate could exceed the target groundwater screening level. For example, a concentration of soil vapor of 1,200 ug/m^3 benzene in soil vapor would in theory correspond to an equilibrium concentration in soil moisture of 5 ug/L, the drinking water standard for this chemical. The screening levels should be considered very conservative, especially for biodegradable, petroleum compounds. The screening levels do not take into account attenuation as the leachate migrates downward through the vadose zone and are most applicable to vapors from leachate in close proximity to the water table. Progressive reduction in the concentration of a chemical in leachate due to volatilization (e.g., chlorinated solvents) or biodegradation (e.g,, hydrocarbons) could be significant. The latter is likely to be significant for TPH and BTEX, although the resulting, nonvolatile degradation compounds are by default considered to be of equal toxicity to the original, parent hydrocarbon compounds (refer to Section 2.6.1). In such cases vapors emanating from downward migrating leachate might dramatically decrease with depth, even though to total concentration of hydrocarbon-related compounds in the leachate remains roughly the same.

The screening levels also do not consider the actual mobility of the soil moisture. Vapor concentrations could be very high in dry soils with little to no mobile, soil moisture (i.e., leachate). Whether or not the leachate (or even the vapors) poses a true threat to groundwater depends on site-specific factors, including the size of the source area and the mass of contaminant present, the rate and amount of downward moving leachate, degradation and resorption to soil, the distance to the water table, the presence of low-permeability layers between the source and the water table, the rate of groundwater flow and the thickness of the leachate-groundwater mixing zone. Note that USEPA guidance recommends a default, dilution-attenuation factor of twenty (USEPA 2002a).

Soil vapor data collected over several depths can provide information regarding the downward migration of VOCs in soil leachate toward groundwater. The concentration of VOCs in soil vapors immediately beneath a building slab or paved area could, for example, be very high due to the dryness of the soil even though very little mass is present and the leaching threat is minimal. The chemical may not be present in leachate (or soil vapor) a short distance from the source if water is not infiltrating the area and carrying the chemical downward. Removal of the cap, however, or the breakage of an underground water pipeline could lead to a surge of contaminated leachate toward groundwater.

Soil vapor data are not useful for estimation of the total mass of contaminant present in the vadose zone. This is due to the difficulty in estimating the fraction of soil moisture present as well as the sorbed-phase mass of a VOC in soil based on vapor data alone (published sorption coefficients can significantly underestimate sorbed-phase mass due to presence of clays, etc.). Most of the mass is likely to be sorbed to soil particles under normal conditions (an exception being the common presence of vapor plumes in very dry soil under building slabs). The collection of a multi-increment soil sample(s) from the suspected source area is recommended to evaluate this issue in more detail and better understand the threat to groundwater posed by the VOCs, as well as optimize remedial actions if necessary.

4.3.5 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, methylethylketone, 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 EHE 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 vapor 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 2.12.5).

Both TPH and methane should be included in soil vapor analyses for petroleum-contaminated sites (see Section 2.6 and Section 4.5.4). 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. Additional guidance on the investigation and mitigation of methane hazards is presented in the HEER *Technical Guidance Manual* (HDOH 2023 and updates).

4.3.6 Terrestrial Ecotoxicity

Detailed, ecological risk assessments are rarely required at the majority of sites overseen by HDOH, given their location in heavily developed, urban areas that lack sensitive, terrestrial ecological habitats. 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. Refer to the HDOH HEER Office *Technical Guidance Manual* for additional guidance on the preparation of ecological risk assessments (HDOH 2023 and updates).

4.4 Advanced Evaluations of Contaminated Groundwater

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

4.4.1 Drinking Water Resource Contamination

Action levels for drinking water are not easily adjustable. Toxicity-based drinking water action 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). Action levels for the remaining chemicals are 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 action 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.

4.4.2 Vapor Intrusion into Buildings

Detailed guidance on advanced approaches for evaluation of vapor intrusion hazards is provided in Section 4.5. A more site-specific evaluation usually begins with the collection of soil vapor data once concentrations of volatile contaminants in soil or groundwater exceed Tier 1 action levels for this potential hazard. The use of site-specific vapor intrusion models in the absence of soil vapor data is generally discouraged.

4.4.3 Discharges into Aquatic Habitats

Fewer than 20% of the action 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 action 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 action 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).

4.4.4 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 vapor for methane buildup and potential explosion hazards in areas of heavy petroleum contamination. Be sure to include TPH and methane in soil vapor analyses (see Sections 2.6, 4.3.4 and 4.5.4).

4.5 Advanced Evaluation of Vapor Intrusion Hazards

4.5.1 Overview of Vapor Intrusion

Use of the soil, groundwater and soil vapor action levels for vapor intrusion concerns presented in this guidance to initially screen sites contaminated with volatile contaminants rather than attempt to develop sites-specific action levels is strongly recommended. Development of the action levels is described in Appendix 1. A detailed discussion of vapor intrusion is presented in Section 7 of the HEER office *Technical Guidance Manual* (HDOH 2023, and updates).

A basic overview of vapor intrusion is provided in Figure 4.7. Potential adverse impacts to indoor air are driven by the concentration of VOCs in the intruding vapors, the vapor entry rate into the structure and the exchange rate of the building with fresh, outdoor air. Wind effects, and in colder areas indoor heating, can cause air to be drawn out of gaps in windows, doors, roof eves and other gaps on the downwind side of a building (USEPA 2004, 2015a,b; CalEPA 2016c; Brewer et al. 2014). This causes the building to become under-pressurized and results in the entry of outdoor air into the structure from similar gaps on the upwind side. Air can be drawn under the slab of the building and up through the floor of the structure if cracks or gaps around utilities are present.

The upwelling of air beneath a building slab or from a crawl space into a building was recognized by building ventilation engineers in the early 1900s, when heating and air conditioning of buildings became more common, as well as by experts studying the intrusion of natural, radon gas into buildings. The operation of a heating, air conditioning and ventilation (HVAC) system for heating inside of house can in particular exacerbate depressurization of the structure and increase vapor entry rates. This can lead to a corresponding exacerbation of impacts to indoor air if not sufficiently offset by equally proportional increase in the leakage of outdoor air into of the upper part of the structure.

This process is referred to as “vapor intrusion” when volatile organic chemicals (VOCs) in underlying, contaminated soil and/or groundwater become entrained in air entering a building floor. This can lead to adverse impacts to indoor air quality under some conditions. The upward migration of VOCs into a building occurs in three stages (see Figure 4-7). The first stage is characterized by outward, diffusive flow of vapor-phase chemicals from high-concentration source areas. If the strength of the source is adequate, VOCs will migrate into the advective zone underlying a building slab. Once in this zone the VOCs mix with outdoor air being pulled under the slab and into the overlying structure due to depressurization caused by wind or other effects (Stage 2). Upon entering the building, the now contaminated air (vapors) mixes with indoor air (Stage 3). This includes mixing with the much larger volume of outdoor being drawn into the building due to pressure differential-driven leakage through gaps in the upper part of the structure.

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. Unless otherwise supported by site-specific data, vapor attenuation factors applied to slab-on-grade design buildings should likewise be applied to crawl space designs.

These processes, well studied in the field by vapor intrusion experts and building design engineers, are expressed quantitatively in the USEPA vapor intrusion model (USEPA 2004) described below and used to develop corresponding soil, groundwater and subslab soil vapor action levels. 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 Hawaiʻi significantly reduces vapor intrusion hazards in comparison to colder areas on the US mainland.

Additional guidance documents on the investigation of vapor intrusion risks include:

- HDOH: Development of Subslab Attenuation Factors (Brewer et al. 2014);
- USEPA: *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings* (USEPA 2004b; see also USEPA 2015a,b);
- Department of Defense (DoD): *Tri-Services Handbook for the Assessment of the Vapor Intrusion Pathway* (DoD 2008);
- CalEPA: *Vapor Intrusion Mitigation Advisory* (CalEPA 2016c);
- Massachusetts Department of Environmental Protection (MADEP): *Indoor Air Sampling And Evaluation Guide* (MADEP 2002c);
- MADEP: *Vapor Intrusion Guidance* (MADEP 2010);
- New Jersey Department of Environmental Protection (NJDEP): Vapor Intrusion *Guidance* (NJDEP 2005); and
- New York Department of Health (NYDOH): *Guidance for Evaluating Soil Vapor Intrusion in the State of New York* (NYDOH 2006).

Note that vapor intrusion attenuation factors presented in the 2015 USEPA guidance documents, in fact finalized several years before publication, have since been determined to be unreliable (Brewer et al. 2014). This information was not incorporated into the general vapor intrusion guidance document published in 2015 (USEPA 2015a) although the Brewer et al. paper is referenced in the guidance specific to petroleum vapor intrusion (USEPA 2015b). Based on discussions with the USEPA vapor intrusion coordinator at the time, this was due to time constraints for completion of the documents (Richard Kapuscinski 2016, personal communication):

> (The Brewer et al. 2014) paper… on subslab attenuation factors was published (Fall 2014) after the intra-agency vetting concluded for the OSWER [Office of Solid Waste and Emergency Response] *Technical Guide For Assessing And Mitigating The Vapor Intrusion Pathway From Subsurface Vapor Sources To Indoor Air* (OSWER Publication 9200.2-154). By contrast, the *Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites* (USEPA 510-R-15-001) was prepared and revised somewhat independently.

Hawaii's guidance and action levels reflect a reduced vapor intrusion risk in tropical climates. Cold winters, heating of buildings and less efficient ventilation can significantly exacerbate potential vapor intrusion hazards in colder climates. This could be reflected by an increased rate of vapor flow into buildings in colder climates as well as a decreased potential for attenuation due to lower, indoor air exchange rates. Due to these factors, *vapor intrusion action levels presented in this guidance for soil, soil vapor and groundwater may not be adequately conservative for use in non-tropical climates. Example modification of HDOH action levels for use in other climate zone is included in Section 13 of the HEER office Technical Guidance Manual.*

4.5.2 Collection of Soil, Groundwater and Soil vapor Data

Refer to Section 7 of the HEER Office *Technical Guidance Manual* for detailed information on the collection of soil, soil vapor and groundwater samples (HDOH 2023 and updates). A brief overview of sampling approaches specific to potential vapor intrusion hazards is provided below.

4.5.2.1 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 action level presented in Table C (0.31 $\mu g/m^3$) by an order of magnitude or more. Ambient levels of dry cleaning solvent (PCE) and other chlorinated solvents in indoor air may also exceed the action levels presented in Table C (see Table 4.8a).

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

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

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

3) At buildings where soil vapor action 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 action 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 action 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 vapor 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 high- permeability fill material (i.e., "sand") as the soil layer that immediately underlies the slab, as done for the models used to develop action levels in this guidance (e.g., "sand" in model default soil types, refer to Appendix 1, Chapter 2).** This will help reflect likely site conditions and ensure a realistic vapor flow rate through the floor slab.

4.5.2.2 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 vapor data is instead preferred (refer to Section 4.5.2). Vapor intrusion action levels for soil should only be applied to sites where relatively minor releases of volatile contaminants have occurred and the collection of soil vapor data is not considered to be necessary and/or feasible (see also HDOH 2007b).

4.5.2.3 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 action levels presented in Appendix 1 of this document (Table C-1a, see also Tables D-1a and D-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.

Action levels for vapor emissions from groundwater into overlying buildings are incorporated into the D-series tables in Appendix 1 and the summary tables presented at the end of this volume as well as the EAL Surfer (electronic version of the EAL 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 5 liters per minute per 100m^2 of floor space (“Qsoil”).

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

4.5.2.4 Collection and Evaluation of Soil Vapor Data

Soil vapor samples should be collected at sites where soil or groundwater data suggest potentially significant vapor intrusion concerns, as described in the HEER office *Technical Guidance Manual* or as otherwise approved by the HEER Office (HDOH 2023 and updates). Soil vapor 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 this is impractical, then samples should be collected from paved areas immediately adjacent to buildings.

In unpaved areas, soil vapor samples should be collected from a depth of 1.5m (five feet) below ground surface. 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 (see CalEPA 2016c). The collection of deeper soil vapor 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 a 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 modeled groundwater and in particular shallow, soil vapor concentrations are reflective of actual field conditions, even if the required, input stratigraphy in the model does not fully match 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) in the USEPA models is 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.

4.5.2.5 Use of Soil Vapor Data to Determine Need for an Indoor Air Study

Refer to Section 7 of the HEER Office *Technical Guidance Manual* for detailed guidance on the collection of indoor air samples (HDOH 2023 and updates). The collection and evaluation of indoor air sample data is discussed in Section 4.5.3. Both subslab sample data and shallow soil vapor data (i.e., ≤1.5m bgs) should be compared to the soil vapor action levels presented in Table C. Where action levels are approached or exceeded, the need to carry out an indoor air study should be more closely evaluated.

The California EPA vapor intrusion guidance recommends that an indoor air study be considered if site-specific, soil vapor-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 2016c). While this approach may seem reasonable in concept, it is often impractical due to likely impacts to indoor air from other sources that will mask potential impacts from subsurface, vapor intrusion (e.g., cleaners, glues, auto exhaust, etc.). Impacts due to subsurface versus vapor intrusion versus indoor or outdoor sources are not distinguishable.

For example, the concentration of TPH, benzene and other auto exhaust-related contaminants in outdoor air near roadways can exceed risk-based action levels by up to two orders of magnitude (Figure 4-8; see also CalARB 2001, Kurtz and Folkes 2002, MADEP 2002d, NYDOH 2003, USEPA 2011b). Trace levels of chlorinated solvents are also commonly reported for indoor air (e.g, PCE used for dry cleaning). In such cases, sampling of indoor air would not be useful unless concentrations of targeted chemical in subslab soil vapor exceed 2,000 times typical indoor ambient concentrations of the chemical (Figure 4-9; default soil vapor:indoor air attenuation factors assumed in vapor intrusion models). Refer also to Appendix 1 Chapter 2 and MADEP (2002a).

Decisions for cleanup of VOC-contaminated soil and groundwater for vapor intrusion concerns should instead be based on an evaluation of soil vapor 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 vapor action 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 vapor action levels for commercial/industrial sites are exceeded is described below:

Step 1. Confirm and Evaluate Soil Vapor Data.

- Confirm soil vapor 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 vapor 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 EALs were exceeded in one or both sampling events, consider the installation of permanent vapor monitoring wells in a denser grid (e.g., 10m 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 vapor are identified.

- If soil vapor EALs for noncarcinogens are not exceeded (based on a target, noncancer risk of 0.2, or 1.0 for TPH) and EALs 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 C-2 in Appendix 1).

- If soil vapor EALs are exceeded by more than amounts noted above, calculate a site-specific, cumulative noncancer Hazard Index and cumulative excess cancer risk (see HEER *Technical Guidance Manual*; see also guidance referenced in USEPA 2023).

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 typical, ambient, outdoor air).** Testing of indoor air is not required. Install permanent vapor monitoring probes in areas of primary concern and test quarterly for a period of one year to confirm soil vapor data. If concentrations of VOCs do not increase significantly (i.e., to exceed cumulative 10^{-5} excess cancer risk or Hazard Index >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 vapor. If resampling of soil vapor 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 vapor data suggest a potential excess cancer risk of >10^{-5} and/or a cumulative noncancer hazard index >1.0 is confirmed and the concentrations of targeted VOCs in soil vapor are high enough that intruding vapors could cause impacts to indoor air in excess of typical ambient levels (see Figure 4-9; refer also to Section 2.6).

The above approach 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 and discussed with HDOH.

4.5.2.6 Soil Vapor and Tight Soils

At sites where soil vapor 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 vapor samples. Adequate time (generally several weeks) should be allowed for VOCs in the surrounding clays to equilibrate with soil vapor in the vapor probe sand pack.

Passive soil vapor sampling techniques may also prove useful in tight soils for identification of large-scale vapor plume patterns and in some cases quantification of VOCs concentrations. Refer to Section 7 of HEER TGM; HDOH 2023),

At sites where groundwater is impacted with VOCs and the collection of soil vapor data is simply not possible, groundwater data should be compared to conservative action 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 action levels (see below).

4.5.2.7 Use of Soil Data

Soil action levels for potential vapor intrusion concerns are incorporated in the EAL lookup tables (see Appendix 1, Table A-D series and Table C-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 action levels to site data is generally acceptable. If soil action levels are exceeded, the need to collect soil vapor 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 vapor 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 vapor intrusion models or corresponding action 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.)

4.5.2.8 Soil Vapor and Mass-Balance Issues

At sites with high levels of VOCs in soil vapor 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 vapor 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.

Note that the actual mass of VOCs present in vapors beneath a building slab might be insufficient to maintain initial impacts over the full span of the exposure duration assumed in development of the soil vapor action levels, however. In such cases, the action 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. The mass of VOCs present can be further assessed through the collection of MI soil samples within the same area (refer to Section 4 of the HEER TGM; HDOH 2023). Access to soil beneath a slab will in many cases, however, be too limited for collection of reliable soil sample data.

4.5.3 Collection of Indoor Air Data

As discussed in the previous section, the collection of indoor data will in some cases be necessary to further evaluate vapor intrusion concerns (see Section 4.5.2.5; see also Figure 4-9). Proposals and workplans for indoor air studies should be discussed with the HEER Office. The collection of indoor air data without soil vapor 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 discussed in Section 4.5.1 and Section 7 of the HEER Office *Technical Guidance Manual* (HDOH 2023) and will not be repeated in detail here.

The California EPA guidance document provides a table of recommended actions at sites where impacts to indoor air are identified (CalEPA 2016c). 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 vapor, 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 vapor 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.

Earlier editions of the 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 HDOH. 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 vapor 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 HDOH. 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 HDOH. 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.

4.5.4 Special Considerations for Petroleum-Contaminated Sites

A discussion of contaminants of potential concern for petroleum is provided in Section 2.6 (see also Figure 2.4). Based on data compiled by the HEER Office, aliphatic compounds associated with Total Petroleum Hydrocarbons (TPH) and not benzene or other individual volatile chemicals generally drives vapor intrusion risks for releases of middle distillates and in some cases even gasolines (see Appendices 1 and 6). As noted in Figure 2.4, soil vapor (and indoor air) samples should be tested for TPH (sometimes reported as *Total Volatile Hydrocarbons* or similar terms) and the noted, individual chemicals. The laboratory standard used for the TPH analyses should match the petroleum product released at the site. Vapor intrusion action levels for TPH in soil and groundwater cannot easily be calculated using the models referenced in Appendix 1 and are not included in the

EAL lookup tables. The direct collection of soil vapor samples at sites where significant soil contamination (e.g., >10m^3 of soil) or free product on groundwater are identified. Carbon range data may be desirable for site-specific EHEs.

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; see Figure 4-8). 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 1 to >5 µg/m^3 (see Figure 4-8), well above the risk-based, action level for residential exposure of 0.30 µg/m^3 (refer to Table C). Ambient concentrations of TPH in indoor and outdoor air typically ranges between 100 and 1,000 µg/m^3 or even higher based on data collected at sites in Hawai'i, well above the residential indoor air action level of 230 µg/m^3. As a general rule, and as discussed in Section 4.5.2.5, indoor air should only be tested if concentrations of target contaminants in soil vapor exceed at least 2,000 times anticipated levels in ambient air. This reflects the default soil vapor:indoor air attenuation factor (SSAF)for residences (see Appendix 1, Section 2.2.4; SSAF of 4,000 applied to commercial/industrial buildings). This correlates to concentrations of TPH in soil vapor of 2,000,000 µg/m^3 and 2,000 µg/m^3 for benzene before impacts to indoor air above ambient conditions might be discernible.

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 vapor exceed action levels (or approved alternatives) then the lower floor of the building should be inspected and cracks and gaps (e.g., around utilities) should be sealed. The building 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 vapor 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 9.4 and the HEER office *Technical Guidance Manual*; HDOH 2023). Gasoline 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 of residual contamination is required.

4.6 Other Advanced EHE Approaches

4.6.1 Commercial/Industrial Land Use

Alternative vapor intrusion, gross contamination and direct exposure action levels commercial/industrial are included in Appendix 1 (Table C series, Table F series and Table I-2, respectively). These action levels are based on an assumption that only working-age adults will be present at the site on a regular basis and only during working hours. The action levels are in turn higher than those used to develop the Tier 1 EALs, based on an assumed, unrestricted, residential land use scenario. Soil action levels for leaching hazards are not affected.

An option to select commercial/industrial land use only over unrestricted ("residential") land use is built into the updated EAL Surfer. Users are cautioned, however, to always compare site data to action levels for unrestricted land use, at least at an initial, screening level. Screening site data with only the action levels for commercial/industrial land use can place an unnecessary burden on future use of the property. If contaminants are not identified above action levels for unrestricted land use then no restrictions need to be placed on the property. Commercial/industrial action levels (or alternative, site-specific action levels) should only be referred to if the site cannot be remediated to Tier 1 EALs or acceptable, alternative action levels for unrestricted future use. Implications for land-use restriction are discussed in more detail in Section 2.9.

4.6.2 Exposed Versus Isolated Soils

As discussed in Chapter 2, the Tier 1 EALs are based on an assumption that contaminated soil is currently exposed at the ground surface or could be disturbed and exposed at the surface in the future. This assumption eliminates the need to consider long-term management of soil at a site.

Alternative and in most cases less stringent action levels can be used to evaluate the need for remediation of isolated soils if full cleanup to the Tier 1 EALs is not feasible. For sites where unrestricted future use is desired, a depth of 3 meters (approximately 10 feet) is recommended to delineate between "shallow" soils, where a potential exists for disturbance of soil by future residents (e.g., excavation of swimming pools), and "isolated" soils where only periodic disturbance during construction and utility maintenance work is anticipated (CalEPA 1996). 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.

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 HDOH 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 the following chapter.

Alternative soil action levels for gross contamination and direct exposure hazards are included in the lookup tables of Appendix 1 (Tables F-3 and I-3, respectively). The direct exposure action levels for deep soils are based on a construction worker exposure scenario (refer to Appendices 1 and 2). The gross hazards action levels are based on an approach developed by Massachusetts DEQ (refer to Appendix 1).

Vapor intrusion and soil leaching hazards must be evaluated for chemicals that are highly mobile before final remedial actions can be determined. Contaminants of potential concern include chlorinated solvents, chlorinated herbicides, petroleum fuels and highly soluble chemicals like perchlorate. For these chemicals, vapor intrusion and soil leaching hazards typically take precedence over direct exposure hazards and drive the nature of remedial actions needed, regardless of the depth of the soil below the ground surface. Refer to Section 4.3.2 and 4.3.3 for additional guidance on the evaluation of these hazards, respectively.

If contamination is present in both shallow and deep soils and full cleanup is not anticipated, then separate action levels for each zone can be established and used during the initial site investigation stage of the project. The pros and cons of remediating deep soils to action levels for unrestricted future reuse should be evaluated on a site-by-site basis. While potentially more costly in the short term, treating all soil to action levels appropriate for unrestricted use of the property can help eliminate concerns about future liability as well as increase the market value of the property. This includes future excavation and offsite reuse of soil from the property (HDOH 2017a).

4.6.3 Petroleum-Contaminated Soil and Groundwater

HDOH has published separate guidance for the cleanup and long-term management of petroleum-contaminated sites (HDOH 2007b; updated as discussed below). A copy of the guidance is included in Appendix 8. Petroleum contamination is widespread in many current and former industrial areas. Complete removal of contamination is not practicable in many of these areas. At a minimum, removal of vadose-zone soil is recommended within the primary release area or exposed during construction activities that is contaminated above gross contamination action levels for isolated, subsurface soils (e.g., 5,000 mg/kg TPH in general refer to Table F-3 in Appendix 1).

Soil vapor data should be used to evaluate potential vapor intrusion hazards at sites where residual petroleum contamination exceeds action levels for unrestricted land use (refer to Section 4.5.4). Free product should be removed from groundwater to the extent necessary to minimize vapor intrusion and methane buildup hazards as well as reduce the potential for offsite migration concerns (e.g., via storm sewers) and reduce future impacts to groundwater. The nature and extent of remaining contamination and actions for long-term management of the site must be documented in an EHMP prepared for the site (refer to Chapter 5).

4.7 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 parklands 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. In addition, 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.

4.8 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 1996); 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 is presented in the HEER office *Technical Guidance Manual* (HDOH 2023 and updates).

Table 4-1. Progressive development of a residential, direct-exposure soil action level for dieldrin (see Section 4.1.2). (For example only. Dieldrin action toxicity factors and levels were updated in 2016.)

Toxicity Factor Type	**[1]Value**	**Target Risk**	**Equivalent Soil Action Level**
Range of Noncancer-Based Action Levels			
LOAEL	0.05 mg/kg-day	HQ=1.0	3,100 mg/kg
NOAEL	0.005 mg/kg-day	HQ=1.0	310 mg/kg
RfD	0.0005 mg/kg-day	HQ=1.0	3.1 mg/kg
		HQ=0.5	1.5 mg/kg
		HQ=0.2	0.60 mg/kg
Range of Cancer-Based Action Levels			
Slope Factor	16 (mg/kg-day)$^{-1}$	10^{-4}	3.0 mg/kg
		10^{-6}	0.03 mg/kg
Final Direct Exposure Soil Action Level Selected: 1.5 mg/kg			

Notes:

HQ	Hazard Quotient
LOAEL	Lowest Observed Adverse Effects Level
mg/kg	milligrams per kilogram
NOAEL	No Observed Adverse Effects Level
RfD	Reference Dose

5

Long-Term Management of Contaminated Sites

An expanded discussion of the long-term management of contaminated sites is included in Section 19 of the Hawai'i Department of Health (HDOH) Hazard Evaluation and Emergency Response (HEER) *Technical Guidance Manual* (HDOH 2023 and updates). Refer also to the HDOH guidance published for the long-term management of petroleum-contaminated sites (HDOH 2007b). Although focused on petroleum contamination, the guidance can also be expanded to other types of releases that require long-term management. A copy of the guidance is included in Appendix 8.

An *Environmental Hazard Management Plan* (EHMP) must be prepared for all sites where residual contamination in soil and groundwater exceeds action levels for unrestricted land use. Ideally the EHMP should be prepared as a stand-alone document which can be easily referenced by the property owner and others who may disturb soil or groundwater at the site. However, the EHMP can be prepared as a separate document, an appendix to a site investigation, or within the main body of a site investigation report, depending on the needs of the project. A basic EHMP should include the following information or be included in a document that contains the same information (refer also to Sections 18 and 19 of the HEER Office Technical Guidance Manual):

- 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 vapor, 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 vapor;
- 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. An EHMP prepared for a site where only a small amount of petroleum-contaminated soil or groundwater has been left in place and only gross contamination hazards remain will likely be relatively short and simple. 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 be at least 30cm (twelve inches) thick (USEPA 2003). For garden areas, at least 60cms (24 inches) of clean fill is recommended. 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 Environmental Hazard Management Plan. Soil re-used off-site must be assessed in accordance with the Fill Guidance and meet most stringent EALs in accordance with the HDOH "Clean Fill" guidance (HDOH 2017a). 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.

These are only a few of the issues that must be considered at sites where contaminated soil and groundwater are to be left in place. Refer to the HEER Office *Technical Guidance Manual* for additional guidance (HDOH 2023).

6

References

API, 1994, *Transport and Fate of Non-BTEX Petroleum Chemicals in Soils and Groundwater*: American Petroleum Institute, Health and Environmental Sciences Department, Publication No. 4593.

ASTM. 1985. *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System): American Society for Testing and Materials, Annual Book of ASTM Standards, D 2487-83, 04.08.*

ASTM, 2006, Standard Provisional Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface: ASTM Designation E2531-06, http://www.astm.org/Standard/index.shtml

ATSDR, 1998, Toxicological Profile for Chlorinated Dibenzo-p-dioxins (CDDs). Agency for Toxic Substances and Disease Registry, December 1998. http://www.atsdr.cdc.gov/toxprofiles/tp104.html.

ATSDR, 2007, *Toxicological Profile for Benzene* (August 2007): US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, http://www.atsdr.cdc.gov/toxprofiles/tp3.html#bookmark04

ATSDR, 2008, Update to the ATSDR Policy Guideline for Dioxins and Dioxin-Like Compounds in Residential Soil. Agency for Toxic Substances and Disease Registry, November 2008. http://www.atsdr.cdc.gov/substances/dioxin/policy/.

Bekins, B. A., Cozzarelli, I.M., Erickson, M.L., Steenson, R.A., and K. A. Thorn, Crude Oil Metabolites in Groundwater at Two Spill Sites: Groundwater, doi: 10.1111/gwat.12419.

Brewer, R., Nagashima, J., Kelley, M. and M. Rigby, 2013, Risk-Based Evaluation of Total Petroleum Hydrocarbons in Vapor Intrusion Studies: International Journal of Environmental Research and Public Health, Volume 10, pp 2441-2467. http://www.mdpi.com/1660-4601/10/6/2441/;

Brewer, R., Nagashima, J., Rigby, M., Schmidt, M. and H. O'Neill, 2014, Estimation of Generic Subslab Attenuation Factors for Vapor Intrusion Investigations. Groundwater Monitoring & Remediation, 34: 79–92. doi: 10.1111/gwmr.12086, http://onlinelibrary.wiley.com/doi/10.1111/gwmr.12086/full

CalARB, 2001, Chlorinated Chemicals in Your Home: California Air Resources Board, Indoor Air Quality Guideline, May 2001.

CalEPA, 1994, *Preliminary Endangerment Assessment Guidance Manual*: California Environmental Protection Agency, Department of Toxics Substances Control, January 1994.

CalEPA, 1996, *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities*: California Environmental Protection Agency, Department of Toxics Substances Control, August, 1996, www.dtsc.ca.gov/ScienceTechnology/index.html.

CalEPA, 2002, *Response Actions For Sites Where Future Uses May Include Sensitive Uses*: California Environmental Protection Agency Department of Toxic Substances Control, Site Mitigation and Brownfields Reuse Program, Management Memo EO-02-002-MM, July 2002.

CalEPA, 2005, Advisory on Methane Assessment and Common Remedies at School Sites, California Environmental Protection Agency, Department of Toxics Substances Control, http://www.dtsc.ca.gov/.

CalEPA, 2013, *San Francisco Bay (Region 2) Water Quality Control Plan (Basin Plan)*: California Environmental Protection Agency, Regional Water Quality Control Board, San Francisco Bay Region, June 2013.

CalEPA, 2016a, *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater*: California Environmental Protection Agency, Regional Water Quality Control Board, San Francisco Bay Area Region, (and updates).

CalEPA, 2016b, Petroleum Metabolites Literature Review and Assessment Framework: California Environmental Protection Agency, San Francisco Bay Regional Water Quality Control Board, June 27, 2016.

CalEPA, 2016c, *Vapor Intrusion Mitigation Advisory*: California Environmental Protection Agency, Department of Toxics Substances Control, October 2011, http://www.dtsc.ca.gov/.

CNMI, 2005, *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater:* the Commonwealth of the Northern Mariana Islands, Division of Environmental Quality, October 2005.

Diamond, G.L., Bradham, K.D., Brattin, W.J., Burgess, M., Griffin, S., Hawkins, C.A., Juhasz, A.L., Klotzbach, J.M., Nelson, C., Lowney, Y.W., Scheckel, K.G., and D.J. Thomas, 2016, Predicting oral relative bioavailability of arsenic in soil from in vitro bioaccessibility: Journal of Toxicology and Environmental Health, vol. 79/4, pp 165-173.

DoD, 2008, DoD: Tri-Services Handbook for the Assessment of the Vapor Intrusion Pathway: Department of Defense, (prepared by Noblis Consultants for the Air Force Institute for Operational Health, Health Risk Assessment Branch, February 2008.

Fetter, C. W., 1988, Applied Hydrology: Merrill Publishing Company, Columbus, Ohio, ISBN 0-0-675-20887-4.

Freeze, R.A. and J.A Cherry. 1979. *Groundwater*: Prentice-Hall, Inc., Edgewood Cliffs, New Jersey, ISBN 0-13-365312-9.

HDOH, 1995, *Risk-Based Corrective Action and Decision Making at Sites with Contaminated Soil and Groundwater*: State of Hawai'i, Department of Health, December, 1995 (revised June, 1996), www.state.hi.us/doh/eh/shwb/ust/ index.html

HDOH, 2006a, *Soil Action Levels and Categories for Bioaccessible Arsenic:* Hawaiʻi Department of Health, Honolulu, http://hawaii.gov/health/environmental/hazard/index.html

HDOH, 2006b, *Proposed dioxin action levels for East Kapolei Brownfield Site*: Hawaiʻi Department of Health, Office of Hazard Evaluation and Emergency Response, March 2006 (amended September 2006), http://www.hawaii.gov/health/ environmental/hazard/eal2005.html

HDOH, 2007a, *Pesticides in former agricultural lands and related areas - Updates on investigation and assessment.* May: Hawaiʻi Department of Health, Honolulu, www.state.hi.us/doh/eh/shwb/ust/index.html.

HDOH, 2007b, *Long-Term Management of Petroleum-Contaminated Soil and Groundwater* Hawaiʻi Department of Health, Honolulu, http://hawaii.gov/health/environmental/hazard/index.html

HDOH, 2010a, Update to Soil Action Levels for inorganic Arsenic and Recommended Soil Management Practices: Hawaiʻi Department of Health, Office of Hazard Evaluation and Emergency Response, October 2010 (updated November 25, 2011), http://www.hawaiidoh.org/

HDOH, 2010b, Update to Soil Action Levels for TEQ Dioxins and Recommended Soil Management Practices: Hawai‘i Department of Health, Office of Hazard Evaluation and Emergency Response, June, http://www.hawaiidoh.org/

HDOH, 2010c, Arsenic in Hawaiian Soils: Questions and Answers on Health Concerns: Hawai’i Department of Health, Office of Hazard Evaluation and Emergency Response, September 2010, http://www.hawaiidoh.org/

HDOH, 2011, Hawaiian Islands Soil Metal Background Evaluation Report: Hawai‘i Department of Health, Office of Hazard Evaluation and Emergency Response, September 2011, prepared by AECOM.

HDOH, 2017a, *Guidance for Soil Stockpile Characterization and Evaluation of Imported and Exported Fill Material*: Hawai‘i Department of Health, Office of Hazard Evaluation and Emergency Response, October 2017.

HDOH, 2017b, *Use of laboratory batch tests to evaluate potential leaching of contaminants from soil* (and updates): Hawai‘i Department of Health, Honolulu, www.state.hi.us/doh/eh/shwb/ust/index.html.

HDOH, 2023, *Technical Guidance Manual*: Hawai‘i Department of Health, Office of Hazard Evaluation and Emergency Response, 2016 (and updates).

ITRC, 2018, *TPH Risk Evaluation at Petroleum Contaminated Sites*: Interstate Technical and Regulatory Council..

Johnson, P.C., Kemblowski, M. W., and Johnson, R.L., 1998, *Assessing the Significance of Subsurface Contaminant Vapor Migration to Enclosed Spaces*: American Petroleum Institute, Health and Environmental Sciences Department, December, 1998, API Publication No. 4674.

Johnson, P. C., 2002, Identification of Critical Parameters for the Johnson and Ettinger (1991) Vapor Intrusion Model. API Bulletin No. 17. American Petroleum Institute. Washington, DC. May 2002, www.api,org/bulletins.

Kurtz, K.P. and D.J. Folkes, 2002, Background Concentrations of Selected Chlorinated Hydrocarbons in Indoor Air: Proceedings Indoor Air 2002.

MADEP, 2002a, *Characterizing Risks Posed by Petroleum Contaminated Sites* (October 2002): Massachusetts Department of Environmental Protection, Policy #WSC-02-41 1, http://mass.gov/dep/cleanup/laws/vph_eph.htm.

MADEP, 2002b, Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup, May 2002.

MADEP, 2002c, *Indoor Air Sampling and Evaluation Guide*: Massachusetts Department of Environmental Protection, Office of Research and Standards, WSC Policy #02-430; http://www.state.ma.us/dep/bwsc/finalpol.htm.

MADEP, 2002d, Residential Typical Indoor Air Concentrations: Massachusetts Department of Environmental Protection, Office of Research and Standards, Technical Update 2002.

MADEP, 2010, *Vapor Intrusion Guidance*: Massachusetts Department of Environmental Protection, Office of Research and Standards, 2010 Draft update.

Mohler, R.E., O'Reilly, K.T, Zemo, D.A., Tiwary, A.K., Magaw, R.I. and K.A. Synowiec, 2013, Nontargeted analysis of petroleum metabolites in groundwater using GC×GC–TOFMS: Environmental Science and Technology, Vol. 47, pp. 10471–10476.

NEIWPCC, 2003, A Hot Dog by Any Other Name Could Be Your Drinking Water: New England Interstate Water Pollution Control Commission, L.U.S.T. Line, Bullet 44, July 2003.

NIOSH, 2007, NIOSH Pocket Guide to Chemical Hazards: National Institute for Occupational Safety and Health (NIOSH), www.cdc.gov/niosh/npg/npg.html.

NJDEP, 2005, *Vapor Intrusion Guidance*: New Jersey Department of Environmental Protection, October 2005, http://www.nj.gov/dep/srp/guidance/vaporintrusion/vig.htm

NYDOH, 2003, Tetrachloroethylene (PERC) in Indoor and Outdoor Air: New York State Department of Health, Fact Sheet, May 2003.

NYDOH, 2006, *Guidance for Evaluating Soil Vapor Intrusion in the State of New York*: New York State Department of Health, Bureau of Environmental Exposure Investigation, October 2006, http://www.health.state.ny.us/environmental/investigations/soil_gas/svi_guidance/

NZME, 2011, Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health: New Zealand Ministry for the Environment, Publication number: ME 1055.

Ramsey, C. and A. Hewitt. 2005, A Methodology for Assessing Sample Representativeness: Environmental Forensics 6:71-75, http://urlx.org/ingentaconnect.com/a385d

Shih, T., Y. Rong, T. Harmon, and M. Suffet, 2004. Evaluation of the impact of fuel hydrocarbons and oxygenates on groundwater resources: Environmental Science and Technology. Vol. 38, No. 1: 42-48.

TPEHE, 2017, *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater (Tropical Pacific Edition)*: prepared under direction of the Commonwealth of the Northern Mariana Islands, Division of Environmental Quality, and the Guam Environmental Protection Agency, Fall 2017.

USDA, 1987, Soil Mechanics Level 1, Module 3, USDA Textural Classification Study Guide: US Department of Agriculture, Soil Conservation Service, February 1987.

USEPA, 1989a, *Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A)*: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Publication EPA/540/1-89/092.

USEPA, 1989b, *Risk Assessment Guidance for Superfund. Volume II, Environmental Evaluation Manual*: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Publication EPA/540/1-89/001.

USEPA, 1990a, Guidance on Remedial Actions for Superfund Sites with PCB Contamination: U.S. Environmental Protection Agency Office of Emergency and Remedial Response, EPA/540/G-90/007, August 1990.

USEPA, 1990b, Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions (Final Rule): U.S. Environmental Protection Agency, Federal Register, Thursday, March 29, 1990, 40 CFR Part 261 et al.

USEPA, 1990c, Dieldrin (CASRN 60-57-1; 09/01/1990): U.S. Environmental Protection Agency Integrated Risk Information System, http://www.epa.gov/iris/subst/0225.htm

USEPA, 1994, Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, February 1994, EPA/540/R-93/081.

USEPA, 1996a, *Soil Screening Guidance: Technical Background Document*: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Publication 9355.4-17A, May 1996, http://www.epa.gov/superfund/health/conmedia/soil/index.htm

USEPA, 1997a, *Exposure Factors Handbook*: U.S. Environmental Protection Agency, Office of Research and Development, Publication EPA/600/P-95/002Fa, August 1997 (updated in 2011).

USEPA, 1997b, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*. U.S. Environmental Protection Agency, Environmental Response Team, Interim Final. June 5, 1997, EPA 540-R-97-006.

USEPA, 1998, Sources of Lead in Soil: U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, February 1998, EPA 747-R-98-001a.

USEPA, 2000, TRW Recommendations for Sampling and Analysis of Soil at Lead (Pb) Sites: U.S. Environmental Protection Agency, Solid Waste and Emergency Response, EPA 540-F-0-010/OSWER 9285.7-38, April 2000, http://www.epa.gov/superfund/lead/guidance.htm.

USEPA 2002a, Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites: U.S. Environmental Protection Agency, Solid Waste and Emergency Response, OSWER 9355.4-24, December 2002, http://www.epa.gov/superfund/health/conmedia/soil/index.htm

USEPA, 2002b, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, December 2002, OSWER 9285.6-10.

USEPA, 2003, Superfund Lead-Contaminated Residential Sites Handbook: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, August 2003, OSWER 9285.7-50.

USEPA, 2004a, *Preliminary Remediation Goals*: U.S. Environmental Protection Agency, Region IX, October 2004, www.epa.gov/region09/waste/sfund/prg/index.htm.

USEPA, 2004b, User's Guide for Subsurface Vapor Intrusion into Buildings: U.S. Environmental Protection Agency Office of Emergency and Remedial Response, February 2004, www.epa.gov/oerrpage/superfund/.

USEPA, 2005, *PCB Site Revitalization Guidance under the Toxics Substances Control Act*: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, November 2005, http://www.epa.gov/epaoswer/hazwaste/pcbs/pubs/guidance.htm

USEPA, 2007, Method 8015C, Nonhalogenated Organics by Gas Chromatography: U.S. Environmental Protection Agency, February 2007.

USEPA, 2008, Method for Toxic Equivalents (TEQs) Determinations for Dioxin-Like Chemical Activity with the CALUX® Bioassay (Method 4435): U.S. Environmental Protection Agency, Solid Waste and Emergency Response, http://www.epa.gov/sw-846/new-meth.htm

USEPA, 2011a, National Program Manager Guidance (Lead Risk Reduction Program): U.S. Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention, Final FY 2012, EPA-740-B-11-001, http://www.epa.gov/planandbudget/annualplan/FY12_OCSPP_NPM_Gdnce.pdf

USEPA, 2011b, *Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990–2005): A Compilation of Statistics for Assessing Vapor Intrusion*: U.S. Environmental Protection Agency, Solid Waste and Emergency Response, EPA 530-R-10-001.

USEPA, 2012a, Recommendations for Default Value for Relative Bioavailability of Arsenic in Soil: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, December 2012, OSWER 9200.1-113.

USEPA, 2012b, EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments, Volume 1: U.S. Environmental Protection Agency, February 2012, EPA/600/R-10/038F.

USEPA, 2015a, Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, June 2015, Washington, D.C., OSWER Publication 9200.2-154.

USEPA, 2015b, Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites: .S. Environmental Protection Agency, Office of Underground Storage Tanks, June 2015, Washington, D.C., EPA 510-R-15-001.

USEPA, 2017, *Regional Screening Levels*: U.S. Environmental Protection Agency, prepared by Oak Ridge National Laboratories, November 2023, https://www.epa.gov/risk/regional-screening-levels-rsls

WHO 2001. Safety Evaluation of Certain Food Additives and Contaminants (PCDDs, PCDFs, PCBs). World Health Organization, Food Additive Series 48, 177p, http://www.inchem.org/documents/jecfa/jecmono/v48je20.htm.

WHO 2002. Safety Evaluation of Certain Food Additives and Contaminants. WHO Technical Report Series, Fifty-seventh report of the Joint FAO/WHO Expert Committee on Food Additives, WHO Technical Report Series 909, http://whqlibdoc.who.int/trs/WHO_TRS_909.pdf.

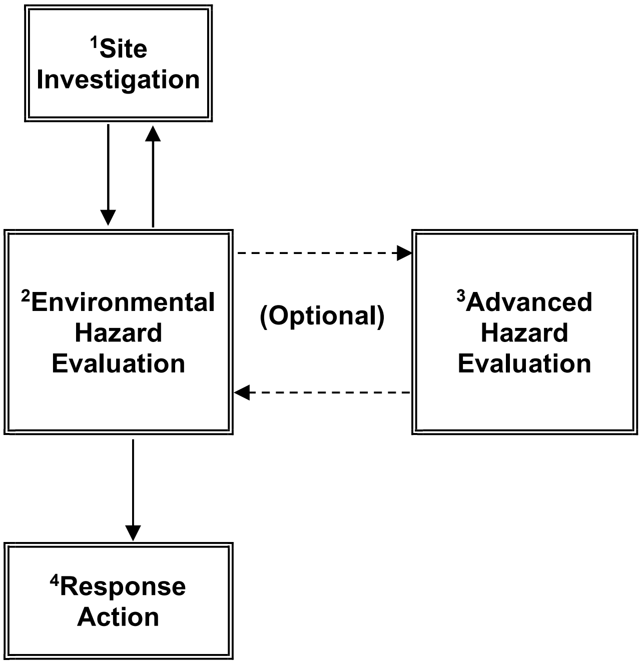
WHO, 2005, The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds (van den Berg, M. et al.): World Health Organization, (ToxSci Advance Access published July 7, 2006), http://www.who.int/ipcs/assessment/tef_update/en/

Zemo D.A., O'Reilly K.T., Mohler R.E., Tiwary A.K., Magaw R.I. and K.A., Synowiec. 2013. Nature and estimated human toxicity of polar metabolite mixtures in groundwater quantified as TPHd/DRO at biodegrading fuel release sites. Groundwater Monit Remed 33(4):44–56.

Zemo, D.A., O'Reilly, K.T., Mohler, R.M., Magaw, R.I., Espino Devine, C., Ahn, S. and A.K. Tiwary. 2016. Life Cycle of Petroleum Biodegradation Metabolite Plumes, and Implications for Risk Management at Fuel Release Sites. Integrated Environmental Assessment and Management. DOI: 10.1002/ieam.1848.

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.

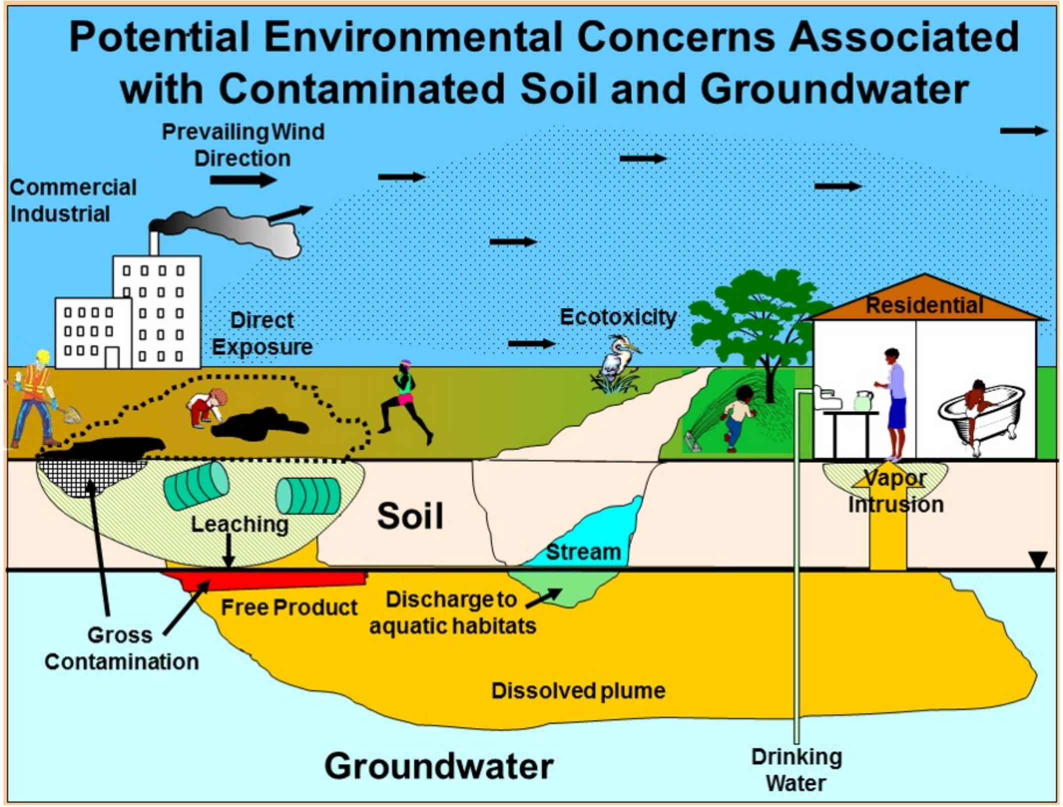
3. An advanced evaluation of specific environmental hazards can be carried out as needed. For example, soil vapor data can be collected to better evaluate vapor intrusion hazards; soil batch tests can be carried out to better evaluate leaching hazards; a site-specific human-health risk assessment and/or 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 1-2a. 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 1-2b. Summary of common environmental hazards associated with contaminated soil and groundwater (schematic).



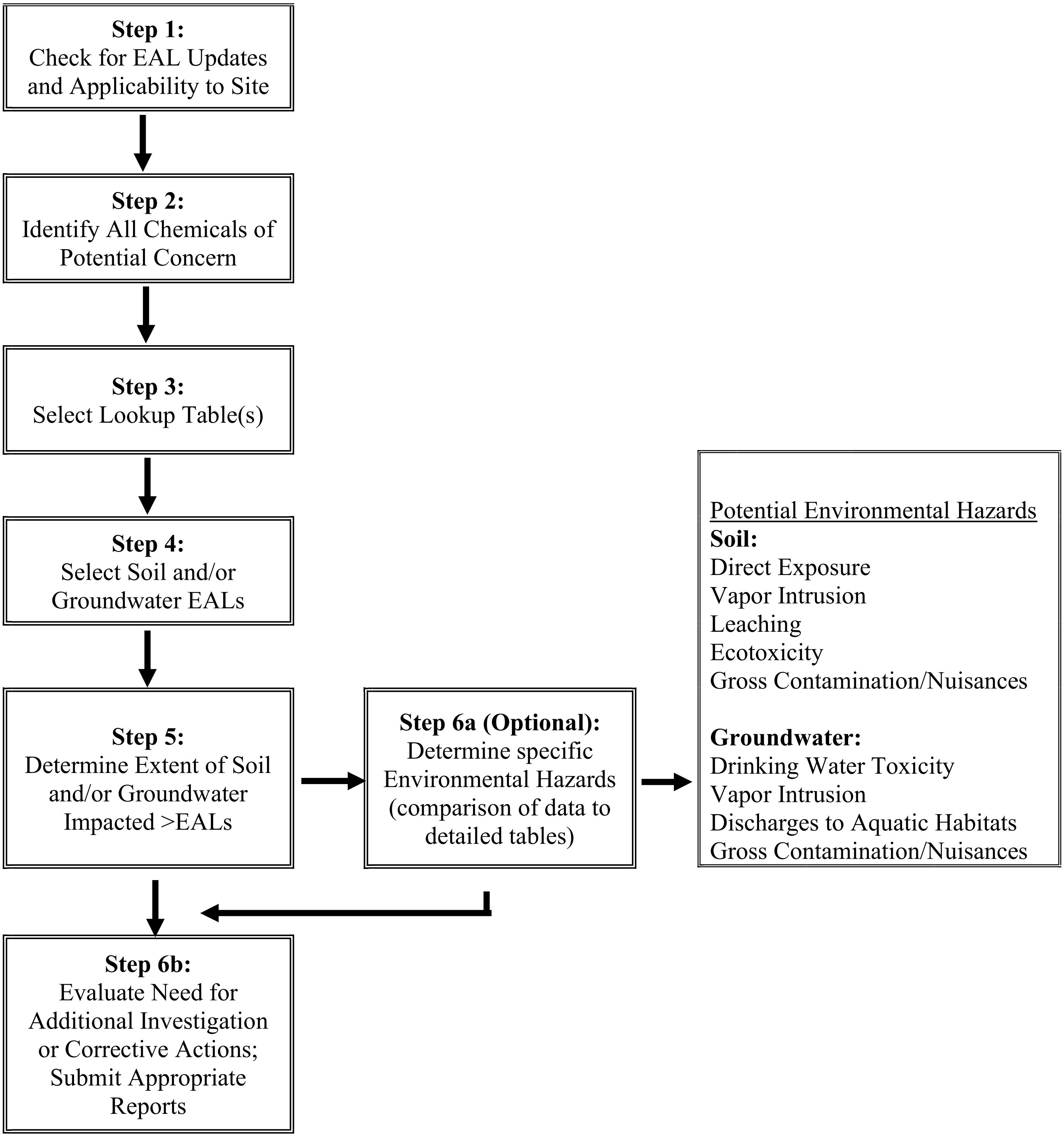


Figure 1-3. Steps for use of the Tier 1 EAL lookup tables during the site assessment process. Although not necessary for sites where cleanup to Tier 1 EALs can easily be attained, identification of specific environmental hazards is recommended and in particular required for sites where long-term, on-site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

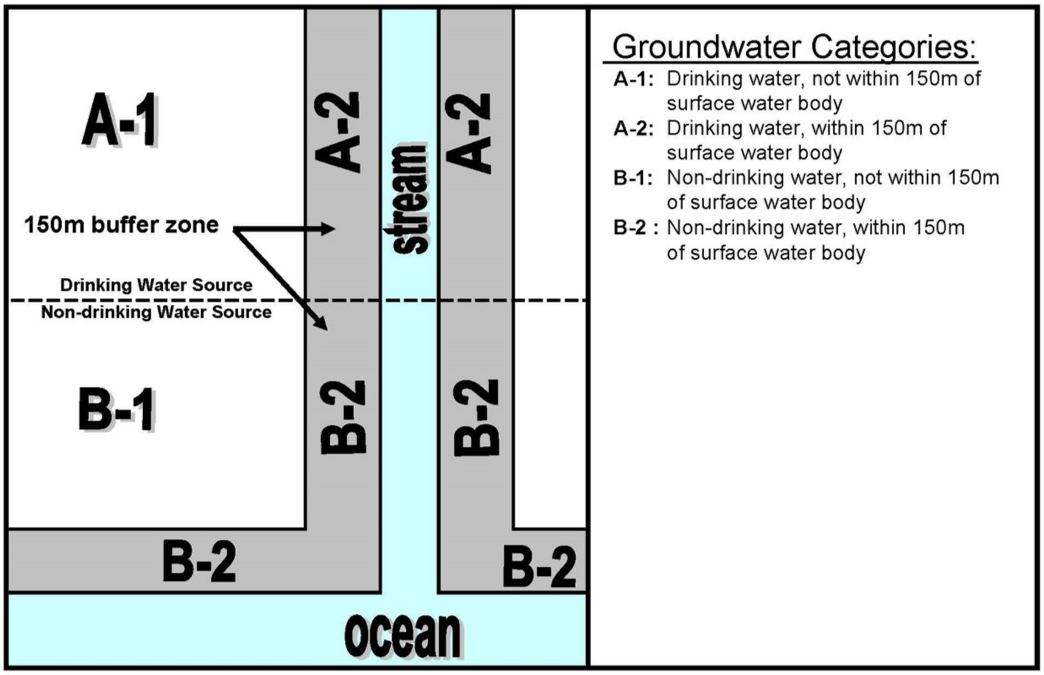


Figure 2.1. Groundwater categories used to develop the Tier 1 EAL lookup tables.

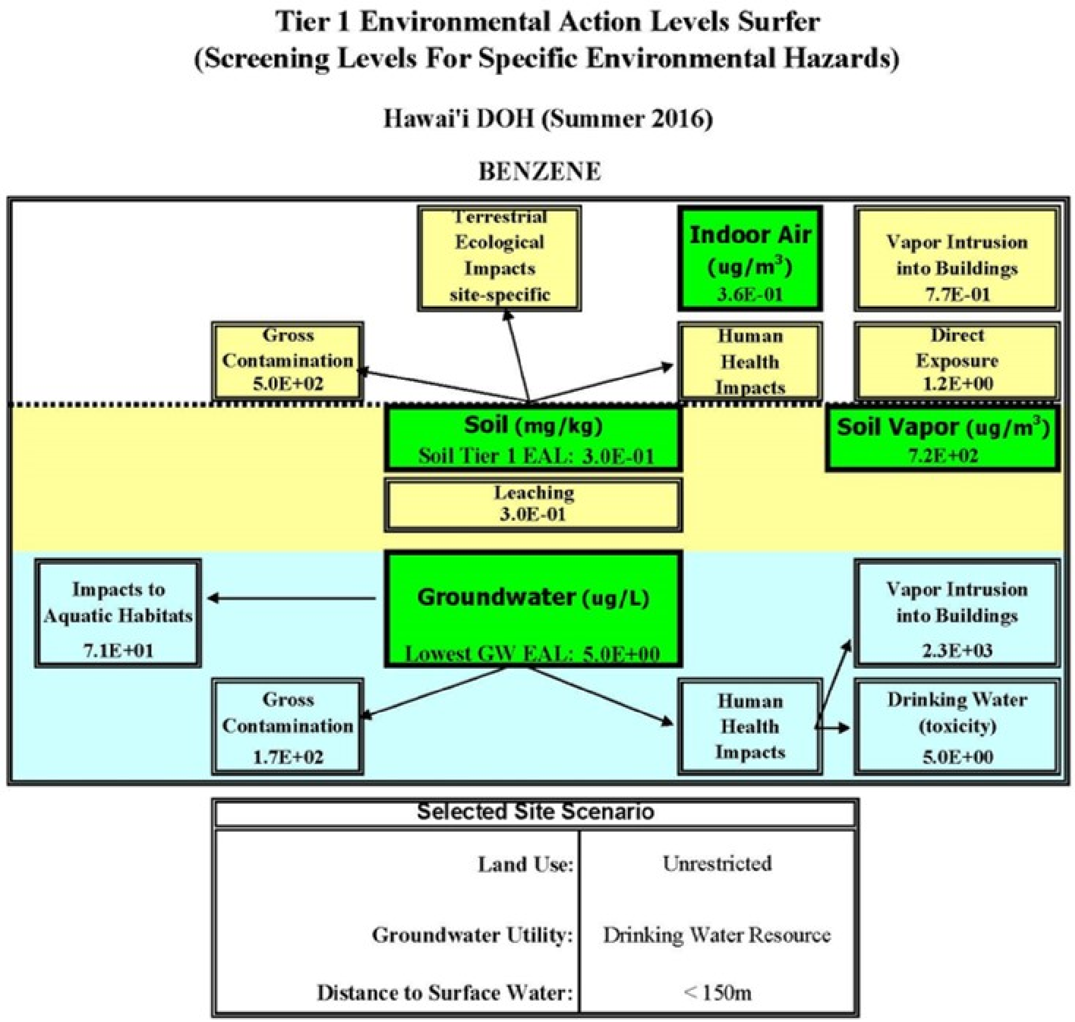
Figure 2-2. Primary references for compilation of Tier 1 Environmental Action levels.

Soil

Environmental Hazard	Primary Reference	Comments
Direct Exposure	USEPA Regional Screening Levels (RSLs)	RSLs 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 action levels
Terrestrial Ecotoxicity		Published soil action levels not recommended for use in Hawai‘i; carry out site-specific assessment as needed
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 (MCL)	USEPA Tapwater RSL 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



Selected Site Scenario	
Land Use:	Unrestricted
Groundwater Utility:	Drinking Water Resource
Distance to Surface Water:	< 150m

Figure 2-3. Example action levels for individual environmental concerns used to select final, Tier 1 soil and groundwater EALs for benzene.

Figure 2-4. Target analytes for releases of petroleum products.

Petroleum Product	**Media**	**Recommended Target Analytes**
Gasolines	Soil	TPH, BTEX, naphthalene, MTBE and appropriate additives and breakdown products (e.g., DBA, TBA, lead, ethanol, etc.)
	Soil Vapor	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 (1- and 2-)
	Soil Vapor	TPH, BTEX, naphthalene, 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 Vapor	TPH, VOCs, naphthalene, methane
	Groundwater	same as soil

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

Figure 2-5. Summary of models and approaches used to develop action levels incorporated into the Tier 1 EALs (refer also to Appendix 1).

Groundwater Action Levels	
Contamination of drinking water supplies	HDOH promulgated drinking water standards or USEPA Regional Screening Levels model for tapwater. Refer to Appendix 1 (Section 5.2 and Table D-3 series) and Appendix 2.
Vapor Intrusion	USEPA vapor intrusion spreadsheets. Refer to Appendix 1 (Section 5.4 and Table C-1a) and Appendix 4.
Impact to Aquatic Habitats	HDOH promulgated surface water standards or USEPA and other references if not available. Refer to Appendix 1 (Section 5.3 and Table D-4 series).
Gross contamination	Massachusetts DEP approach, modified as indicated. Refer to Appendix 1 (Section 5.5 and Table G series).
Soil Action Levels	
Environmental Hazard	**Reference**
Direct Exposure	USEPA Regional Screening Levels models for direct exposure concerns. Refer to Appendix 1 (Section 4.2 and Table I series) and Appendix 2.
Vapor Intrusion	USEPA vapor intrusion spreadsheets. Refer to Appendix 1 (Section 4.3 and Table C-1b) and Appendix 4.
Leaching	Massachusetts DEP soil leaching model. Refer to Appendix 1 (Section 4.4 and Table E) and Appendix 5.
Gross contamination	Massachusetts DEP approach, modified as indicated. Refer to Appendix 1 (Section 4.5 and Table F series).
Soil vapor and Indoor Air Action Levels	
Vapor Intrusion	USEPA vapor intrusion spreadsheets. Refer to Appendix 1 (Sections 3-2 and 3.3 and Tables C-2 and C-3) and Appendix 4.

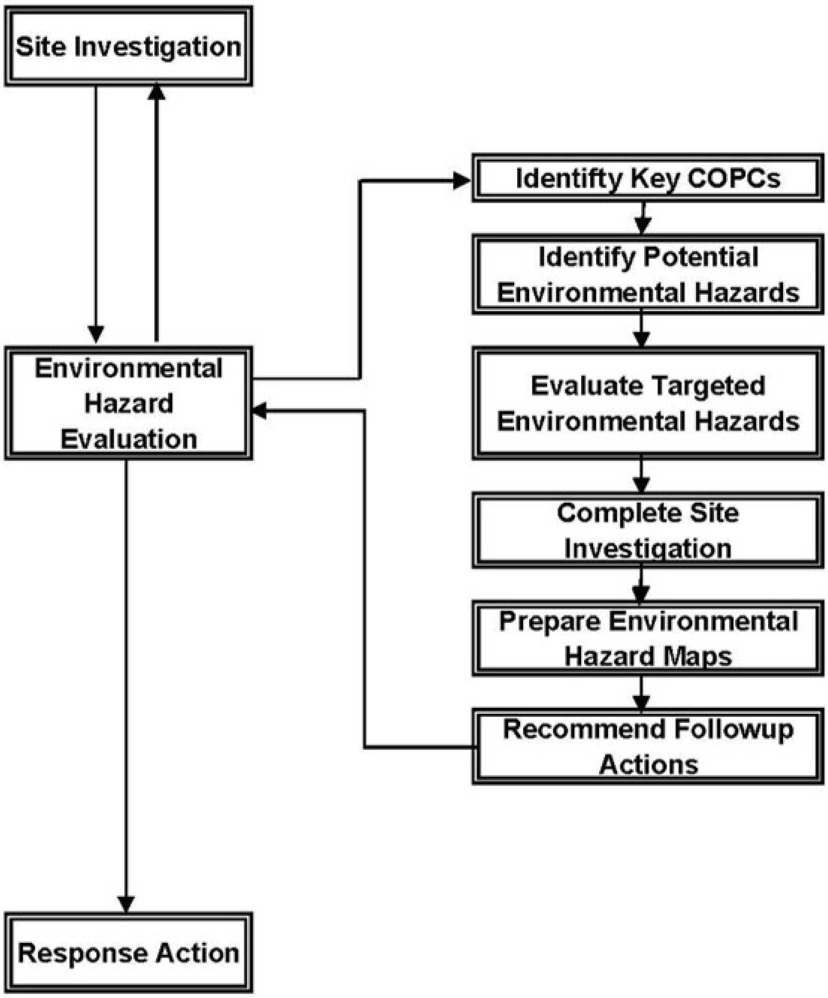
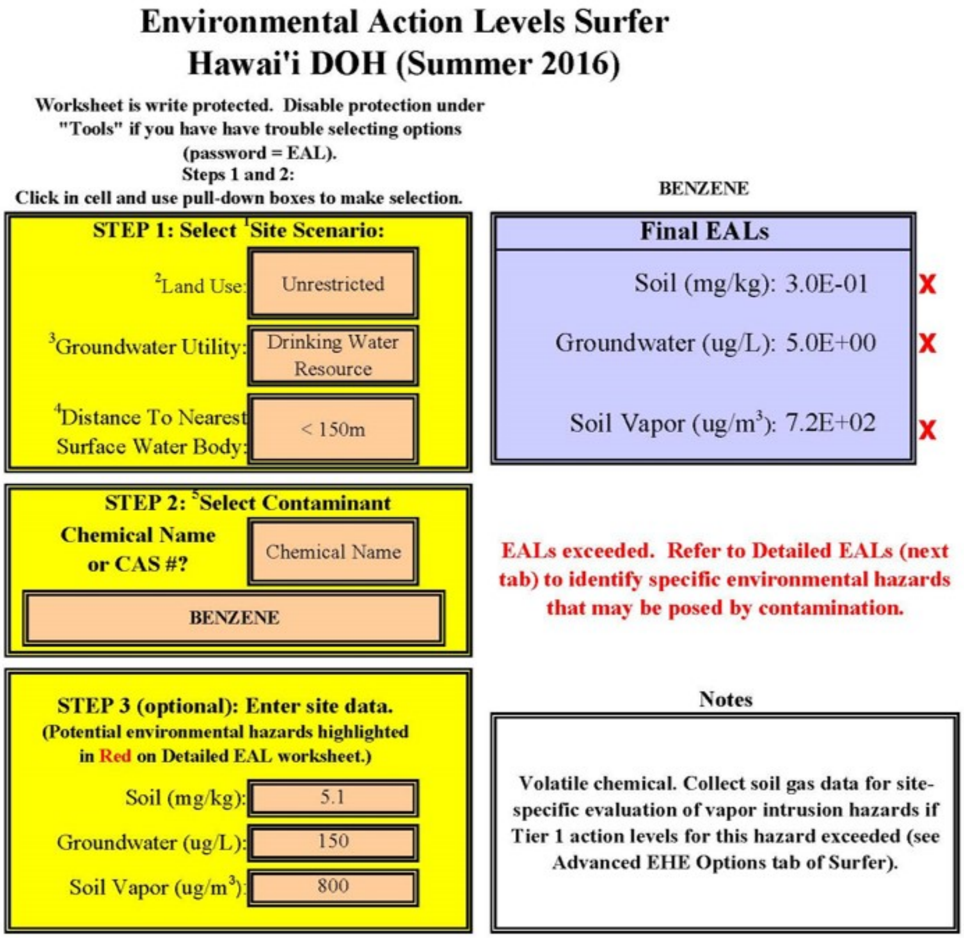


Figure 3-1. Overview of the Environmental Hazard Evaluation process (preparation of environmental hazard maps optional).



Environmental Action Levels Surfer
Hawai'i DOH (Summer 2016)

Worksheet is write protected. Disable protection under "Tools" if you have have trouble selecting options (password = EAL).
Steps 1 and 2:
Click in cell and use pull-down boxes to make selection.

STEP 1: Select [1]Site Scenario:

[2]Land Use: Unrestricted
[3]Groundwater Utility: Drinking Water Resource
[4]Distance To Nearest Surface Water Body: < 150m

STEP 2: [5]Select Contaminant

Chemical Name or CAS #? Chemical Name

BENZENE

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

Soil (mg/kg): 5.1
Groundwater (ug/L): 150
Soil Vapor (ug/m^3): 800

BENZENE

Final EALs

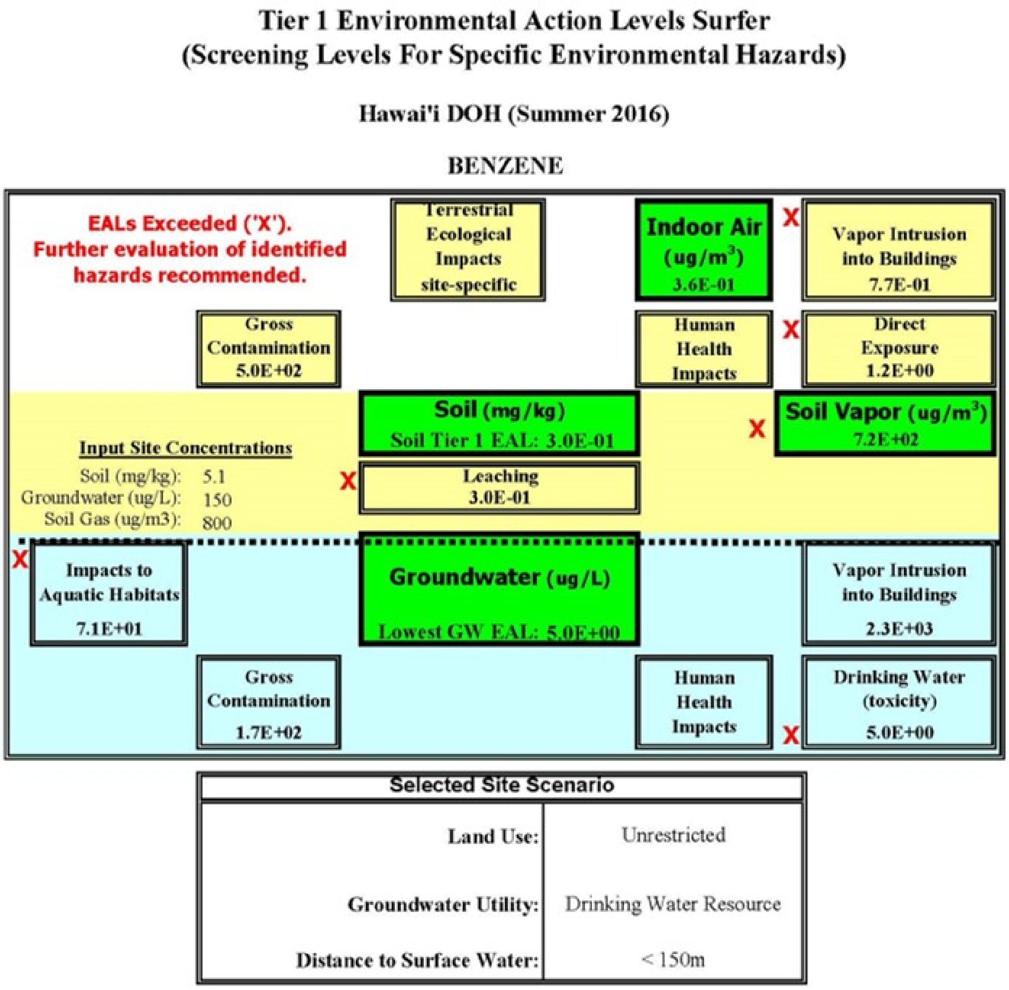
Soil (mg/kg): 3.0E-01 X
Groundwater (ug/L): 5.0E+00 X
Soil Vapor (ug/m^3): 7.2E+02 X

EALs exceeded. Refer to Detailed EALs (next tab) to identify specific environmental hazards that may be posed by contamination.

Notes

Volatile chemical. Collect soil gas data for site-specific evaluation of vapor intrusion hazards if Tier 1 action levels for this hazard exceeded (see Advanced EHE Options tab of Surfer).

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



Tier 1 Environmental Action Levels Surfer
(Screening Levels For Specific Environmental Hazards)

Hawai'i DOH (Summer 2016)

BENZENE

EALs Exceeded ('X').
Further evaluation of identified hazards recommended.

Terrestrial Ecological Impacts site-specific

X Indoor Air (ug/m^3) 3.6E-01

X Vapor Intrusion into Buildings 7.7E-01

Gross Contamination 5.0E+02

Human Health Impacts

X Direct Exposure 1.2E+00

Soil (mg/kg) Soil Tier 1 EAL: 3.0E-01

X Soil Vapor (ug/m^3) 7.2E+02

X Leaching 3.0E-01

Input Site Concentrations

Soil (mg/kg):	5.1
Groundwater (ug/L):	150
Soil Gas (ug/m3):	800

X Impacts to Aquatic Habitats 7.1E+01

Groundwater (ug/L) Lowest GW EAL: 5.0E+00

Vapor Intrusion into Buildings 2.3E+03

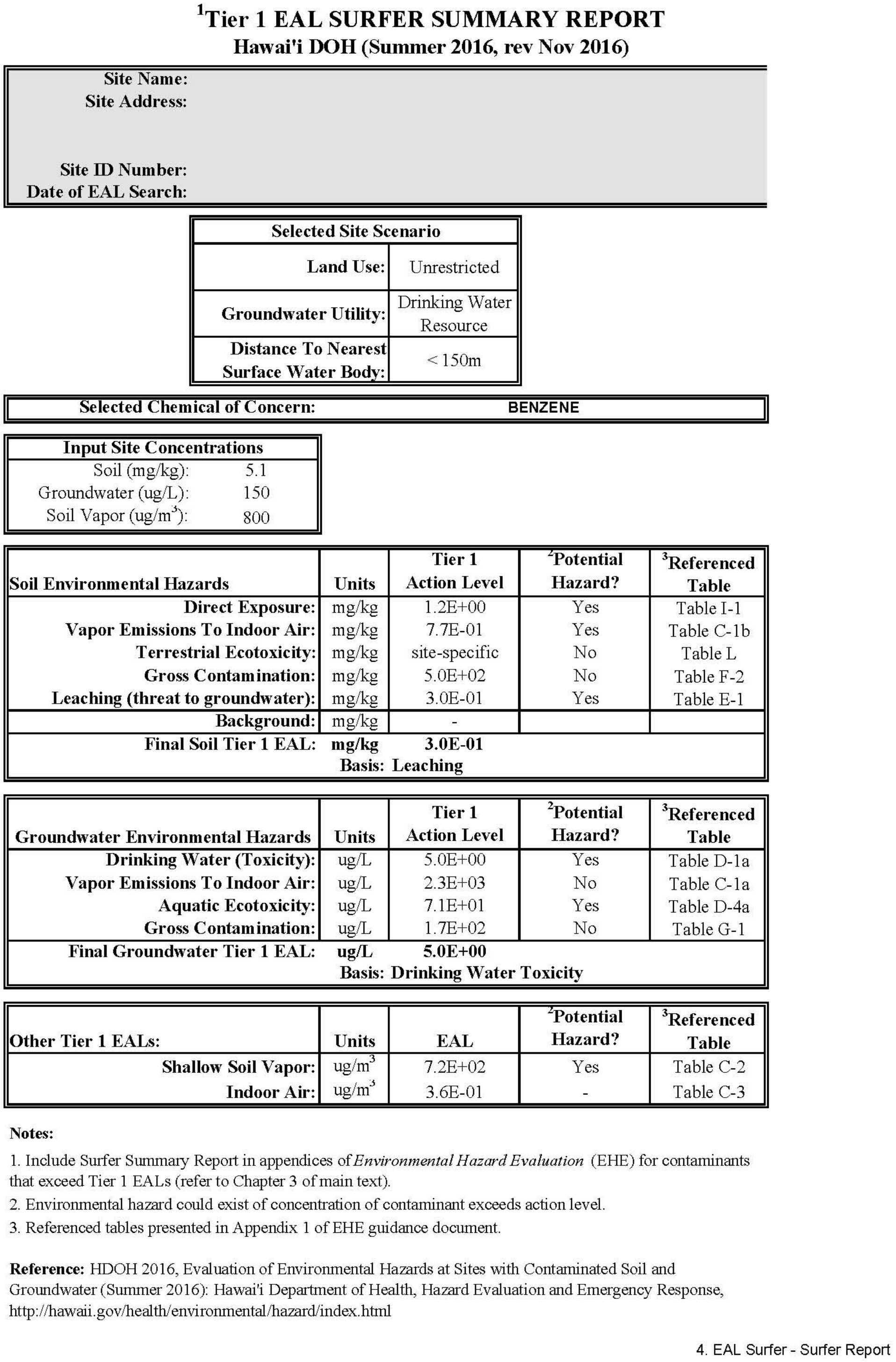
Gross Contamination 1.7E+02

Human Health Impacts

X Drinking Water (toxicity) 5.0E+00

Selected Site Scenario	
Land Use:	Unrestricted
Groundwater Utility:	Drinking Water Resource
Distance to Surface Water:	< 150m

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



[1]Tier 1 EAL SURFER SUMMARY REPORT
Hawai'i DOH (Summer 2016, rev Nov 2016)

Site Name:	
Site Address:	
Site ID Number:	
Date of EAL Search:	

Selected Site Scenario	
Land Use:	Unrestricted
Groundwater Utility:	Drinking Water Resource
Distance To Nearest Surface Water Body:	< 150m

Selected Chemical of Concern: BENZENE

Input Site Concentrations	
Soil (mg/kg):	5.1
Groundwater (ug/L):	150
Soil Vapor (ug/m^3):	800

Soil Environmental Hazards	**Units**	**Tier 1 Action Level**	**[2]Potential Hazard?**	**[3]Referenced Table**
Direct Exposure:	mg/kg	1.2E+00	Yes	Table I-1
Vapor Emissions To Indoor Air:	mg/kg	7.7E-01	Yes	Table C-1b
Terrestrial Ecotoxicity:	mg/kg	site-specific	No	Table L
Gross Contamination:	mg/kg	5.0E+02	No	Table F-2
Leaching (threat to groundwater):	mg/kg	3.0E-01	Yes	Table E-1
Background:	mg/kg	-		
Final Soil Tier 1 EAL:	**mg/kg**	**3.0E-01**		
	Basis:	**Leaching**		

Groundwater Environmental Hazards	**Units**	**Tier 1 Action Level**	**[2]Potential Hazard?**	**[3]Referenced Table**
Drinking Water (Toxicity):	ug/L	5.0E+00	Yes	Table D-1a
Vapor Emissions To Indoor Air:	ug/L	2.3E+03	No	Table C-1a
Aquatic Ecotoxicity:	ug/L	7.1E+01	Yes	Table D-4a
Gross Contamination:	ug/L	1.7E+02	No	Table G-1
Final Groundwater Tier 1 EAL:	**ug/L**	**5.0E+00**		
	Basis:	**Drinking Water Toxicity**		

Other Tier 1 EALs:	**Units**	**EAL**	**[2]Potential Hazard?**	**[3]Referenced Table**
Shallow Soil Vapor:	ug/m^3	7.2E+02	Yes	Table C-2
Indoor Air:	ug/m^3	3.6E-01	-	Table C-3

Notes:

1. Include Surfer Summary Report in appendices of *Environmental Hazard Evaluation* (EHE) for contaminants that exceed Tier 1 EALs (refer to Chapter 3 of main text).
2. Environmental hazard could exist of concentration of contaminant exceeds action level.
3. Referenced tables presented in Appendix 1 of EHE guidance document.

Reference: HDOH 2016, Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater (Summer 2016): Hawai'i Department of Health, Hazard Evaluation and Emergency Response, http://hawaii.gov/health/environmental/hazard/index.html

4. EAL Surfer - Surfer Report

Figure 3-2c. Example printout of EAL Surfer summary report, using benzene at noted concentrations in soil and groundwater as an example.

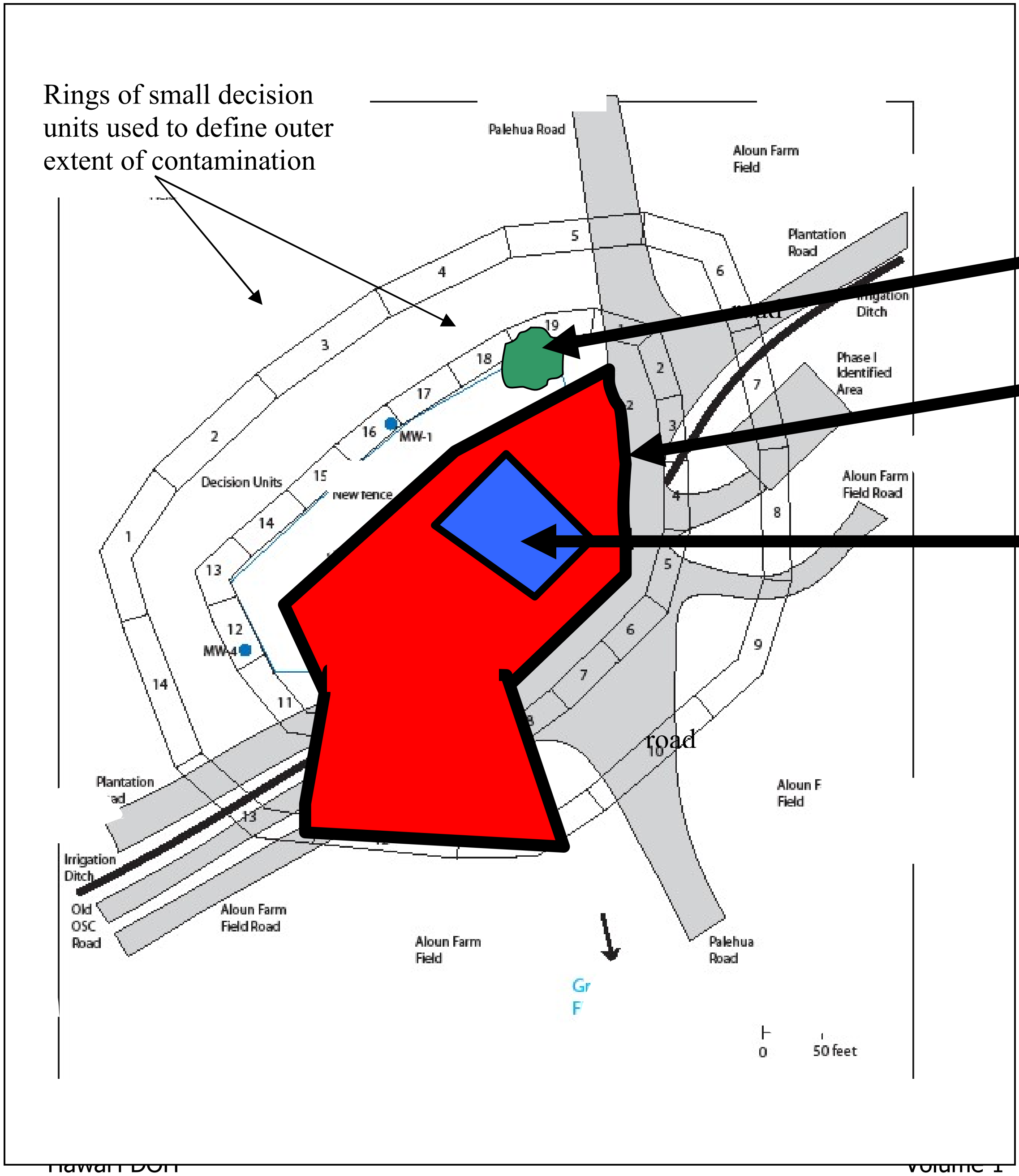
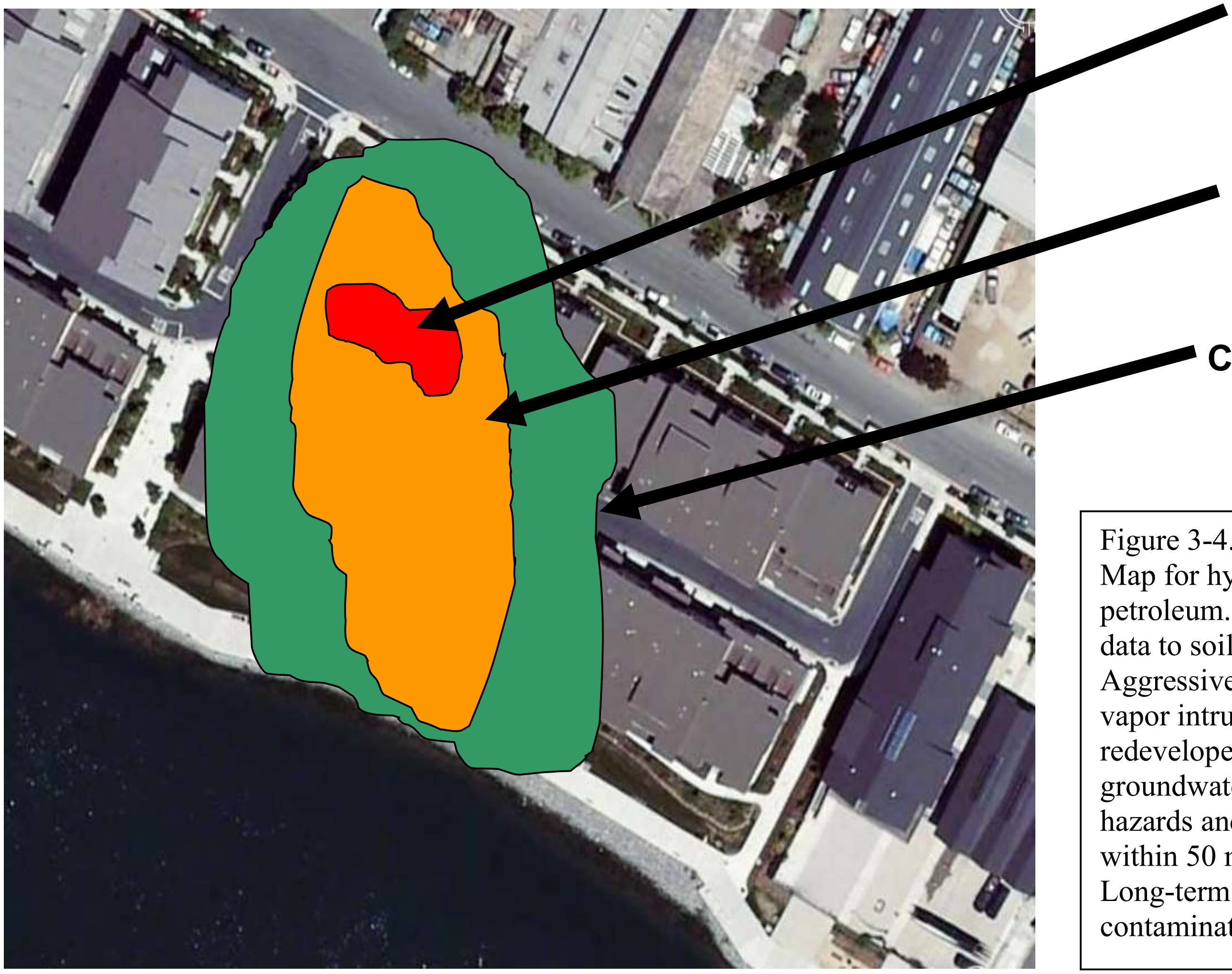


Figure 3-3. Soil Environmental Hazard Map for hypothetical site contaminated with pesticides (including dioxins and arsenic) and heavy oil. Areas delineated by comparison of site data to soil screening levels for the noted hazard. Minimum soil cap required for soil that poses direct exposure hazard in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



Vapor intrusion hazards (TPHgasoline and benzene)

Acute aquatic toxicity and gross contamination hazards (TPHgasoline, benzene, ethylbenzene and xylenes)

Chronic aquatic toxicity hazards (same contaminants)

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).

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.

		[1,2]**Common Environmental Hazards Posed by Contaminated Soil**				
	Key Questions	**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 3.5b. Example format for summary of environmental hazards posed by contaminated groundwater 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 3-5 notes

1. Refer to Section 1.2 and Figures 1-2a,b for summary of common environmental hazards posed by contaminated soil and groundwater
2. Compare representative site data for targeted contaminants to HDOH action levels (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.

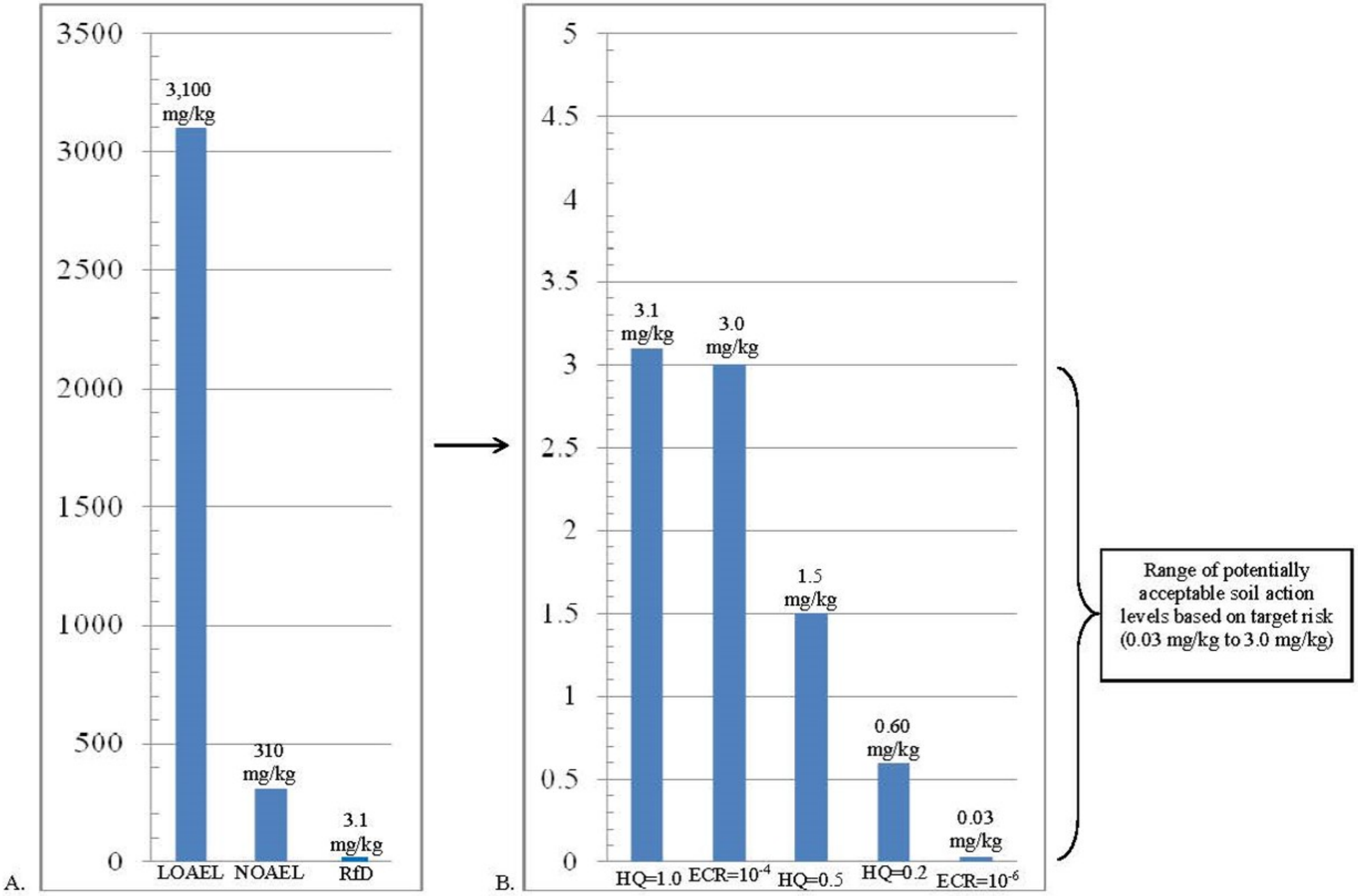


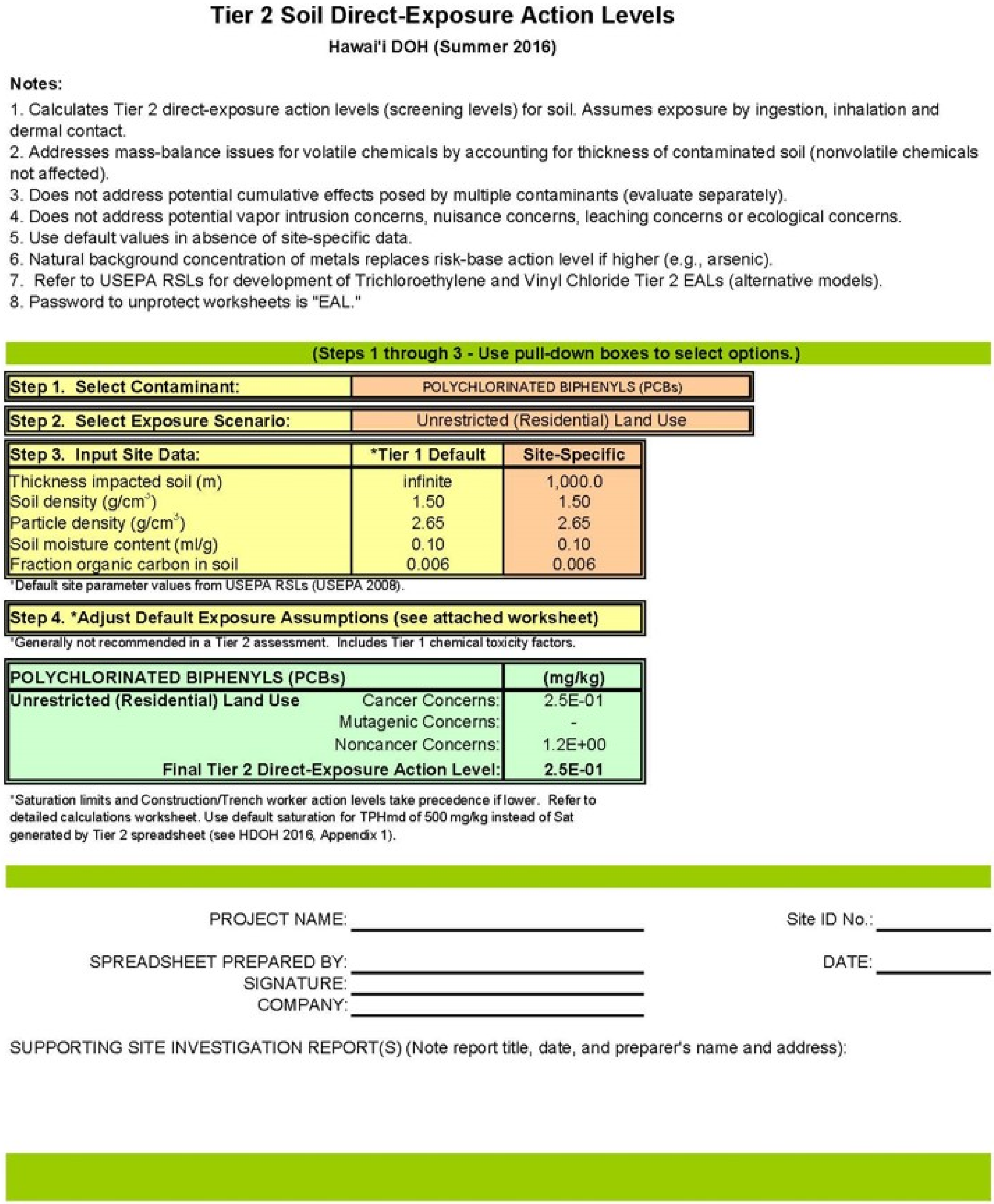
Figure 4-1. Progressive selection of a Tier 1 soil action level for dieldrin (see Section 4.2 for discussion). Y axis represents dieldrin concentrations in soil equivalent to noted toxicity factor, target risk and default exposure assumptions. A: Downward adjustment of initial Lowest Observed Adverse Effects Level (LOAEL) determined from toxicological studies to incorporate safety and uncertainty factors (LOAEL to No Observed Adverse Effects Level [NOAEL] to reference dose [RfD], noted soil concentrations based on an noncancer hazard quotient [HQ] of 1.0). B: Further adjustment of soil action level downward to consider the range of acceptable, noncancer HQ and excess cancer risks. A residential direct-exposure soil action of 1.5 mg/kg was ultimately selected for use in the Environmental Hazard Evaluation (EHE) guidance (see Table I-1 in Appendix 1). (For example only; toxicity factors updated in 2016.)

Figure 4-2a. 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 action 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 vapor 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 4-2b. 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 and 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 and transport models in combination with long-term monitoring to evaluate plume migration potential.
Vapor Intrusion	• Collection of soil vapor 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 Soil Direct-Exposure Action Levels

Hawai'i DOH (Summer 2016)

Notes:

1. Calculates Tier 2 direct-exposure action levels (screening levels) for soil. Assumes exposure by ingestion, inhalation and dermal contact.
2. Addresses mass-balance issues for volatile chemicals by accounting for thickness of contaminated soil (nonvolatile chemicals not affected).
3. Does not address potential cumulative effects posed by multiple contaminants (evaluate separately).
4. Does not address potential vapor intrusion concerns, nuisance concerns, leaching concerns or ecological concerns.
5. Use default values in absence of site-specific data.
6. Natural background concentration of metals replaces risk-base action level if higher (e.g., arsenic).
7. Refer to USEPA RSLs for development of Trichloroethylene and Vinyl Chloride Tier 2 EALs (alternative models).
8. Password to unprotect worksheets is "EAL."

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

Step 1. Select Contaminant:	POLYCHLORINATED BIPHENYLS (PCBs)
Step 2. Select Exposure Scenario:	Unrestricted (Residential) 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 RSLs (USEPA 2008).

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

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

POLYCHLORINATED BIPHENYLS (PCBs)		**(mg/kg)**
Unrestricted (Residential) Land Use	Cancer Concerns:	2.5E-01
	Mutagenic Concerns:	-
	Noncancer Concerns:	1.2E+00
	Final Tier 2 Direct-Exposure Action Level:	**2.5E-01**

*Saturation limits and Construction/Trench worker action levels take precedence if lower. Refer to detailed calculations worksheet. Use default saturation for TPHmd of 500 mg/kg instead of Sat generated by Tier 2 spreadsheet (see HDOH 2016, Appendix 1).

PROJECT NAME: ____________________ 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 4-3. Primary input page of Tier2 Direct Exposure Model for site-specific calculation of soil action levels for direct exposure to contaminants in soil. Noted action levels reflect an input cancer risk of 10^{-6} and noncancer Hazard Quotient of 1.0.

Figure 4-4. Summary of Arsenic Soil Action Levels and associated soil management categories.

Soil Management Category	**Action**
Total Arsenic (< 2 mm size fraction)	
Category A Total Arsenic ≤24 mg/kg	**Background.** Within range of expected background conditions in non-agricultural and non-industrial areas (upperbound background noted, HDOH 2011). No further action required and no restrictions on land use.
Bioaccessible Arsenic (<250 µm size fraction)	
Category B Total Arsenic >24 mg/kg and Bioaccessible Arsenic ≤23 mg/kg	**Minimally Impacted-Unrestricted Land Use.** Exceeds expected background conditions but at levels anticipated for many agricultural fields where arsenic-based chemicals were used historically. Potential health risks considered to be within the range of acceptable health risks for long-term exposure. Include Category B soil in remedial actions for more heavily contaminated spill areas as practicable in order to reduce exposure (e.g., outer margins of pesticide mixing areas). Offsite reuse of soil as fill material that exceeds 24 mg/kg total arsenic but meets bioaccessible action levels should documented and kept with property records to avoid the need for retesting in the future. Use of soil for intermediate (e.g., temporarily inactive portions) or interim (e.g., daily or weekly) cover at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. Although not strictly necessary from a health-risk standpoint, owners of existing homes where pesticide-related, Category B soils are identified may want to consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.) as described in the HDOH fact sheet *Arsenic in Hawaiian Soils: Questions and Answers on Health Concerns* (HDOH 2010c).

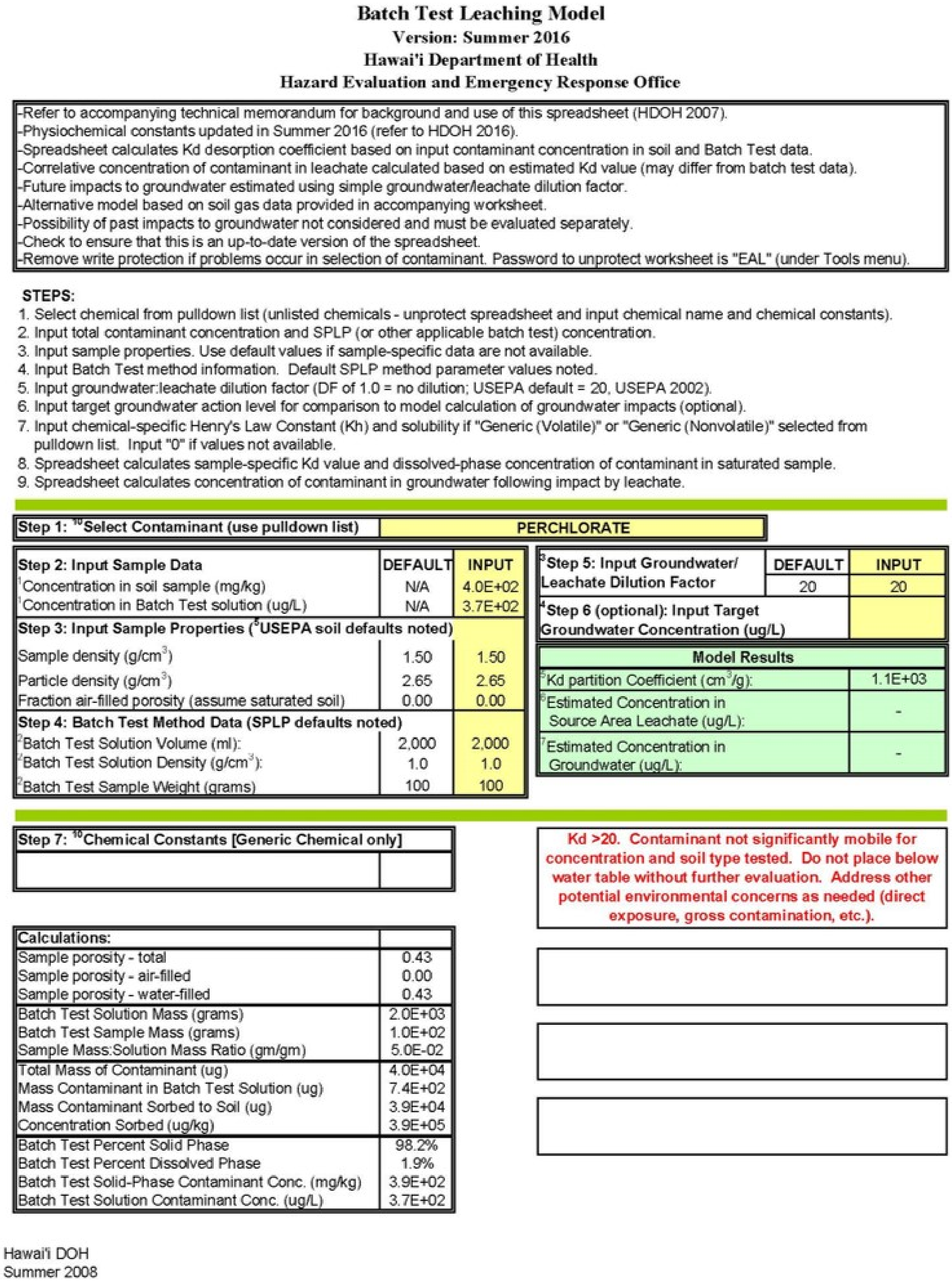
Figure 4-4 (cont.). Summary of Arsenic Soil Action Levels and associated soil management categories.

Category C (Bioaccessible Arsenic >23 but ≤95 mg/kg)	**Moderately Impacted-Commercial/Industrial Land Use Only.** Identified at several, former pesticide mixing areas and wood treatment facilities. May be co-located with pentachlorophenol, dioxin and triazine pesticide contamination at agricultural sites. Restriction to commercial/industrial land use is typically required in the absence of remediation or significant institutional and engineered controls and HDOH approval. Use of soil as soil as intermediate (e.g., temporarily inactive portions) or interim (e.g., daily or weekly) cover at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. Preparation of a site-specific, *Environmental Hazard Management Plan* (EHMP) required if soil is left on site for long-term management (HDOH 2007b, 2023). Treatment to reduce bioavailability and/or removal of isolated spill areas is recommended when practicable in order to minimize future management and liability concerns. This includes controls to ensure no off-site dispersion (e.g., dust or surface runoff) or inadvertent excavation and reuse at properties with sensitive land uses.
Category D (Bioaccessible Arsenic >95 mg/kg)	**Heavily Impacted-Remedial Actions Required.** Identified at a small number of former pesticide storage and mixing areas (e.g., sugarcane operations), former plantation housing areas and wood treatment facilities. May be co-located with dioxin and triazine pesticide contamination. Remedial actions required under any land use scenario in order to reduce potential exposure. Potentially adverse health risks under both sensitive and commercial/industrial land use scenarios in the absence of significant institutional and/or engineered controls. Disposal of soil at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. Preparation of site-specific EHMP required if left on site.

Figure 4-5. Summary of TEQ Dioxin Soil Action Levels and associated soil management categories.

Soil Management Category	*Action
Category A (≤20 ng/kg)	**Background.** Within range of expected background conditions in non-agricultural and non-industrial areas. No further action required and no restrictions on land use.
Category B (>20 but ≤240 ng/kg)	**Minimally Impacted.** Exceeds expected background conditions but within range anticipated for agricultural fields. Potential health risks considered to be insignificant. Include Category B soil in remedial actions for more heavily contaminated spill areas as practicable in order to reduce exposure (e.g., outer margins of pesticide mixing areas). Offsite reuse of soil for fill material or as final cover on a decommissioned landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. For existing homes, consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.).
Category C (>240 but ≤1,500 ng/kg)	**Moderately Impacted.** Typical of incinerator ash, burn pits, wood treatment operations that used pentachlorophenol (PCP), and the margins of heavily impacted, pesticide mixing areas associated with former sugarcane operations that used PCP. Restriction to commercial/industrial land use is typically required in the absence of remediation or significant institutional and engineered controls and HDOH approval. Use of soil as intermediate (e.g., temporarily inactive portions) or interim (e.g., daily or weekly) cover at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. Preparation of a site-specific, *Environmental Hazard Management Plan* (EHMP) required if soil left on site for long-term management. Removal of isolated spill areas recommended when practicable in order to minimize future management and liability concerns. This includes controls to ensure no off-site dispersion (e.g., dust or surface runoff) or inadvertent excavation and reuse at properties with sensitive land uses.
Category D (>1,500 ng/kg)	**Heavily Impacted.** Typical of former pesticide mixing areas that used PCP (e.g., sugarcane operations). Remedial actions required under any land use scenario in order to reduce potential exposure. Potentially adverse health risks under both sensitive and commercial/industrial land use scenarios in the absence of significant institutional and/or engineered controls. Disposal of soil at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions.

*Consider remediation of sites with Category C or D soils to the HDOH default soil background level of 20 ng/kg if to be used for residential or other sensitive purposes (refer to HDOH 2010b).



Batch Test Leaching Model
Version: Summer 2016
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).
-Physiochemical constants updated in Summer 2016 (refer to HDOH 2016).
-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.
-Remove write protection if problems occur in selection of contaminant. 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 2002).
6. Input target groundwater action level for comparison to model calculation of groundwater impacts (optional).
7. Input chemical-specific Henry's Law Constant (Kh) and solubility if "Generic (Volatile)" or "Generic (Nonvolatile)" selected from pulldown list. Input "0" if values not available.
8. Spreadsheet calculates sample-specific Kd value and dissolved-phase concentration of contaminant in saturated sample.
9. Spreadsheet calculates concentration of contaminant in groundwater following impact by leachate.

Step 1: [10]Select Contaminant (use pulldown list)	**PERCHLORATE**

Step 2: Input Sample Data	**DEFAULT**	**INPUT**
[1]Concentration in soil sample (mg/kg)	N/A	4.0E+02
[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

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

Model Results	
[5]Kd partition Coefficient (cm^3/g):	1.1E+03
[6]Estimated Concentration in Source Area Leachate (ug/L):	-
[7]Estimated Concentration in Groundwater (ug/L):	-

Step 7: [10]Chemical Constants [Generic Chemical only]	

Kd >20. Contaminant not significantly mobile for concentration and soil type tested. Do not place below water table without further evaluation. Address other potential environmental concerns as needed (direct exposure, gross contamination, etc.).

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)	4.0E+04
Mass Contaminant in Batch Test Solution (ug)	7.4E+02
Mass Contaminant Sorbed to Soil (ug)	3.9E+04
Concentration Sorbed (ug/kg)	3.9E+05
Batch Test Percent Solid Phase	98.2%
Batch Test Percent Dissolved Phase	1.9%
Batch Test Solid-Phase Contaminant Conc. (mg/kg)	3.9E+02
Batch Test Solution Contaminant Conc. (ug/L)	3.7E+02

Hawai'i DOH
Summer 2008

Figure 4-6. Input page of HDOH Soil Batch Leaching Test model (HDOH 2017b and updates).

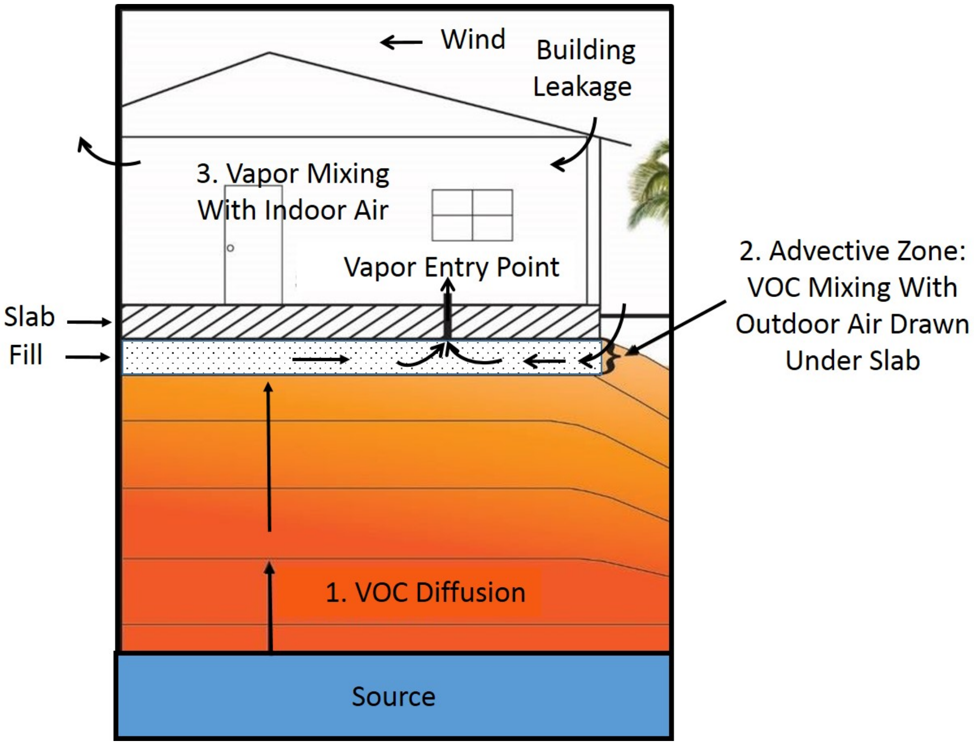
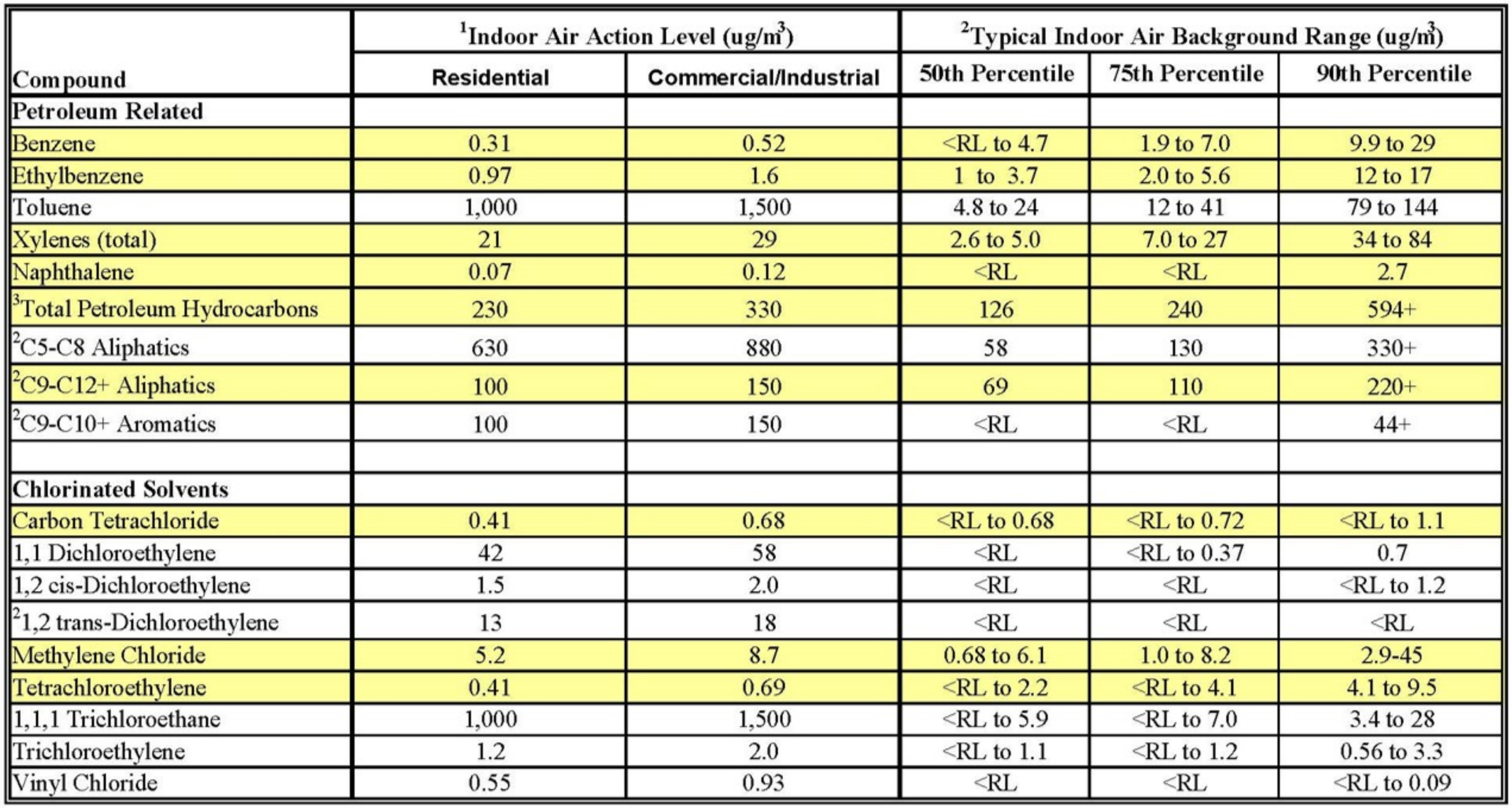


Figure 4-7. The three stages of vapor intrusion: 1) Outward diffusion of volatile organic chemicals (VOCs) from source area, 2) Advective zone mixing of VOCs with outdoor air drawn under the building slab due to depressurization of the overlying structure and 3) Intrusion and mixing of VOC-contaminated air/vapors with indoor air, including outdoor air drawn into the building due to leakage in the above-ground portion of the structure.

Figure 4-8. Comparison of indoor air action levels to typical concentrations of volatile chemicals in indoor, residential air. Concentrations of the chemicals in the indoor air of commercial/industrial buildings could be much higher, depending on chemicals used and stored in the building. Ambient levels of highlighted chemicals may exceed action levels some or much of the time at a conservative target risk level.



Compound	[1]Indoor Air Action Level (ug/m^3)		[2]Typical Indoor Air Background Range (ug/m^3)		
	Residential	**Commercial/Industrial**	**50th Percentile**	**75th Percentile**	**90th Percentile**
Petroleum Related					
Benzene	0.31	0.52	<RL to 4.7	1.9 to 7.0	9.9 to 29
Ethylbenzene	0.97	1.6	1 to 3.7	2.0 to 5.6	12 to 17
Toluene	1,000	1,500	4.8 to 24	12 to 41	79 to 144
Xylenes (total)	21	29	2.6 to 5.0	7.0 to 27	34 to 84
Naphthalene	0.07	0.12	<RL	<RL	2.7
[3]Total Petroleum Hydrocarbons	230	330	126	240	594+
[2]C5-C8 Aliphatics	630	880	58	130	330+
[2]C9-C12+ Aliphatics	100	150	69	110	220+
[2]C9-C10+ Aromatics	100	150	<RL	<RL	44+
Chlorinated Solvents					
Carbon Tetrachloride	0.41	0.68	<RL to 0.68	<RL to 0.72	<RL to 1.1
1,1 Dichloroethylene	42	58	<RL	<RL to 0.37	0.7
1,2 cis-Dichloroethylene	1.5	2.0	<RL	<RL	<RL to 1.2
[2]1,2 trans-Dichloroethylene	13	18	<RL	<RL	<RL
Methylene Chloride	5.2	8.7	0.68 to 6.1	1.0 to 8.2	2.9-45
Tetrachloroethylene	0.41	0.69	<RL to 2.2	<RL to 4.1	4.1 to 9.5
1,1,1 Trichloroethane	1,000	1,500	<RL to 5.9	<RL to 7.0	3.4 to 28
Trichloroethylene	1.2	2.0	<RL to 1.1	<RL to 1.2	0.56 to 3.3
Vinyl Chloride	0.55	0.93	<RL	<RL	<RL to 0.09

Figure 4-8 (cont.). Notes

1. See Table C and Appendix 1, Table E-3. Refer to Chapter 6 of Appendix 1 for discussion of indoor air screening levels for TPH and individual carbon ranges.
2. Primary reference: USEPA 2011b. Reporting Limit (RL) for individual VOCs varied between studies.
3. TPH as sum of individual hydrocarbon ranges (excludes BTEX). Levels of TPH in indoor air could exceed 1,000 ug/m^3 if petroleum-based fuels, cleaners or other products stored or recently used in the building.

Figure 4-9. Chance that impacts to indoor air from the intrusion of subsurface vapors into a building will not be discernible from typical background concentrations at the noted concentration of the chemical in subslab soil vapor (see Table 4-8a). Based on a residential home scenario levels. Equivalent subslab soil vapor levels for commercial/industrial buildings necessary to impact indoor air above typical background could be much higher. For general guidance only

	[1]**Chance that Indoor Air Impacts will not be Discernible from Background Indoor Air at Noted Subslab Soil vapor Concentration (µg/m^3).**		
Compound	**Up to 50%**	**Up to 25%**	**Up to 10%**
Petroleum Related			
Benzene	9,400	14,000	58,000
Ethylbenzene	7,400	11,200	34,000
Toluene	48,000	82,000	288,000
Xylenes (total)	10,000	54,000	168,000
Naphthalene	-	-	5,400
Total Petroleum Hydrocarbons	252,000	480,000	1,188,000
C5-C8 Aliphatics	116,000	260,000	660,000
C9-C12+ Aliphatics	138,000	220,000	440,000
C9-C10+ Aromatics	-	-	88,000
Chlorinated Solvents			
Carbon Tetrachloride	1,360	1,440	2,200
1,1 Dichloroethylene	-	740	1,400
1,2 cis-Dichloroethylene	-	-	2,400
[2]1,2 trans-Dichloroethylene	-	-	-
Methylene Chloride	12,200	16,400	90,000
Tetrachloroethylene	4,400	8,200	19,000
1,1,1 Trichloroethane	11,800	14,000	56,000
Trichloroethylene	2,200	2,400	6,600
Vinyl Chloride	-	-	180

Notes

1. Uppermost concentration for range noted in Figure 4-8a divided by the default, Indoor Air:Subslab Soil vapor Attenuation Factor for residential homes of 0.0005 (1/2000).

TABLES

TABLE A: GROUNDWATER <u>IS</u> A CURRENT OR POTENTIAL SOURCE OF DRINKING WATER

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	[1]Soil (mg/kg)	[2]Groundwater (ug/L)	[1]Soil (mg/kg)	[2]Groundwater (ug/L)
ACENAPHTHENE	1.2E+02	2.0E+01	1.2E+02	1.5E+01
ACENAPHTHYLENE	1.3E+02	3.0E+02	5.5E+00	1.3E+01
ACETONE	3.7E+00	6.0E+03	9.2E-01	1.5E+03
ALDRIN	3.9E+00	1.2E-03	3.9E+00	1.4E-04
AMETRYN	1.1E+01	1.5E+02	1.1E+01	1.5E+02
AMINO,2- DINITROTOLUENE,4,6-	9.1E-02	1.9E+00	9.1E-02	1.9E+00
AMINO,4- DINITROTOLUENE,2,6-	9.1E-02	1.9E+00	9.1E-02	1.9E+00
ANTHRACENE	4.2E+00	1.8E-01	4.2E+00	2.0E-02
ANTIMONY	6.3E+00	6.0E+00	6.3E+00	6.0E+00
ARSENIC	2.4E+01	1.0E+01	2.4E+01	1.0E+01
ATRAZINE	1.1E-01	3.0E+00	1.1E-01	3.0E+00
BARIUM	1.0E+03	2.0E+03	1.0E+03	2.2E+02
BENOMYL	1.6E-01	2.8E+00	7.8E-03	1.4E-01
BENZENE	3.0E-01	5.0E+00	3.0E-01	5.0E+00
BENZO(a)ANTHRACENE	1.0E+01	5.2E-02	1.0E+01	2.7E-02
BENZO(a)PYRENE	3.6E+00	2.0E-01	3.6E+00	6.0E-02
BENZO(b)FLUORANTHENE	5.8E+00	5.8E-02	5.8E+00	5.8E-02
BENZO(g,h,i)PERYLENE	3.5E+01	1.3E-01	3.5E+01	1.3E-01
BENZO(k)FLUORANTHENE	3.5E+01	3.6E-01	3.5E+01	3.6E-01
BERYLLIUM	3.1E+01	4.0E+00	3.1E+01	6.6E-01
BIPHENYL, 1,1-	1.0E+01	5.0E-01	1.0E+01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	7.4E-05	1.4E-02	7.4E-05	1.4E-02
BIS(2-CHLORO-1-METHYLETHYL)ETHER	3.9E-03	3.6E-01	3.9E-03	3.6E-01
BIS(2-ETHYLHEXYL)PHTHALATE	3.7E+01	6.0E+00	3.7E+01	3.0E+00
BORON	1.0E+03	9.8E+02	1.0E+03	9.8E+02
BROMODICHLOROMETHANE	2.5E-03	1.3E-01	2.5E-03	1.3E-01
BROMOFORM	6.9E-01	8.0E+01	6.9E-01	8.0E+01
BROMOMETHANE	2.2E-01	1.9E+01	2.2E-01	1.6E+01
CADMIUM	1.7E+01	3.0E+00	1.7E+01	3.0E+00
CARBON TETRACHLORIDE	1.0E-01	5.0E+00	1.0E-01	5.0E+00
CHLORDANE (TECHNICAL)	1.7E+01	9.0E-02	1.7E+01	4.0E-03
CHLOROANILINE, p-	6.8E-03	3.7E-01	6.8E-03	3.7E-01
CHLOROBENZENE	2.2E+00	5.0E+01	1.5E+00	2.5E+01
CHLOROETHANE	1.2E+00	1.6E+01	1.2E+00	1.6E+01
CHLOROFORM	2.6E-02	7.0E+01	2.6E-02	2.8E+01
CHLOROMETHANE	4.0E+00	1.1E+03	4.0E+00	1.1E+03
CHLOROPHENOL, 2-	1.2E-02	1.8E-01	1.2E-02	1.8E-01
CHROMIUM (Total)	1.1E+03	1.6E+01	1.1E+03	1.1E+01
CHROMIUM III	1.0E+03	5.7E+02	1.0E+03	2.0E+01
CHROMIUM VI	3.0E+01	2.0E-01	3.0E+01	2.0E-01
CHRYSENE	7.3E+00	2.4E-01	7.3E+00	2.4E-01
COBALT	8.0E+01	2.4E+00	8.0E+01	2.4E+00
COPPER	6.3E+02	2.9E+00	6.3E+02	2.9E+00
CYANIDE (Free)	4.8E+00	1.0E+00	4.8E+00	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	1.4E-02	9.7E-01	1.4E-02	9.7E-01
DALAPON	1.1E-01	2.0E+02	1.1E-01	2.0E+02
DIBENZO(a,h)ANTHTRACENE	1.1E+00	4.8E-03	1.1E+00	4.8E-03
DIBROMO,1,2- CHLOROPROPANE,3-	8.1E-04	4.0E-02	8.1E-04	4.0E-02
DIBROMOCHLOROMETHANE	8.8E-03	8.7E-01	8.8E-03	8.7E-01
DIBROMOETHANE, 1,2-	4.2E-04	4.0E-02	4.2E-04	4.0E-02
DICHLOROBENZENE, 1,2-	7.5E-01	1.0E+01	7.5E-01	1.0E+01
DICHLOROBENZENE, 1,3-	5.7E-01	5.0E+00	5.7E-01	5.0E+00
DICHLOROBENZENE, 1,4-	5.5E-02	5.0E+00	5.5E-02	5.0E+00
DICHLOROBENZIDINE, 3,3-	6.6E-02	1.3E-01	6.6E-02	1.3E-01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.2E+00	2.6E-02	2.2E+00	1.1E-02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.9E+00	8.9E-03	1.9E+00	8.9E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.8E+00	6.2E-03	1.8E+00	1.0E-03
DICHLOROETHANE, 1,1-	1.1E-01	2.8E+00	1.1E-01	2.8E+00
DICHLOROETHANE, 1,2-	2.3E-02	5.0E+00	2.3E-02	5.0E+00
DICHLOROETHYLENE, 1,1-	1.2E+00	7.0E+00	1.2E+00	7.0E+00
DICHLOROETHYLENE, Cis 1,2-	1.8E+00	7.0E+01	1.8E+00	7.0E+01

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	[1]Soil (mg/kg)	[2]Groundwater (ug/L)	[1]Soil (mg/kg)	[2]Groundwater (ug/L)
DICHLOROETHYLENE, Trans 1,2-	1.8E+00	1.0E+02	1.8E+00	1.0E+02
DICHLOROPHENOL, 2,4-	7.3E-03	3.0E-01	7.3E-03	3.0E-01
DICHLOROPHENOXYACETIC ACID (2,4-D)	3.4E-01	7.0E+01	3.4E-01	7.0E+01
DICHLOROPROPANE, 1,2-	1.4E-01	5.0E+00	1.4E-01	5.0E+00
DICHLOROPROPENE, 1,3-	1.6E-02	4.7E-01	2.1E-03	6.0E-02
DIELDRIN	2.5E+00	3.5E-03	2.5E+00	1.9E-03
DIETHYLPHTHALATE	1.7E+01	9.8E+02	3.7E+00	2.1E+02
DIMETHYLPHENOL, 2,4-	2.9E+01	3.6E+02	9.8E+00	1.2E+02
DIMETHYLPHTHALATE	7.4E+01	3.2E+03	2.6E+01	1.1E+03
DINITROBENZENE, 1,3-	1.1E-01	2.0E+00	1.1E-01	2.0E+00
DINITROPHENOL, 2,4-	3.0E+00	3.9E+01	1.1E+00	1.4E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	2.3E-02	2.4E-01	2.3E-02	2.4E-01
DINITROTOLUENE, 2,6- (2,6-DNT)	4.7E-03	4.9E-02	4.7E-03	4.9E-02
DIOXANE, 1,4-	2.1E-04	4.6E-01	2.1E-04	4.6E-01
DIOXINS (TEQ)	2.4E-04	3.0E-05	2.4E-04	3.1E-09
DIURON	6.5E-01	3.6E+01	6.5E-01	3.6E+01
ENDOSULFAN	1.3E+01	3.4E-02	1.3E+01	8.7E-03
ENDRIN	3.8E+00	3.7E-02	3.8E+00	2.3E-03
ETHANOL	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETHYLBENZENE	3.7E+00	3.0E+01	9.0E-01	7.3E+00
FLUORANTHENE	1.2E+02	1.3E+01	8.7E+01	8.0E-01
FLUORENE	9.3E+01	2.5E+02	9.3E+01	3.9E+00
GLYPHOSATE	2.4E+02	7.0E+02	2.4E+02	7.0E+02
HEPTACHLOR	1.3E+00	5.3E-02	1.3E+00	3.6E-03
HEPTACHLOR EPOXIDE	2.0E-01	5.3E-02	2.0E-01	3.6E-03
HEXACHLOROBENZENE	1.6E-01	3.0E-04	1.6E-01	3.0E-04
HEXACHLOROBUTADIENE	5.7E-02	2.8E-01	5.7E-02	2.8E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	7.5E-02	1.6E-01	2.9E-02	6.3E-02
HEXACHLOROETHANE	5.2E-02	9.2E-01	5.2E-02	9.2E-01
HEXAZINONE	1.4E+01	6.4E+02	1.4E+01	6.4E+02
INDENO(1,2,3-cd)PYRENE	5.7E+00	1.8E-02	5.7E+00	1.8E-02
ISOPHORONE	8.5E-01	7.8E+01	8.5E-01	7.8E+01
LEAD	2.0E+02	1.5E+01	2.0E+02	5.6E+00
MERCURY	4.7E+00	2.0E+00	4.7E+00	2.5E-02
METHOXYCHLOR	1.6E+01	7.0E-01	1.6E+01	3.0E-02
METHYL ETHYL KETONE	9.3E+00	8.4E+03	9.3E+00	8.4E+03
METHYL ISOBUTYL KETONE	3.8E+00	1.3E+03	5.0E-01	1.7E+02
METHYL MERCURY	1.6E+00	9.9E-02	1.6E+00	2.8E-03
METHYL TERT BUTYL ETHER	2.8E-02	5.0E+00	2.8E-02	5.0E+00
METHYLENE CHLORIDE	1.2E-01	5.0E+00	1.2E-01	5.0E+00
METHYLNAPHTHALENE, 1-	4.2E+00	1.0E+01	8.9E-01	2.1E+00
METHYLNAPHTHALENE, 2-	4.1E+00	1.0E+01	1.9E+00	4.7E+00
MOLYBDENUM	7.8E+01	9.9E+01	7.8E+01	9.9E+01
NAPHTHALENE	4.4E+00	1.7E+01	3.1E+00	1.2E+01
NICKEL	4.1E+02	5.0E+00	4.1E+02	5.0E+00
NITROBENZENE	#VALUE!	#VALUE!	#VALUE!	#VALUE!
NITROGLYCERIN	3.8E-02	2.0E+00	3.8E-02	2.0E+00
NITROTOLUENE, 2-	1.9E-02	3.1E-01	1.9E-02	3.1E-01
NITROTOLUENE, 3-	1.1E-01	1.7E+00	1.1E-01	1.7E+00
NITROTOLUENE, 4-	2.6E-01	4.3E+00	2.6E-01	4.3E+00
PENTACHLOROPHENOL	9.8E-02	1.0E+00	9.8E-02	1.0E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	1.9E+00	1.7E+01	1.9E+00	1.7E+01
PERCHLORATE	7.0E-03	1.5E+01	7.0E-03	1.5E+01
PHENANTHRENE	4.6E+02	2.5E+02	6.9E+01	2.3E+00

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**
PHENOL	9.3E+00	3.0E+02	1.8E+00	5.8E+01
POLYCHLORINATED BIPHENYLS (PCBs)	1.2E+00	5.0E-01	1.2E+00	1.4E-02
PROPICONAZOLE	1.1E+02	4.3E+02	2.5E+01	9.5E+01
PYRENE	4.4E+01	6.8E+01	4.4E+01	4.6E+00
SELENIUM	7.8E+01	2.0E+01	7.8E+01	5.0E+00
SILVER	7.8E+01	1.0E+00	7.8E+01	1.0E-01
SIMAZINE	9.7E-02	4.0E+00	9.7E-02	4.0E+00
STYRENE	9.1E-01	1.0E+01	9.1E-01	1.0E+01
TERBACIL	2.1E+00	2.5E+02	2.1E+00	2.5E+02
tert-BUTYL ALCOHOL	2.4E-02	6.0E+01	2.4E-02	6.0E+01
TETRACHLOROETHANE, 1,1,1,2-	1.7E-02	5.7E-01	1.7E-02	5.7E-01
TETRACHLOROETHANE, 1,1,2,2-	1.4E-03	7.6E-02	1.4E-03	7.6E-02
TETRACHLOROETHYLENE	9.8E-02	5.0E+00	9.8E-02	5.0E+00
TETRACHLOROPHENOL, 2,3,4,6-	5.1E-01	1.1E+01	5.6E-02	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	8.8E+01	1.0E+03	1.9E+01	2.2E+02
THALLIUM	7.8E-01	2.0E+00	7.8E-01	2.0E+00
TOLUENE	3.2E+00	4.0E+01	7.8E-01	9.8E+00
TOXAPHENE	4.8E-01	2.1E-01	4.8E-01	2.0E-04
TPH (gasolines)	1.0E+02	7.4E+01	1.0E+02	7.4E+01
TPH (middle distillates)	1.8E+02	9.1E+01	1.8E+02	9.1E+01
TPH (residual fuels)	5.0E+02	9.1E+01	5.0E+02	9.1E+01
TRICHLOROBENZENE, 1,2,4-	1.8E-01	7.0E+01	1.8E-01	7.0E+01
TRICHLOROETHANE, 1,1,1-	2.3E+01	2.0E+02	1.2E+00	1.1E+01
TRICHLOROETHANE, 1,1,2-	8.9E-03	5.0E+00	8.9E-03	5.0E+00
TRICHLOROETHYLENE	8.9E-02	5.0E+00	8.9E-02	5.0E+00
TRICHLOROPHENOL, 2,4,5-	4.5E+00	1.7E+01	5.0E-01	1.9E+00
TRICHLOROPHENOL, 2,4,6-	2.6E-01	4.1E+00	2.6E-01	4.1E+00
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	2.8E+00	1.6E+02	2.8E+00	1.6E+02
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	1.5E+00	5.0E+01	8.7E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	5.0E-03	6.0E-01	5.0E-03	6.0E-01
TRICHLOROPROPENE, 1,2,3-	1.6E-01	3.3E+00	1.6E-01	3.3E+00
TRIFLURALIN	1.8E+01	2.2E+00	1.8E+01	1.1E+00
TRINITROBENZENE, 1,3,5-	7.5E+00	2.7E+01	2.8E+00	1.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	3.0E+01	3.9E+01	3.0E+01	3.9E+01
TRINITROTOLUENE, 2,4,6- (TNT)	1.2E+00	2.5E+00	1.2E+00	2.5E+00
VANADIUM	7.7E+02	9.0E+01	7.7E+02	2.7E+01

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	^{1}**Soil (mg/kg)**	^{2}**Groundwater (ug/L)**	^{1}**Soil (mg/kg)**	^{2}**Groundwater (ug/L)**
VINYL CHLORIDE	3.6E-02	2.0E+00	3.6E-02	2.0E+00
XYLENES	2.1E+00	2.0E+01	1.4E+00	1.3E+01
ZINC	1.0E+03	2.2E+01	1.0E+03	2.2E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	-	2.0	-
Sodium Adsorption Ratio	5.0	-	5.0	-

Notes:

1. Based on unrestricted current or future land use. Considered adequate for residential housing, schools, medical facilities, day-care centers, parks and other sensitive uses.
2. Assumes potential impacts to drinking water source and discharge of groundwater into a freshwater, marine or estuary surface water system. Compare to *dissolved-phase* concentration.

Source of Soil Action Levels: Refer to Appendix 1, Tables A-1 and A-2.

Source of Groundwater Action Levels: Appendix 1, Table D-1a (≤150m to Surface Water Body) and Table D-1b (>150m to Surface Water Body).

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

Soil Action Levels intended to address direct-exposure, vapor intrusion, groundwater protection (leaching) and gross contamination hazards. Soil gas data should be collected for additional evaluation of potential vapor intrusion hazards at sites with significant areas of VOC-impacted soil. See also Section 4.4 and Table C. The need for a site-specific, ecological risk assessment should be evaluated if sensitive, terrestrial or aquatic habitats are within or nearby areas of contaminated soil.

Groundwater Action Levels intended to address surface water impacts, vapor intrusion and nuisance hazards Use in conjunction with soil gas action levels to evaluate potential impacts to vapor intrusion hazards if groundwater action levels for this concern approached or exceeded (refer to Table C-1a in Appendix 1). See also Section 4.4 and Table C.

Groundwater action levels should be compared to dissolved-phase chemical concentrations unless otherwise instructed by HDOH.

Groundwater ALs >150m to Surface Water Body: Groundwater screened with respect to acute surface water goals (See Table D-1b).

Groundwater ALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic surface water goals (see Table D-1a).

TPH -Total Petroleum Hydrocarbons: TPH Action Levels must be used in conjunction with Action Levels for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Section 2.6 in text.

TPH soil action levels for gross contamination hazards in isolated soils may be used as final cleanup levels if soil situated >3m deep at residential site and >1m (or otherwise capped) at commercial sites AND site data indicate that remaining contamination will not pose leaching or vapor intrusion hazards (refer to Table F-3 in Appendix 1; TPHg = 4,500 mg/kg, TPHmd & TPHrf = 5,000 mg/kg). TPH soil action levels noted in above table should be applied at sites with elevated threats to drinking water resources or aquatic habitats. Refer to Section 2.6 in text.

TABLE B: GROUNDWATER IS NOT A CURRENT OR POTENTIAL SOURCE OF DRINKING WATER

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**
ACENAPHTHENE	1.2E+02	2.0E+02	1.2E+02	1.5E+01
ACENAPHTHYLENE	1.3E+02	3.0E+02	5.5E+00	1.3E+01
ACETONE	9.2E+00	1.5E+04	9.2E-01	1.5E+03
ALDRIN	3.9E+00	1.3E+00	3.9E+00	1.4E-04
AMETRYN	1.1E+02	1.8E+03	5.0E+01	7.0E+02
AMINO,2- DINITROTOLUENE,4,6-	1.5E+00	1.6E+02	8.5E-01	1.8E+01
AMINO,4- DINITROTOLUENE,2,6-	1.5E+00	9.8E+01	5.2E-01	1.1E+01
ANTHRACENE	4.2E+00	1.8E-01	4.2E+00	2.0E-02
ANTIMONY	6.3E+00	1.8E+02	6.3E+00	3.0E+01
ARSENIC	2.4E+01	6.9E+01	2.4E+01	3.6E+01
ATRAZINE	2.3E+00	3.3E+02	4.5E-01	1.2E+01
BARIUM	1.0E+03	2.0E+03	1.0E+03	2.2E+02
BENOMYL	1.6E-01	2.8E+00	7.8E-03	1.4E-01
BENZENE	7.7E-01	1.7E+03	7.7E-01	7.1E+01
BENZO(a)ANTHRACENE	1.1E+01	4.7E+00	1.0E+01	2.7E-02
BENZO(a)PYRENE	3.6E+00	8.0E-01	3.6E+00	6.0E-02
BENZO(b)FLUORANTHENE	1.1E+01	7.5E-01	1.1E+01	6.8E-01
BENZO(g,h,i)PERYLENE	3.5E+01	1.3E-01	3.5E+01	1.3E-01
BENZO(k)FLUORANTHENE	3.9E+01	4.0E-01	3.9E+01	4.0E-01
BERYLLIUM	3.1E+01	3.5E+01	3.1E+01	6.6E-01
BIPHENYL, 1,1-	1.0E+01	5.0E+00	1.0E+01	5.0E+00
BIS(2-CHLOROETHYL)ETHER	7.9E-03	1.8E+02	7.9E-03	1.8E+02
BIS(2-CHLORO-1-METHYLETHYL)ETHER	3.9E-03	3.6E-01	3.9E-03	3.6E-01
BIS(2-ETHYLHEXYL)PHTHALATE	3.7E+01	2.7E+01	3.7E+01	3.0E+00
BORON	1.0E+03	3.4E+04	1.0E+03	1.0E+03
BROMODICHLOROMETHANE	1.6E-02	1.1E+02	1.6E-02	1.1E+02
BROMOFORM	9.5E+00	1.1E+03	2.0E+00	2.3E+02
BROMOMETHANE	2.2E-01	3.8E+01	2.2E-01	1.6E+01
CADMIUM	1.7E+01	3.0E+00	1.7E+01	3.0E+00
CARBON TETRACHLORIDE	1.0E-01	1.1E+02	1.0E-01	9.8E+00
CHLORDANE (TECHNICAL)	1.7E+01	9.0E-02	1.7E+01	4.0E-03
CHLOROANILINE, p-	2.6E+00	4.6E+02	3.6E-01	1.9E+01
CHLOROBENZENE	2.2E+00	2.2E+02	1.5E+00	2.5E+01
CHLOROETHANE	1.2E+01	1.6E+02	1.2E+01	1.6E+02
CHLOROFORM	2.6E-02	1.1E+02	2.6E-02	2.8E+01
CHLOROMETHANE	4.0E+00	1.1E+03	4.0E+00	1.1E+03
CHLOROPHENOL, 2-	1.2E-01	1.8E+00	1.2E-01	1.8E+00
CHROMIUM (Total)	1.1E+03	1.6E+01	1.1E+03	1.1E+01
CHROMIUM III	1.0E+03	5.7E+02	1.0E+03	2.0E+01
CHROMIUM VI	3.0E+01	1.6E+01	3.0E+01	1.1E+01
CHRYSENE	3.0E+01	1.0E+00	3.0E+01	1.0E+00
COBALT	8.0E+01	1.2E+02	8.0E+01	1.9E+01
COPPER	6.3E+02	2.9E+00	6.3E+02	2.9E+00
CYANIDE (Free)	4.8E+00	1.0E+00	4.8E+00	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	7.7E+00	5.2E+02	1.2E+00	7.9E+01
DALAPON	1.6E+00	3.0E+03	1.6E-01	3.0E+02
DIBENZO(a,h)ANTHTRACENE	1.1E+00	1.3E+00	1.1E+00	8.0E-01
DIBROMO,1,2- CHLOROPROPANE,3-	8.1E-04	4.0E-02	8.1E-04	4.0E-02
DIBROMOCHLOROMETHANE	3.1E+00	2.9E+03	3.4E-01	3.4E+01
DIBROMOETHANE, 1,2-	1.0E-03	1.9E+01	1.0E-03	1.9E+01
DICHLOROBENZENE, 1,2-	7.5E+00	1.0E+02	1.1E+00	1.4E+01
DICHLOROBENZENE, 1,3-	4.2E+01	3.7E+02	2.5E+00	2.2E+01
DICHLOROBENZENE, 1,4-	5.5E-02	1.1E+02	5.5E-02	9.4E+00
DICHLOROBENZIDINE, 3,3-	1.2E+00	4.1E+01	1.2E+00	4.5E+00
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.2E+00	1.9E-01	2.2E+00	1.1E-02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.9E+00	7.0E+00	1.9E+00	4.1E-01
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.8E+00	1.3E-02	1.8E+00	1.0E-03
DICHLOROETHANE, 1,1-	3.8E-01	8.3E+02	3.8E-01	4.7E+01
DICHLOROETHANE, 1,2-	2.3E-02	1.8E+02	2.3E-02	1.8E+02
DICHLOROETHYLENE, 1,1-	8.9E+00	3.9E+03	4.2E+00	2.5E+01
DICHLOROETHYLENE, Cis 1,2-	1.8E+00	5.5E+03	1.8E+00	6.2E+02

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**
DICHLOROETHYLENE, Trans 1,2-	1.8E+00	2.6E+03	1.8E+00	5.6E+02
DICHLOROPHENOL, 2,4-	7.3E-02	3.0E+00	7.3E-02	3.0E+00
DICHLOROPHENOXYACETIC ACID (2,4-D)	6.4E-01	1.3E+02	3.4E-01	7.0E+01
DICHLOROPROPANE, 1,2-	1.6E-01	1.0E+02	1.6E-01	1.0E+02
DICHLOROPROPENE, 1,3-	1.5E-01	2.6E+02	2.1E-03	6.0E-02
DIELDRIN	2.5E+00	7.1E-01	2.5E+00	1.9E-03
DIETHYLPHTHALATE	1.7E+01	9.8E+02	3.7E+00	2.1E+02
DIMETHYLPHENOL, 2,4-	5.7E+01	7.0E+02	9.8E+00	1.2E+02
DIMETHYLPHTHALATE	7.4E+01	3.2E+03	2.6E+01	1.1E+03
DINITROBENZENE, 1,3-	1.3E+00	1.0E+02	5.8E-01	1.0E+01
DINITROPHENOL, 2,4-	2.5E+01	3.8E+02	1.1E+00	1.4E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	1.7E+00	1.1E+02	8.7E-01	9.1E+00
DINITROTOLUENE, 2,6- (2,6-DNT)	3.5E-01	1.1E+02	3.5E-01	8.1E+01
DIOXANE, 1,4-	5.3E+00	5.0E+04	5.3E+00	5.0E+04
DIOXINS (TEQ)	2.4E-04	3.0E-03	2.4E-04	3.1E-09
DIURON	3.6E+00	2.0E+02	1.1E+00	6.0E+01
ENDOSULFAN	1.3E+01	3.4E-02	1.3E+01	8.7E-03
ENDRIN	3.8E+00	3.7E-02	3.8E+00	2.3E-03
ETHANOL	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ETHYLBENZENE	1.7E+01	1.4E+02	9.0E-01	7.3E+00
FLUORANTHENE	1.2E+02	1.3E+01	8.7E+01	8.0E-01
FLUORENE	9.3E+01	3.0E+02	9.3E+01	3.9E+00
GLYPHOSATE	5.0E+02	2.2E+04	5.0E+02	1.8E+03
HEPTACHLOR	1.3E+00	5.3E-02	1.3E+00	3.6E-03
HEPTACHLOR EPOXIDE	2.0E-01	5.3E-02	2.0E-01	3.6E-03
HEXACHLOROBENZENE	1.6E-01	3.0E-04	1.6E-01	3.0E-04
HEXACHLOROBUTADIENE	1.3E+00	1.1E+01	6.1E-02	3.0E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	7.5E-02	1.6E-01	2.9E-02	6.3E-02
HEXACHLOROETHANE	2.0E+00	1.0E+02	6.8E-01	1.2E+01
HEXAZINONE	4.2E+02	5.0E+04	3.7E+02	1.7E+04
INDENO(1,2,3-cd)PYRENE	1.1E+01	9.5E-02	1.1E+01	9.5E-02
ISOPHORONE	4.7E+01	4.3E+03	1.0E+01	9.2E+02
LEAD	2.0E+02	2.9E+01	2.0E+02	5.6E+00
MERCURY	4.7E+00	2.1E+00	4.7E+00	2.5E-02
METHOXYCHLOR	1.6E+01	7.0E-01	1.6E+01	3.0E-02
METHYL ETHYL KETONE	5.5E+01	5.0E+04	1.5E+01	1.4E+04
METHYL ISOBUTYL KETONE	6.5E+00	2.2E+03	5.0E-01	1.7E+02
METHYL MERCURY	1.6E+00	9.9E-02	1.6E+00	2.8E-03
METHYL TERT BUTYL ETHER	2.3E+00	1.8E+03	2.3E+00	7.3E+02
METHYLENE CHLORIDE	2.2E+01	8.5E+03	2.2E+01	1.5E+03
METHYLNAPHTHALENE, 1-	1.6E+01	3.7E+01	8.9E-01	2.1E+00
METHYLNAPHTHALENE, 2-	1.7E+01	4.2E+01	1.9E+00	4.7E+00
MOLYBDENUM	7.8E+01	7.2E+03	7.8E+01	3.7E+02
NAPHTHALENE	7.0E+00	2.1E+02	3.1E+00	1.2E+01
NICKEL	4.1E+02	5.0E+00	4.1E+02	5.0E+00
NITROBENZENE	5.6E+00	2.0E+03	5.6E+00	3.8E+02
NITROGLYCERIN	1.3E+00	1.6E+02	3.5E-01	1.8E+01
NITROTOLUENE, 2-	3.1E+00	6.4E+02	3.1E+00	7.1E+01
NITROTOLUENE, 3-	1.3E+00	3.8E+02	1.3E+00	4.2E+01
NITROTOLUENE, 4-	2.5E+01	4.1E+02	2.8E+00	4.6E+01
PENTACHLOROPHENOL	9.8E-01	1.3E+01	7.8E-01	7.9E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	1.1E+02	2.2E+04	1.1E+02	2.2E+04
PERCHLORATE	1.2E+00	5.0E+03	1.2E+00	6.0E+02
PHENANTHRENE	4.6E+02	3.0E+02	6.9E+01	2.3E+00

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**
PHENOL	9.3E+00	3.0E+02	1.8E+00	5.8E+01
POLYCHLORINATED BIPHENYLS (PCBs)	1.2E+00	2.0E+00	1.2E+00	1.4E-02
PROPICONAZOLE	1.1E+02	4.3E+02	2.5E+01	9.5E+01
PYRENE	4.4E+01	6.8E+01	4.4E+01	4.6E+00
SELENIUM	7.8E+01	2.0E+01	7.8E+01	5.0E+00
SILVER	7.8E+01	1.0E+00	7.8E+01	1.0E-01
SIMAZINE	1.9E+00	8.0E+01	2.2E-01	9.0E+00
STYRENE	1.0E+01	1.1E+02	2.9E+00	3.2E+01
TERBACIL	2.1E+00	2.5E+02	2.1E+00	2.5E+02
tert-BUTYL ALCOHOL	2.0E+01	5.0E+04	7.3E+00	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	2.2E+00	7.7E+02	3.2E-01	1.1E+01
TETRACHLOROETHANE, 1,1,2,2-	1.0E-02	2.4E+02	1.0E-02	2.0E+02
TETRACHLOROETHYLENE	9.8E-02	1.9E+02	9.8E-02	5.3E+01
TETRACHLOROPHENOL, 2,3,4,6-	5.1E-01	1.1E+01	5.6E-02	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	1.1E+02	1.2E+03	1.9E+01	2.2E+02
THALLIUM	7.8E-01	4.7E+02	7.8E-01	6.0E+00
TOLUENE	3.2E+01	4.0E+02	7.8E-01	9.8E+00
TOXAPHENE	4.8E-01	2.1E-01	4.8E-01	2.0E-04
TPH (gasolines)	1.0E+02	5.0E+03	1.0E+02	5.0E+02
TPH (middle distillates)	1.8E+02	2.5E+03	1.8E+02	6.4E+02
TPH (residual fuels)	5.0E+02	2.5E+03	5.0E+02	6.4E+02
TRICHLOROBENZENE, 1,2,4-	1.8E-01	4.2E+02	1.8E-01	1.1E+02
TRICHLOROETHANE, 1,1,1-	2.2E+02	6.0E+03	1.2E+00	1.1E+01
TRICHLOROETHANE, 1,1,2-	8.9E-03	1.1E+02	8.9E-03	1.1E+02
TRICHLOROETHYLENE	8.9E-02	2.1E+02	8.9E-02	4.7E+01
TRICHLOROPHENOL, 2,4,5-	4.5E+00	1.7E+01	5.0E-01	1.9E+00
TRICHLOROPHENOL, 2,4,6-	2.5E+00	3.9E+01	3.1E-01	4.9E+00
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	1.2E+01	6.9E+02	1.2E+01	6.9E+02
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	7.9E+00	2.7E+02	8.7E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	5.0E-03	1.4E+02	5.0E-03	1.4E+01
TRICHLOROPROPENE, 1,2,3-	1.6E-01	3.3E+00	1.6E-01	3.3E+00
TRIFLURALIN	5.6E+01	2.1E+01	1.8E+01	1.1E+00
TRINITROBENZENE, 1,3,5-	7.5E+00	2.7E+01	2.8E+00	1.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	3.0E+01	3.9E+01	3.0E+01	3.9E+01
TRINITROTOLUENE, 2,4,6- (TNT)	7.3E+00	2.1E+02	6.1E+00	1.3E+01
VANADIUM	7.7E+02	9.0E+01	7.7E+02	2.7E+01

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CONTAMINANT	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**
VINYL CHLORIDE	3.6E-02	1.8E+01	3.6E-02	1.8E+01
XYLENES	2.4E+01	2.3E+02	1.4E+00	1.3E+01
ZINC	1.0E+03	2.2E+01	1.0E+03	2.2E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	not applicable	2.0	not applicable
Sodium Adsorption Ratio	5.0	not applicable	5.0	not applicable

Notes:

1. Based on unrestricted current or future land use. Considered adequate for residential housing, schools, medical facilities, day-care centers, parks and other sensitive uses.
2. Assumes potential discharge of groundwater into a freshwater, marine or estuary surface water system. Compare to *dissolved-phase* concentration.

Source of Soil Action Levels: Refer to Appendix 1, Tables B-1 and B-2.

Source of Groundwater Action Levels: Appendix 1, Table D-1c (≤150m to Surface Water Body) and Table D-1d (>150m to Surface Water Body).

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

Soil Action Levels intended to address direct-exposure, vapor intrusion, groundwater protection (leaching) and gross contamination hazards. Soil gas data should be collected for additional evaluation of potential vapor intrusion hazards at sites with significant areas of VOC-impacted soil. See also Section 4.4 and Table C. The need for a site-specific, ecological risk assessment should be evaluated if sensitive, terrestrial or aquatic habitats are within or nearby areas of contaminated soil.

Groundwater Action Levels intended to address surface water impacts, vapor intrusion and nuisance hazards Use in conjunction with soil gas action levels to evaluate potential impacts to vapor intrusion hazards if groundwater action levels for this concern approached or exceeded (refer to Table C-1a in Appendix 1). See also Section 4.4 and Table C.

Groundwater action levels should be compared to dissolved-phase chemical concentrations unless otherwise instructed by HDOH.

Groundwater ALs >150m to Surface Water Body: Groundwater screened with respect to acute surface water goals (See Table D-1d).

Groundwater ALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic surface water goals (see Table D-1c).

TPH -Total Petroleum Hydrocarbons: TPH Action Levels must be used in conjunction with Action Levels for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Section 2.6 in text.

TPH soil action levels for gross contamination hazards in isolated soils may be used as final cleanup levels if soil situated >3m deep at residential site and >1m (or otherwise capped) at commercial sites AND site data indicate that remaining contamination will not pose leaching or vapor intrusion hazards (refer to Table F-3 in Appendix 1; TPHg = 4,500 mg/kg, TPHmd & TPHrf = 5,000 mg/kg). TPH soil action levels noted in above table should be applied at sites with elevated threats to drinking water resources or aquatic habitats. Refer to Section 2.6 in text.

TABLE C: INDOOR AIR AND SOIL VAPOR

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Vapor
(Vapor Intrusion Hazards)

			INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL VAPOR ACTION LEVELS	
CHEMICAL PARAMETER	Physical State		[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)	[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)
ACENAPHTHENE	V	S	4.4E+01	1.8E+02	8.8E+04	7.4E+05
ACENAPHTHYLENE	V	S	3.3E+01	1.4E+02	6.7E+04	5.6E+05
ACETONE	V	L	6.6E+02	2.8E+03	1.3E+06	1.1E+07
ALDRIN	SV	S	5.7E-02	2.5E-01	1.1E+02	1.0E+03
AMETRYN	NV	S				
AMINO,2- DINITROTOLUENE,4,6-	NV	S				
AMINO,4- DINITROTOLUENE,2,6-	NV	S				
ANTHRACENE	V	S	2.3E+02	9.6E+02	4.6E+05	3.9E+06
ANTIMONY	NV	S				
ARSENIC	NV	S				
ATRAZINE	NV	S				
BARIUM	NV	S				
BENOMYL	NV	S				
BENZENE	V	L	3.6E-01	1.6E+00	7.2E+02	6.3E+03
BENZO(a)ANTHRACENE	SV	S	1.7E-01	2.0E+00	3.4E+02	8.2E+03
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	8.3E-02	3.5E-01	1.7E+02	1.4E+03
BIS(2-CHLOROETHYL)ETHER	V	L	8.5E-03	3.7E-02	1.7E+01	1.5E+02
BIS(2-CHLORO-1-METHYLETHYL)ETHER	V	L	2.8E-01	1.2E+00	5.6E+02	4.9E+03
BIS(2-ETHYLHEXYL)PHTHALATE	NV	S				
BORON	NV	S				
BROMODICHLOROMETHANE	V	L	7.6E-02	3.3E-01	1.5E+02	1.3E+03
BROMOFORM	SV	S	2.6E+00	1.1E+01	5.1E+03	4.5E+04
BROMOMETHANE	V	G	1.0E+00	4.4E+00	2.1E+03	1.8E+04
CADMIUM	NV	S				
CARBON TETRACHLORIDE	V	L	4.7E-01	2.0E+00	9.4E+02	8.2E+03
CHLORDANE (TECHNICAL)	SV	S	2.8E-01	1.2E+00	5.6E+02	4.9E+03
CHLOROANILINE, p-	NV	S				
CHLOROBENZENE	V	L	1.0E+01	4.4E+01	2.1E+04	1.8E+05
CHLOROETHANE	V	G	8.3E+02	3.5E+03	1.7E+06	1.4E+07
CHLOROFORM	V	L	1.2E-01	5.3E-01	2.4E+02	2.1E+03
CHLOROMETHANE	V	G	1.9E+01	7.9E+01	3.8E+04	3.2E+05
CHLOROPHENOL, 2-	V	L	3.7E+00	1.5E+01	7.3E+03	6.1E+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	1.7E-01	7.0E-01	3.3E+02	2.8E+03
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	1.7E-04	2.0E-03	3.4E-01	8.2E+00
DIBROMOCHLOROMETHANE	V	S	1.5E+01	6.1E+01	2.9E+04	2.5E+05
DIBROMOETHANE, 1,2-	V	S	4.7E-03	2.0E-02	9.4E+00	8.2E+01
DICHLOROBENZENE, 1,2-	V	L	4.2E+01	1.8E+02	8.3E+04	7.0E+05
DICHLOROBENZENE, 1,3-	V	L	2.5E+01	1.1E+02	5.0E+04	4.2E+05
DICHLOROBENZENE, 1,4-	V	S	2.6E-01	1.1E+00	5.1E+02	4.5E+03
DICHLOROBENZIDINE, 3,3-	NV	S				
DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV	S				
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	SV	S	2.9E-02	1.3E-01	5.8E+01	5.1E+02
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV	S				
DICHLOROETHANE, 1,1-	V	L	1.8E+00	7.7E+00	3.5E+03	3.1E+04
DICHLOROETHANE, 1,2-	V	L	1.1E-01	4.7E-01	2.2E+02	1.9E+03
DICHLOROETHYLENE, 1,1-	V	L	4.2E+01	1.8E+02	8.3E+04	7.0E+05

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Vapor
(Vapor Intrusion Hazards)

			INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL VAPOR ACTION LEVELS	
CHEMICAL PARAMETER	Physical State		[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)	[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)
DICHLOROETHYLENE, Cis 1,2-	V	L	8.3E+00	3.5E+01	1.7E+04	1.4E+05
DICHLOROETHYLENE, Trans 1,2-	V	L	8.3E+00	3.5E+01	1.7E+04	1.4E+05
DICHLOROPHENOL, 2,4-	NV	S				
DICHLOROPHENOXYACETIC ACID (2,4-D)	NV	S				
DICHLOROPROPANE, 1,2-	V	L	7.6E-01	3.3E+00	1.5E+03	1.3E+04
DICHLOROPROPENE, 1,3-	V	L	7.0E-01	3.1E+00	1.4E+03	1.2E+04
DIELDRIN	NV	S				
DIETHYLPHTHALATE	NV	S				
DIMETHYLPHENOL, 2,4-	NV	S				
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-	V	L	5.6E-01	2.5E+00	1.1E+03	9.8E+03
DIOXINS (TEQ)	SV	S	7.4E-06	3.2E-05	1.5E-02	1.3E-01
DIURON	NV	S				
ENDOSULFAN	SV	S				
ENDRIN	NV	S				
ETHANOL	V	L				
ETHYLBENZENE	V	L	1.1E+01	4.9E+01	2.2E+04	2.0E+05
FLUORANTHENE	NV	S				
FLUORENE	V	S	2.9E+01	1.2E+02	5.8E+04	4.9E+05
GLYPHOSATE	NV	S				
HEPTACHLOR	SV	S	2.2E-02	9.4E-02	4.3E+01	3.8E+02
HEPTACHLOR EPOXIDE	SV	S	1.1E-02	4.7E-02	2.2E+01	1.9E+02
HEXACHLOROBENZENE	SV	S	6.1E-03	2.7E-02	1.2E+01	1.1E+02
HEXACHLOROBUTADIENE	SV	S	1.3E-01	5.6E-01	2.6E+02	2.2E+03
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV	S				
HEXACHLOROETHANE	SV	S	2.6E-01	1.1E+00	5.1E+02	4.5E+03
HEXAZINONE	NV	S				
INDENO(1,2,3-cd)PYRENE	NV	S				
ISOPHORONE	NV	L				
LEAD	NV	S				
MERCURY	NV	S				
METHOXYCHLOR	NV	S				
METHYL ETHYL KETONE	V	L	1.0E+03	4.4E+03	2.1E+06	1.8E+07
METHYL ISOBUTYL KETONE	V	L	6.3E+02	2.6E+03	1.3E+06	1.1E+07
METHYL MERCURY	NV	S				
METHYL TERT BUTYL ETHER	V	L	1.1E+01	4.7E+01	2.2E+04	1.9E+05
METHYLENE CHLORIDE	V	L	1.0E+02	5.3E+02	2.0E+05	2.1E+06
METHYLNAPHTHALENE, 1-	V	S	5.1E+01	2.1E+02	1.0E+05	8.6E+05
METHYLNAPHTHALENE, 2-	V	S	2.9E+00	1.2E+01	5.8E+03	4.9E+04
MOLYBDENUM	NV	S				
NAPHTHALENE	V	S	6.3E-01	2.6E+00	1.3E+03	1.1E+04
NICKEL	NV	S				
NITROBENZENE	V	L	7.0E-02	3.1E-01	1.4E+02	1.2E+03
NITROGLYCERIN	NV	L				
NITROTOLUENE, 2-	V	S	6.6E-01	2.8E+00	1.3E+03	1.1E+04
NITROTOLUENE, 3-	NV	S				
NITROTOLUENE, 4-	NV	S				
PENTACHLOROPHENOL	NV	S				
PENTAERYTHRITOLTETRANITRATE (PETN)	NV	S				

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Vapor
(Vapor Intrusion Hazards)

			INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL VAPOR ACTION LEVELS	
CHEMICAL PARAMETER	Physical State		[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)	[1]Residential (ug/m3)	Commercial/ Industrial (ug/m^3)
PERCHLORATE	NV	S				
PHENANTHRENE	V	S	2.9E+01	1.2E+02	5.8E+04	4.9E+05
PHENOL	NV	S				
POLYCHLORINATED BIPHENYLS (PCBs)	SV	S	4.9E-02	2.2E-01	9.9E+01	8.6E+02
PROPICONAZOLE	NV	L				
PYRENE	V	S	2.2E+01	9.2E+01	4.4E+04	3.7E+05
SELENIUM	NV	S				
SILVER	NV	S				
SIMAZINE	NV	S				
STYRENE	V	L	2.1E+02	8.8E+02	4.2E+05	3.5E+06
TERBACIL	NV	S				
tert-BUTYL ALCOHOL	V	L	1.0E+03	4.4E+03	2.1E+06	1.8E+07
TETRACHLOROETHANE, 1,1,1,2-	V	L	3.8E-01	1.7E+00	7.6E+02	6.6E+03
TETRACHLOROETHANE, 1,1,2,2-	V	L	4.8E-02	2.1E-01	9.7E+01	8.5E+02
TETRACHLOROETHYLENE	V	L	4.6E-01	2.0E+00	9.2E+02	8.0E+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	4.4E+03	2.1E+06	1.8E+07
TOXAPHENE	NV	S				
TPH (gasolines)	V	L	2.0E+02	8.4E+02	4.0E+05	3.3E+06
TPH (middle distillates)	V	L	1.3E+02	5.4E+02	2.6E+05	2.2E+06
TPH (residual fuels)	SV	L	1.3E+02	5.4E+02	2.6E+05	2.2E+06
TRICHLOROBENZENE, 1,2,4-	V	S	4.2E-01	1.8E+00	8.3E+02	7.0E+03
TRICHLOROETHANE, 1,1,1-	V	L	1.0E+03	4.4E+03	2.1E+06	1.8E+07
TRICHLOROETHANE, 1,1,2-	V	L	4.2E-02	1.8E-01	8.3E+01	7.0E+02
TRICHLOROETHYLENE	V	L	4.2E-01	1.8E+00	8.3E+02	7.0E+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	6.3E-02	2.6E-01	1.3E+02	1.1E+03
TRICHLOROPROPENE, 1,2,3-	V	L	6.3E-02	2.6E-01	1.3E+02	1.1E+03
TRIFLURALIN	SV	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 C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Vapor
(Vapor Intrusion Hazards)

			INDOOR AIR ACTION LEVELS		[2]SHALLOW SOIL VAPOR ACTION LEVELS	
CHEMICAL PARAMETER	**Physical State**		**[1]Residential (ug/m3)**	**Commercial/ Industrial (ug/m^3)**	**[1]Residential (ug/m3)**	**Commercial/ Industrial (ug/m^3)**
VINYL CHLORIDE	V	G	1.7E-01	2.8E+00	3.4E+02	1.1E+04
XYLENES	V	L	2.1E+01	8.8E+01	4.2E+04	3.5E+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" considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.)

2. Soil Vapor: Screening levels based on soil vapor data collected immediately beneath a building slab or within 1.5 meters (five feet) ground surface in open areas. Intended for evaluation of potential vapor intrusion hazards.

Soil vapor action levels apply to areas that overlie contaminated soil and/or contaminated groundwater.

TPH -Total Petroleum Hydrocarbons. TPH (or equivalent) must be included in analyses for soil vapor collected at petroleum release sites, in addition to individual, targeted VOCs (e.g., BTEX, etc.). See Volume 1, Section 2.6 and Appendix 1, Chapter 5.

TABLE D: SUMMARY OF SURFACE WATER ACTION LEVELS

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

[1]Surface Water Bodies

	SURFACE WATER ACTION LEVELS		
CHEMICAL PARAMETER	**[2]Freshwater (ug/L)**	**[3]Marine (ug/L)**	**[4]Estuarine (ug/L)**
ACENAPHTHENE	1.5E+01	2.0E+01	1.5E+01
ACENAPHTHYLENE	1.3E+01	3.1E+02	1.3E+01
ACETONE	1.7E+03	1.5E+03	1.5E+03
ALDRIN	2.6E-05	2.6E-05	2.6E-05
AMETRYN	1.5E+02	7.0E+02	7.0E+02
AMINO,2- DINITROTOLUENE,4,6-	1.9E+00	2.0E+01	1.8E+01
AMINO,4- DINITROTOLUENE,2,6-	1.9E+00	1.1E+01	1.1E+01
ANTHRACENE	2.0E-02	7.3E-01	2.0E-02
ANTIMONY	6.0E+00	3.0E+01	3.0E+01
ARSENIC	1.4E-01	1.4E-01	1.4E-01
ATRAZINE	3.0E+00	1.2E+01	1.2E+01
BARIUM	2.2E+02	2.2E+02	2.2E+02
BENOMYL	1.4E-01	1.4E-01	1.4E-01
BENZENE	5.0E+00	1.3E+01	1.3E+01
BENZO(a)ANTHRACENE	1.8E-02	1.8E-02	1.8E-02
BENZO(a)PYRENE	1.8E-02	1.8E-02	1.8E-02
BENZO(b)FLUORANTHENE	1.8E-02	1.8E-02	1.8E-02
BENZO(g,h,i)PERYLENE	1.3E-01	1.3E-01	1.3E-01
BENZO(k)FLUORANTHENE	1.8E-02	1.8E-02	1.8E-02
BERYLLIUM	3.8E-02	3.8E-02	3.8E-02
BIPHENYL, 1,1-	5.0E-01	5.0E-01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	1.4E-02	4.4E-01	4.4E-01
BIS(2-CHLORO-1-METHYLETHYL)ETHER	3.6E-01	3.6E-01	3.6E-01
BIS(2-ETHYLHEXYL)PHTHALATE	2.2E+00	2.2E+00	2.2E+00
BORON	9.8E+02	1.0E+03	1.0E+03
BROMODICHLOROMETHANE	1.3E-01	3.4E+02	3.4E+02
BROMOFORM	8.0E+01	1.4E+02	1.4E+02
BROMOMETHANE	1.6E+01	1.6E+01	1.6E+01
CADMIUM	3.0E+00	9.3E+00	3.0E+00
CARBON TETRACHLORIDE	2.3E+00	2.3E+00	2.3E+00
CHLORDANE (TECHNICAL)	1.6E-05	1.6E-05	1.6E-05
CHLOROANILINE, p-	3.7E-01	1.9E+01	1.9E+01
CHLOROBENZENE	2.5E+01	5.0E+01	2.5E+01
CHLOROETHANE	1.6E+01	1.6E+01	1.6E+01
CHLOROFORM	5.1E+00	5.1E+00	5.1E+00
CHLOROMETHANE	1.1E+03	1.1E+03	1.1E+03
CHLOROPHENOL, 2-	1.8E-01	1.8E-01	1.8E-01
CHROMIUM (Total)	1.1E+01	5.0E+01	1.1E+01
CHROMIUM III	7.4E+01	2.0E+01	2.0E+01
CHROMIUM VI	2.0E-01	5.0E+01	1.1E+01
CHRYSENE	1.8E-02	1.8E-02	1.8E-02
COBALT	2.4E+00	2.3E+01	1.9E+01
COPPER	6.0E+00	2.9E+00	2.9E+00
CYANIDE (Free)	5.2E+00	1.0E+00	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	9.7E-01	1.9E+02	7.9E+01
DALAPON	2.0E+02	3.0E+02	3.0E+02

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

[1]Surface Water Bodies

CHEMICAL PARAMETER	SURFACE WATER ACTION LEVELS [2]Freshwater (ug/L)	[3]Marine (ug/L)	[4]Estuarine (ug/L)
DIBENZO(a,h)ANTHTRACENE	4.8E-03	1.8E-02	1.8E-02
DIBROMO,1,2- CHLOROPROPANE,3-	4.0E-02	4.0E-02	4.0E-02
DIBROMOCHLOROMETHANE	8.7E-01	1.3E+01	1.3E+01
DIBROMOETHANE, 1,2-	4.0E-02	1.4E+03	1.4E+03
DICHLOROBENZENE, 1,2-	1.0E+01	1.0E+01	1.0E+01
DICHLOROBENZENE, 1,3-	2.2E+01	7.1E+01	2.2E+01
DICHLOROBENZENE, 1,4-	5.0E+00	1.1E+01	9.4E+00
DICHLOROBENZIDINE, 3,3-	7.0E-03	7.0E-03	7.0E-03
DICHLORODIPHENYLDICHLOROETHANE (DDD)	3.1E-04	3.1E-04	3.1E-04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.2E-04	2.2E-04	2.2E-04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	8.0E-06	8.0E-06	8.0E-06
DICHLOROETHANE, 1,1-	2.8E+00	4.7E+01	4.7E+01
DICHLOROETHANE, 1,2-	5.0E+00	7.9E+01	7.9E+01
DICHLOROETHYLENE, 1,1-	6.0E-01	6.0E-01	6.0E-01
DICHLOROETHYLENE, Cis 1,2-	7.0E+01	6.2E+02	6.2E+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)	7.0E+01	7.0E+01	7.0E+01
DICHLOROPROPANE, 1,2-	5.0E+00	1.0E+01	1.0E+01
DICHLOROPROPENE, 1,3-	4.7E-01	6.0E-02	6.0E-02
DIELDRIN	2.5E-05	2.5E-05	2.5E-05
DIETHYLPHTHALATE	2.2E+02	2.1E+02	2.1E+02
DIMETHYLPHENOL, 2,4-	1.2E+02	1.2E+02	1.2E+02
DIMETHYLPHTHALATE	1.1E+03	2.9E+03	1.1E+03
DINITROBENZENE, 1,3-	2.0E+00	1.0E+01	1.0E+01
DINITROPHENOL, 2,4-	3.9E+01	1.4E+01	1.4E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	2.4E-01	3.0E+00	3.0E+00
DINITROTOLUENE, 2,6- (2,6-DNT)	4.9E-02	8.1E+01	8.1E+01
DIOXANE, 1,4-	4.6E-01	5.0E+04	5.0E+04
DIOXINS (TEQ)	3.1E-09	3.1E-09	3.1E-09
DIURON	3.6E+01	6.0E+01	6.0E+01
ENDOSULFAN	5.6E-02	8.7E-03	8.7E-03
ENDRIN	2.3E-03	2.3E-03	2.3E-03
ETHANOL	0.0E+00	0.0E+00	0.0E+00
ETHYLBENZENE	3.0E+01	7.3E+00	7.3E+00
FLUORANTHENE	8.0E-01	7.1E+00	8.0E-01
FLUORENE	1.9E+01	3.9E+00	3.9E+00
GLYPHOSATE	7.0E+02	1.8E+03	1.8E+03
HEPTACHLOR	9.0E-05	9.0E-05	9.0E-05
HEPTACHLOR EPOXIDE	3.9E-05	3.9E-05	3.9E-05
HEXACHLOROBENZENE	2.4E-04	2.4E-04	2.4E-04
HEXACHLOROBUTADIENE	2.8E-01	3.0E-01	3.0E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	2.0E-02	2.0E-02	2.0E-02
HEXACHLOROETHANE	9.2E-01	2.9E+00	2.9E+00
HEXAZINONE	6.4E+02	1.7E+04	1.7E+04
INDENO(1,2,3-cd)PYRENE	1.8E-02	1.8E-02	1.8E-02

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

[1]Surface Water Bodies

	SURFACE WATER ACTION LEVELS		
CHEMICAL PARAMETER	[2]Freshwater (ug/L)	[3]Marine (ug/L)	[4]Estuarine (ug/L)
ISOPHORONE	7.8E+01	9.2E+02	9.2E+02
LEAD	1.5E+01	5.6E+00	5.6E+00
MERCURY	4.7E-02	2.5E-02	2.5E-02
METHOXYCHLOR	3.0E-02	3.0E-02	3.0E-02
METHYL ETHYL KETONE	8.4E+03	8.4E+03	8.4E+03
METHYL ISOBUTYL KETONE	1.7E+02	1.7E+02	1.7E+02
METHYL MERCURY	2.8E-03	2.8E-03	2.8E-03
METHYL TERT BUTYL ETHER	5.0E+00	1.8E+02	1.8E+02
METHYLENE CHLORIDE	5.0E+00	5.9E+02	5.9E+02
METHYLNAPHTHALENE, 1-	2.1E+00	2.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	4.7E+00	1.0E+01	4.7E+00
MOLYBDENUM	9.9E+01	3.7E+02	3.7E+02
NAPHTHALENE	1.7E+01	1.2E+01	1.2E+01
NICKEL	5.0E+00	8.3E+00	5.0E+00
NITROBENZENE	#VALUE!	3.8E+02	3.8E+02
NITROGLYCERIN	2.0E+00	1.8E+01	1.8E+01
NITROTOLUENE, 2-	3.1E-01	7.1E+01	7.1E+01
NITROTOLUENE, 3-	1.7E+00	4.2E+01	4.2E+01
NITROTOLUENE, 4-	4.3E+00	4.6E+01	4.6E+01
PENTACHLOROPHENOL	1.0E+00	3.0E+00	3.0E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	1.7E+01	2.2E+04	2.2E+04
PERCHLORATE	1.5E+01	6.0E+02	6.0E+02
PHENANTHRENE	2.3E+00	4.6E+00	2.3E+00
PHENOL	1.6E+02	5.8E+01	5.8E+01
POLYCHLORINATED BIPHENYLS (PCBs)	7.9E-05	7.9E-05	7.9E-05
PROPICONAZOLE	9.5E+01	9.5E+01	9.5E+01
PYRENE	4.6E+00	1.0E+01	4.6E+00
SELENIUM	5.0E+00	7.1E+01	5.0E+00
SILVER	1.0E+00	1.0E-01	1.0E-01
SIMAZINE	4.0E+00	9.0E+00	9.0E+00
STYRENE	1.0E+01	1.1E+01	1.1E+01
TERBACIL	2.5E+02	2.5E+02	2.5E+02
tert-BUTYL ALCOHOL	6.0E+01	1.8E+04	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	5.7E-01	1.1E+01	1.1E+01
TETRACHLOROETHANE, 1,1,2,2-	7.6E-02	3.5E+00	3.5E+00
TETRACHLOROETHYLENE	2.9E+00	2.9E+00	2.9E+00
TETRACHLOROPHENOL, 2,3,4,6-	1.2E+00	1.2E+00	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	2.2E+02	3.3E+02	2.2E+02
THALLIUM	2.0E+00	1.2E+01	6.0E+00
TOLUENE	4.0E+01	9.8E+00	9.8E+00
TOXAPHENE	2.0E-04	2.0E-04	2.0E-04
TPH (gasolines)	7.4E+01	3.7E+03	5.0E+02
TPH (middle distillates)	9.1E+01	6.4E+02	6.4E+02
TPH (residual fuels)	9.1E+01	6.4E+02	6.4E+02
TRICHLOROBENZENE, 1,2,4-	7.0E+01	1.1E+02	1.1E+02
TRICHLOROETHANE, 1,1,1-	7.6E+01	1.1E+01	1.1E+01

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

[1]Surface Water Bodies

	SURFACE WATER ACTION LEVELS		
CHEMICAL PARAMETER	**[2]Freshwater (ug/L)**	**[3]Marine (ug/L)**	**[4]Estuarine (ug/L)**
TRICHLOROETHANE, 1,1,2-	5.0E+00	1.4E+01	1.4E+01
TRICHLOROETHYLENE	5.0E+00	2.6E+01	2.6E+01
TRICHLOROPHENOL, 2,4,5-	1.9E+00	1.2E+01	1.9E+00
TRICHLOROPHENOL, 2,4,6-	1.2E+00	1.2E+00	1.2E+00
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	1.6E+02	6.9E+02	6.9E+02
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	3.0E+01	5.0E+01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	6.0E-01	1.4E+01	1.4E+01
TRICHLOROPROPENE, 1,2,3-	3.3E+00	3.3E+00	3.3E+00
TRIFLURALIN	1.1E+00	1.1E+00	1.1E+00
TRINITROBENZENE, 1,3,5-	1.1E+01	1.0E+01	1.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	3.9E+01	3.9E+01	3.9E+01
TRINITROTOLUENE, 2,4,6- (TNT)	2.5E+00	2.0E+01	1.3E+01
VANADIUM	2.7E+01	8.1E+01	2.7E+01
VINYL CHLORIDE	2.0E+00	1.7E+02	1.7E+02
XYLENES	2.0E+01	1.3E+01	1.3E+01
ZINC	2.2E+01	8.6E+01	2.2E+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. Compiled for screening of contaminated groundwater that could discharge to surface water. Check with agency overseeing surface water quality for application to aquatic habitats.

2. Source of Freshwater EALs: Refer to Appendix 1, Table D-2a for basis. Includes consideration of drinking water action levels.

3. Source of Marine EALs: Refer to Appendix 1, Table D-2b for basis.

4. Source of Estuarine EALs: Refer to Appendix 1, Table D-2c for basis.

Surface water action 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 Chapter 2 of text and Appendix 1 for details.

Estuarine action levels lowest of freshwater and marine action levels.

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

TPH -Total Petroleum Hydrocarbons. TPH EALs must be used in conjunction with EALs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Section 2.6 and Appendix 1, Chapter 5, and HEER office Technical Guidance Manual.

TABLE E: SOIL VAPOR ACTION LEVELS FOR EVALUATION OF VADOZE-ZONE LEACHATE

TABLE E. SOIL VAPOR SCREENING LEVELS
FOR EVALUATION OF VADOSE-ZONE LEACHATE
(Potential impacts to highly vulnerable drinking water aquifers)

CHEMICAL PARAMETER	[1]Target Groundwater Screening Level (µg/L)	[2]Soil Vapor Screening Level (µg/m^3)
ACENAPHTHENE	-	-
ACENAPHTHYLENE	-	-
ACETONE	6.0E+03	1.7E+05
ALDRIN	-	-
AMETRYN	-	-
AMINO,2- DINITROTOLUENE,3,6-	-	-
AMINO,4- DINITROTOLUENE,2,6-	-	-
ANTHRACENE	-	-
ANTIMONY	-	-
ARSENIC	-	-
ATRAZINE	-	-
BARIUM	-	-
BENOMYL	-	-
BENZENE	5.0E+00	2.3E+04
BENZO(a)ANTHRACENE	-	-
BENZO(a)PYRENE	-	-
BENZO(b)FLUORANTHENE	-	-
BENZO(g,h,i)PERYLENE	-	-
BENZO(k)FLUORANTHENE	-	-
BERYLLIUM	-	-
BIPHENYL, 1,1-	5.0E-01	1.3E+02
BIS(2-CHLOROETHYL)ETHER	1.4E-02	1.9E-01
BIS(2-CHLORO-1-METHYLETHYL)ETHER	3.6E-01	3.3E+01
BIS(2-ETHYLHEXYL)PHTHALATE	-	-
BORON	-	-
BROMODICHLOROMETHANE	1.3E-01	2.3E+02
BROMOFORM	-	-
BROMOMETHANE	1.9E+01	1.1E+05
CADMIUM	-	-
CARBON TETRACHLORIDE	5.0E+00	1.1E+05
CHLORDANE (TECHNICAL)	-	-
CHLOROANILINE, p-	-	-
CHLOROBENZENE	5.0E+01	1.3E+05
CHLOROETHANE	1.6E+01	1.4E+05
CHLOROFORM	7.0E+01	2.1E+05
CHLOROMETHANE	1.1E+03	7.7E+06
CHLOROPHENOL, 2-	1.8E-01	1.7E+00
CHROMIUM (Total)	-	-
CHROMIUM III	-	-
CHROMIUM VI	-	-
CHRYSENE	-	-
COBALT	-	-
COPPER	-	-
CYANIDE (Free)	-	-

TABLE E. SOIL VAPOR SCREENING LEVELS FOR EVALUATION OF VADOSE-ZONE LEACHATE
(Potential impacts to highly vulnerable drinking water aquifers)

CHEMICAL PARAMETER	[1]Target Groundwater Screening Level (µg/L)	[2]Soil Vapor Screening Level ($\mu g/m^3$)
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	-	-
DALAPON	-	-
DIBENZO(a,h)ANTHTRACENE	-	-
DIBROMO,1,2- CHLOROPROPANE,3-	4.0E-02	4.8E+00
DIBROMOCHLOROMETHANE	8.7E-01	5.6E+02
DIBROMOETHANE, 1,2-	4.0E-02	2.2E+01
DICHLOROBENZENE, 1,2-	1.0E+01	1.6E+04
DICHLOROBENZENE, 1,3-	5.0E+00	7.8E+03
DICHLOROBENZENE, 1,4-	5.0E+00	9.9E+03
DICHLOROBENZIDINE, 3,3-	-	-
DICHLORODIPHENYLDICHLOROETHANE (DDD)	-	-
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	-	-
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	-	-
DICHLOROETHANE, 1,1-	2.8E+00	1.3E+04
DICHLOROETHANE, 1,2-	5.0E+00	4.8E+03
DICHLOROETHYLENE, 1,1-	7.0E+00	1.5E+05
DICHLOROETHYLENE, Cis 1,2-	7.0E+01	2.4E+05
DICHLOROETHYLENE, Trans 1,2-	1.0E+02	7.6E+05
DICHLOROPHENOL, 2,4-	-	-
DICHLOROPHENOXYACETIC ACID (2,4-D)	-	-
DICHLOROPROPANE, 1,2-	5.0E+00	1.2E+04
DICHLOROPROPENE, 1,3-	4.7E-01	1.4E+03
DIELDRIN	-	-
DIETHYLPHTHALATE	-	-
DIMETHYLPHENOL, 2,4-	3.6E+02	-
DIMETHYLPHTHALATE	-	-
DINITROBENZENE, 1,3-	-	-
DINITROPHENOL, 2,4-	-	-
DINITROTOLUENE, 2,4- (2,4-DNT)	-	-
DINITROTOLUENE, 2,6- (2,6-DNT)	-	-
DIOXANE, 1,4-	-	-
DIOXIN (TEQ)	-	-
DIURON	-	-
ENDOSULFAN	-	-
ENDRIN	-	-
ETHANOL	-	-
ETHYLBENZENE	3.0E+01	1.9E+05
FLUORANTHENE	-	-
FLUORENE	-	-
GLYPHOSATE	-	-
HEPTACHLOR	-	-
HEPTACHLOR EPOXIDE	-	-
HEXACHLOROBENZENE	-	-
HEXACHLOROBUTADIENE	-	-

TABLE E. SOIL VAPOR SCREENING LEVELS
FOR EVALUATION OF VADOSE-ZONE LEACHATE
(Potential impacts to highly vulnerable drinking water aquifers)

CHEMICAL PARAMETER	[1]Target Groundwater Screening Level (µg/L)	[2]Soil Vapor Screening Level (µg/m^3)
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	-	-
HEXACHLOROETHANE	-	-
HEXAZINONE	-	-
INDENO(1,2,3-cd)PYRENE	-	-
ISOPHORONE	-	-
LEAD	-	-
MERCURY	-	-
METHOXYCHLOR	-	-
METHYL ETHYL KETONE	8.4E+03	3.9E+05
METHYL ISOBUTYL KETONE	1.3E+03	1.5E+05
METHYL MERCURY	-	-
METHYL TERT BUTYL ETHER	5.0E+00	2.4E+03
METHYLENE CHLORIDE	5.0E+00	1.3E+04
METHYLNAPHTHALENE, 1-	-	-
METHYLNAPHTHALENE, 2-	-	-
MOLYBDENUM	-	-
NAPHTHALENE	1.7E+01	6.1E+03
NICKEL	-	-
NITROBENZENE	#VALUE!	#VALUE!
NITROGLYCERIN	-	-
NITROTOLUENE, 2-	3.1E-01	3.2E+00
NITROTOLUENE, 3-	1.7E+00	-
NITROTOLUENE, 4-	-	-
PENTACHLOROPHENOL	-	-
PENTAERYTHRITOLTETRANITRATE (PETN)	-	-
PERCHLORATE	-	-
PHENANTHRENE	-	-
PHENOL	-	-
POLYCHLORINATED BIPHENYLS (PCBs)	-	-
PROPICONAZOLE	-	-
PYRENE	-	-
SELENIUM	-	-
SILVER	-	-
SIMAZINE	-	-
STYRENE	1.0E+01	2.2E+04
TERBACIL	-	-
tert-BUTYL ALCOHOL	6.0E+01	4.4E+02
TETRACHLOROETHANE, 1,1,1,2-	5.7E-01	1.1E+03
TETRACHLOROETHANE, 1,1,2,2-	7.6E-02	2.3E+01
TETRACHLOROETHYLENE	5.0E+00	7.2E+04
TETRACHLOROPHENOL, 2,3,4,6-	-	-
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	-	-
THALLIUM	-	-
TOLUENE	4.0E+01	2.2E+05

TABLE E. SOIL VAPOR SCREENING LEVELS
FOR EVALUATION OF VADOSE-ZONE LEACHATE
(Potential impacts to highly vulnerable drinking water aquifers)

CHEMICAL PARAMETER	[1]Target Groundwater Screening Level (µg/L)	[2]Soil Vapor Screening Level ($\mu g/m^3$)
TOXAPHENE	-	-
TPH (gasolines)	7.4E+01	2.1E+07
TPH (middle distillates)	9.1E+01	2.5E+07
TPH (residual fuels)	-	-
TRICHLOROBENZENE, 1,2,4-	7.0E+01	8.1E+04
TRICHLOROETHANE, 1,1,1-	2.0E+02	2.8E+06
TRICHLOROETHANE, 1,1,2-	5.0E+00	3.4E+03
TRICHLOROETHYLENE	5.0E+00	4.0E+04
TRICHLOROPHENOL, 2,4,5-	-	-
TRICHLOROPHENOL, 2,4,6-	-	-
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	-	-
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	-	-
TRICHLOROPROPANE, 1,2,3-	6.0E-01	1.7E+02
TRICHLOROPROPENE, 1,2,3-	3.3E+00	4.8E+04
TRIFLURALIN	-	-
TRINITROBENZENE, 1,3,5-	-	-
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	-	-
TRINITROTOLUENE, 2,4,6- (TNT)	-	-
VANADIUM	-	-
VINYL CHLORIDE	2.0E+00	4.4E+04
XYLENES	2.0E+01	1.1E+05
ZINC	-	-
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	-	-
Sodium Adsorption Ratio	-	-

Notes:

1 Lowest of drinking water goals based on toxicity and taste and odors. Focus on volatile petroleum hydrocarbons, chlorinated solvents, explosives or agricultural fumigants of potential concern or related breakdown products (refer also to Section 9 of the Hawai'i DOH Technical Guidance Manual (HDOH 2009). Petroleum fuels focus on BTEX, MTCE, naphthalene, TPHg and TPHmd.

2. Theoretical, equilibrium concentration of VOC in soil gas when concentration of VOC in soil moisture/leachate is equal to twenty times the target drinking water screening level (default atenuation/dilution factor; see Section 4.3.4).

TABLE F: CHEMICAL CAS NUMBERS

Table F. CHEMICAL CHEMICAL ABSTRACT SERVICE (CAS) NUMBERS.

CAS Number	CHEMICAL PARAMETER
83-32-9	ACENAPHTHENE
208-96-8	ACENAPHTHYLENE
67-64-1	ACETONE
309-00-2	ALDRIN
834-12-8	AMETRYN
35572-78-2	AMINO,2- DINITROTOLUENE,4,6-
19406-51-0	AMINO,4- DINITROTOLUENE,2,6-
120-12-7	ANTHRACENE
7440-36-0	ANTIMONY
7440-38-2	ARSENIC
1912-24-9	ATRAZINE
7440-39-3	BARIUM
17804-35-2	BENOMYL
71-43-2	BENZENE
56-55-3	BENZO(a)ANTHRACENE
50-32-8	BENZO(a)PYRENE
205-99-2	BENZO(b)FLUORANTHENE
191-24-2	BENZO(g,h,i)PERYLENE
207-08-9	BENZO(k)FLUORANTHENE
7440-41-7	BERYLLIUM
92-52-4	BIPHENYL, 1,1-
111-44-4	BIS(2-CHLOROETHYL)ETHER
39638-32-9	BIS(2-CHLORO-1-METHYLETHYL)ETHER
117-81-7	BIS(2-ETHYLHEXYL)PHTHALATE
7440-42-8	BORON
75-27-4	BROMODICHLOROMETHANE
75-25-2	BROMOFORM
74-83-9	BROMOMETHANE
7440-43-9	CADMIUM
56-23-5	CARBON TETRACHLORIDE
12789-03-6	CHLORDANE (TECHNICAL)
106-47-8	CHLOROANILINE, p-
108-90-7	CHLOROBENZENE
75-00-3	CHLOROETHANE
67-66-3	CHLOROFORM
74-87-3	CHLOROMETHANE
95-57-8	CHLOROPHENOL, 2-
7440-47-3	CHROMIUM (Total)
16065-83-1	CHROMIUM III
18540-29-9	CHROMIUM VI
218-01-9	CHRYSENE
7440-48-4	COBALT
7440-50-8	COPPER
57-12-5	CYANIDE (Free)
121-82-4	CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX
75-99-0	DALAPON
53-70-3	DIBENZO(a,h)ANTHTHRACENE
96-12-8	DIBROMO,1,2- CHLOROPROPANE,3-
124-48-1	DIBROMOCHLOROMETHANE
106-93-4	DIBROMOETHANE, 1,2-
95-50-1	DICHLOROBENZENE, 1,2-
541-73-1	DICHLOROBENZENE, 1,3-
106-46-7	DICHLOROBENZENE, 1,4-
91-94-1	DICHLOROBENZIDINE, 3,3-
72-54-8	DICHLORODIPHENYLDICHLOROETHANE (DDD)
72-55-9	DICHLORODIPHENYLDICHLOROETHYLENE (DDE)
50-29-3	DICHLORODIPHENYLTRICHLOROETHANE (DDT)
75-34-3	DICHLOROETHANE, 1,1-

107-06-2	DICHLOROETHANE, 1,2-
75-35-4	DICHLOROETHYLENE, 1,1-
156-59-2	DICHLOROETHYLENE, Cis 1,2-
156-60-5	DICHLOROETHYLENE, Trans 1,2-
120-83-2	DICHLOROPHENOL, 2,4-
94-75-7	DICHLOROPHENOXYACETIC ACID (2,4-D)
78-87-5	DICHLOROPROPANE, 1,2-
542-75-6	DICHLOROPROPENE, 1,3-
60-57-1	DIELDRIN
84-66-2	DIETHYLPHTHALATE
105-67-9	DIMETHYLPHENOL, 2,4-
131-11-3	DIMETHYLPHTHALATE
99-65-0	DINITROBENZENE, 1,3-
51-28-5	DINITROPHENOL, 2,4-
121-14-2	DINITROTOLUENE, 2,4- (2,4-DNT)
606-20-2	DINITROTOLUENE, 2,6- (2,6-DNT)
123-91-1	DIOXANE, 1,4-
1746-01-6	DIOXINS (TEQ)
330-54-1	DIURON
115-29-7	ENDOSULFAN
72-20-8	ENDRIN
64-17-5	ETHANOL
100-41-4	ETHYLBENZENE
206-44-0	FLUORANTHENE
86-73-7	FLUORENE
1071-83-6	GLYPHOSATE
76-44-8	HEPTACHLOR
1024-57-3	HEPTACHLOR EPOXIDE
118-74-1	HEXACHLOROBENZENE
87-68-3	HEXACHLOROBUTADIENE
58-89-9	HEXACHLOROCYCLOHEXANE (gamma) LINDANE
67-72-1	HEXACHLOROETHANE
51235-04-2	HEXAZINONE
193-39-5	INDENO(1,2,3-cd)PYRENE
78-59-1	ISOPHORONE
7439-92-1	LEAD
7487-94-7	MERCURY
72-43-5	METHOXYCHLOR
78-93-3	METHYL ETHYL KETONE
108-10-1	METHYL ISOBUTYL KETONE
22967-92-6	METHYL MERCURY
1634-04-4	METHYL TERT BUTYL ETHER
75-09-2	METHYLENE CHLORIDE
90-12-0	METHYLNAPHTHALENE, 1-
91-57-6	METHYLNAPHTHALENE, 2-
7439-98-7	MOLYBDENUM
91-20-3	NAPHTHALENE
7440-02-0	NICKEL
98-95-3	NITROBENZENE
55-63-0	NITROGLYCERIN
88-72-2	NITROTOLUENE, 2-
99-08-1	NITROTOLUENE, 3-
99-99-0	NITROTOLUENE, 4-
87-86-5	PENTACHLOROPHENOL
78-11-5	PENTAERYTHRITOLTETRANITRATE (PETN)
14797-73-0	PERCHLORATE

85-01-8	PHENANTHRENE
108-95-2	PHENOL
11097-69-1	POLYCHLORINATED BIPHENYLS (PCBs)
60207-90-1	PROPICONAZOLE
129-00-0	PYRENE
7782-49-2	SELENIUM
7440-22-4	SILVER
122-34-9	SIMAZINE
100-42-5	STYRENE
5902-51-2	TERBACIL
75-65-0	tert-BUTYL ALCOHOL
630-20-6	TETRACHLOROETHANE, 1,1,1,2-
79-34-5	TETRACHLOROETHANE, 1,1,2,2-
127-18-4	TETRACHLOROETHYLENE
58-90-2	TETRACHLOROPHENOL, 2,3,4,6-
2691-41-0	TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX
7440-28-0	THALLIUM
108-88-3	TOLUENE
8001-35-2	TOXAPHENE
Gas	TPH (gasolines)
Diesel	TPH (middle distillates)
Oil	TPH (residual fuels)
120-82-1	TRICHLOROBENZENE, 1,2,4-
71-55-6	TRICHLOROETHANE, 1,1,1-
79-00-5	TRICHLOROETHANE, 1,1,2-
79-01-6	TRICHLOROETHYLENE
95-95-4	TRICHLOROPHENOL, 2,4,5-
88-06-2	TRICHLOROPHENOL, 2,4,6-
93-76-5	TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)
93-72-1	TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)
96-18-4	TRICHLOROPROPANE, 1,2,3-
96-19-5	TRICHLOROPROPENE, 1,2,3-
1582-09-8	TRIFLURALIN
99-35-4	TRINITROBENZENE, 1,3,5-
479-45-8	TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)
118-96-7	TRINITROTOLUENE, 2,4,6- (TNT)
7440-62-2	VANADIUM
75-01-4	VINYL CHLORIDE
1330-20-7	XYLENES
7440-66-6	ZINC