# Conducting Ecological Risk Assessments



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# Acronyms Used in this Directive

| | |
|---|---|
| AUF | Area Use Factor |
| bgs | Below Ground Surface |
| COC | Contaminant of Concern |
| COI | Contaminant of Interest |
| COPC | Contaminant of Potential Concern |
| cm | Centimeters |
| CSM | Conceptual Site Model |
| DEQ | Oregon Department of Environmental Quality |
| EC | Effective Concentration |
| EPC | Exposure Point Concentration |
| ERA | Ecological Risk Assessment |
| HI | Hazard Index |
| HQ | Hazard quotient |
| IMD | Internal Management Directive |
| ISM | Incremental Sampling Methodology |
| LC50 | Median Lethal Concentration |
| LD50 | Median Lethal Dose |
| LOAEL | Lowest Observed Effect Level |
| LOF | Locality of Facility |
| MDL | Method Detection Limit |
| NOAEL | No Observed Effect Level |
| RBC | Risk-Based Concentration |
| RME | Reasonable Maximum Exposure |
| T&E | Threatened and Endangered |
| TRV | Toxicity Reference Value |
| UCL | Upper Confidence Limit |
| UPL | Upper Prediction Limit |
| EPA | US Environmental Protection Agency |

# 1. Introduction

## 1.1 Purpose

This Internal Management Directive (IMD) provides the process framework and methods Oregon Department of Environmental Quality staff should use for ecological risk assessments (ERAs) at cleanup sites in Oregon. ERAs are required elements of remedial investigations conducted to characterize the nature and extent of hazardous substances at a site and determine the need for remedy. The process and methods presented in this IMD are based primarily on concepts and approaches in U.S. Environmental Protection Agency ERA guidance (EPA, 1997 and 1989) and are consistent with Oregon Revised Statute[i] and Oregon Administrative Rule[ii]. The goal of this IMD is to 1) provide a process to help determine if an ERA is necessary at a specific site, and 2) for those sites requiring an ERA, provide recommended approaches and methods to evaluate risk and determine the need for remedial action.

This IMD document replaces the prior *Guidance for Ecological Risk Assessment* (DEQ, 2001). Development of this IMD was necessary to 1) correct errors in the 2001 guidance, 2) incorporate new science and technologies, 3) provide a means for identifying sites that warrant ERAs and those that do not, and 4) provide clear and transparent expectations for conducting ERAs consistent with Oregon statute and rule.

This IMD is intended to be useful for the majority of small to medium sites of low to medium complexity. For highly complex sites, ERAs need to be site-specific and ERA methods should be developed in coordination with project managers and toxicologists before conducting work. This IMD may be updated to address additional ERA elements, including new science and technologies.

Prior to undertaking an ERA, practitioners should be familiar with the terms, concepts, and approaches in applicable EPA and other ERA guidance (Suter et al., 2000; EPA, 1997, 1989). Familiarity with State of Oregon regulations governing cleanup projects[iii] is also preferred. This IMD should be used in conjunction with *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (DEQ, 2007) and any new amendments and the *Decision Unit Characterization* IMD (DEQ, 2020).

## 1.2 Process

The ERA process involves the general steps discussed below, and is depicted in Figure 1. The two major components of the process are the Scoping and the Risk Assessment, with the level of effort scaled to site complexity.

### 1.2.1 Scoping

Scoping includes gathering basic site information, identification of potentially complete exposure pathways, and estimation of the area of potential contact between ecological receptors and hazardous substances (i.e., the Locality of the Facility [LOF][iv]). The results of this analysis determines if a risk assessment is necessary. An ERA may not be necessary if the scoping phase

demonstrates that exceedance of acceptable risk levels is unlikely [v]. The Scoping process is described in further detail in Section 2.

### 1.2.2 Risk Assessment

DEQ follows the standard EPA ERA process within three risk assessment options called Tiers presented in this IMD. These options make it easier to select the appropriate level of effort for the risk assessment by outlining methods consistent with scale and complexity of the site. The Tiers range from simple comparisons with default risk based concentrations (RBCs) to complex evaluations incorporating site-specific exposures and effects. The three Tiers are summarized below with full descriptions provided in Section 3.

**Tier I – Generic Screening Level Risk Assessment**:
The simplest risk assessment involves comparing site concentrations to the default ecological RBCs developed by DEQ.

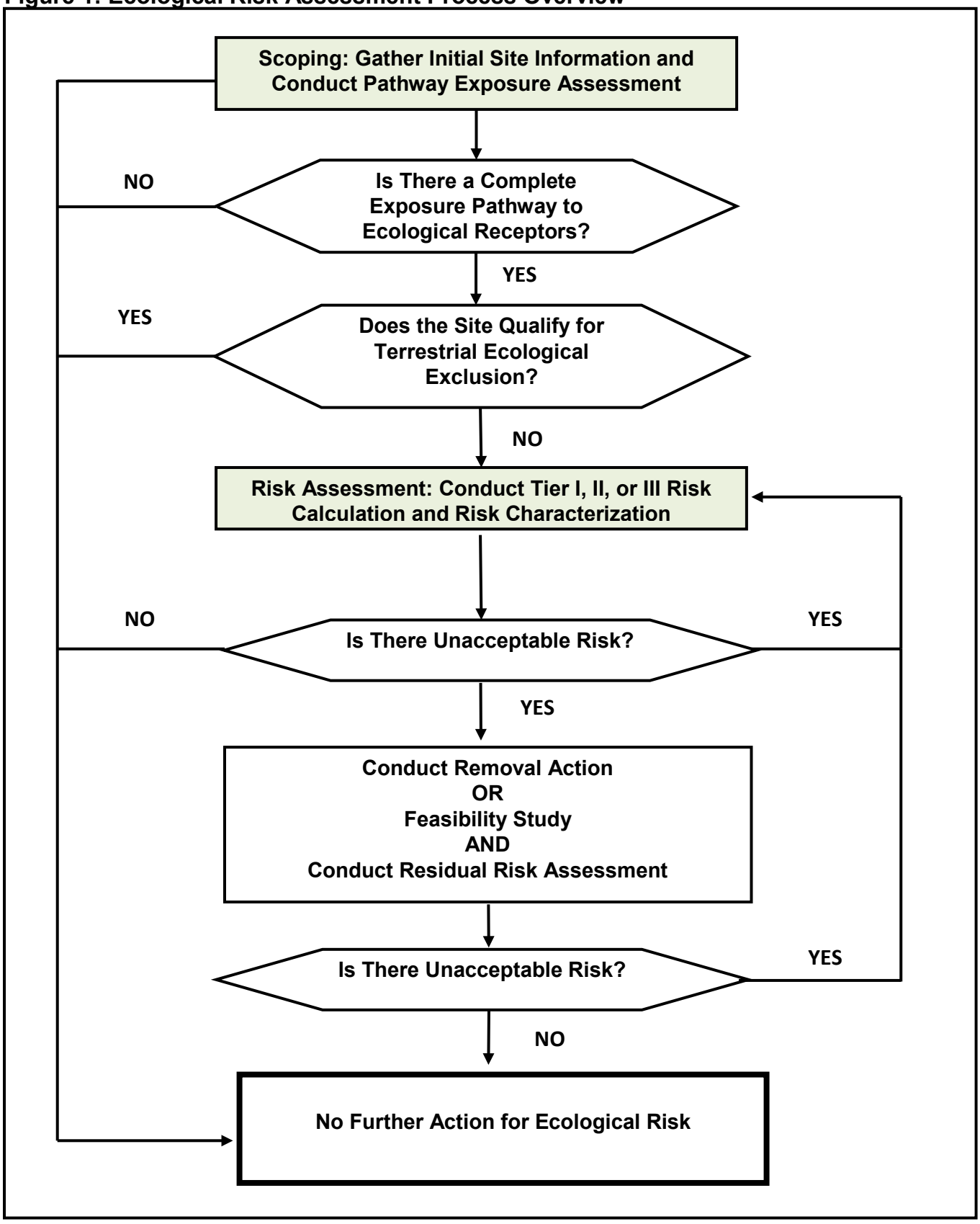
**Tier II – Refined Screening Level Risk Assessment**:
The refined risk assessment relies on the standard assessment framework of comparing site concentrations to RBCs, but allows for site-specific adjustments, such as receptor-specific home range or uptake parameters.

**Tier III – Advanced Risk Assessment**:
The advanced risk assessment goes beyond the standard screening framework, and determines effects site-specifically using biological surveys, toxicity testing, or body burden analysis. These assessments may also include alternative methods for evaluating exposure, including probabilistic approaches to estimate the likelihood of unacceptable risk.

The risk assessment Tiers do not need to be conducted sequentially, and can be selected to match the level of effort appropriate to assess ecological exposure at specific sites. However, it is generally worthwhile to conduct Tier I or Tier II screening before deciding to conduct a more complex Tier III ERA.

An important part of a complete risk assessment, regardless of Tier, is the risk characterization element. Risk characterization uses a lines of evidence approach to weigh the nature, magnitude, spatial extent, and uncertainty to determine the likelihood of adverse effects. Risk characterization methods are described in Section 3.5.

**Figure 1: Ecological Risk Assessment Process Overview**

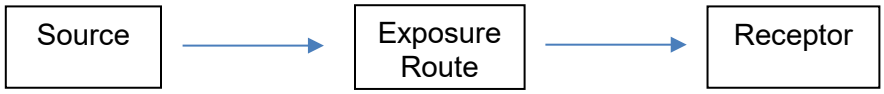


# 2. Scoping

The scoping evaluation assembles basic site information to describe ecological features and species present, and evaluates the potential for complete exposure pathways between receptors and site-related contaminants. Detailed instructions for conducting site scoping are provided in Appendix A, including recommended submittals and documentation. Basic site information that is typically generated as part of the remedial investigation (or equivalent)[vi] should be assembled to determine whether or not ecological receptors could be exposed to site-related contaminants. For very simple sites where ecological exposure is not expected, such as in highly urbanized areas, a checklist of basic information may be used to determine if complete exposure pathways are present (Appendix A1). For all other sites an exposure pathway assessment consistent with direction provided in Appendix A2 should be conducted.

## 2.1 Exposure Pathway Assessment

An exposure pathway assessment evaluates whether ecological exposure to hazardous substances may occur within the Locality of Facility (LOF). Complete exposure requires a contaminant source, an exposure route or pathway, such as dermal contact or ingestion, and a receptor.




In order to determine if complete exposure pathways are present, information on site characteristics is needed to inform the assessment. This includes:

- A description of current and historical site use
- Contaminants of interest (COIs) known or suspected to be present
- Current and future land use and zoning
- Surface features and transport pathways, such as pavement, storm water catch basins, outfalls
- Habitat type present on or adjacent to the site

Attachment A1 is a checklist of basic information needed to inform the exposure pathway assessment. The checklist includes aerial and topographic maps, and a description of site conditions that includes the presence of impermeable surfaces (pavement, structures), terrestrial open habitats (bare soil, grasses, shrubs), forests and woodlands, and sensitive environments such as wetlands, riparian zones, and open water (e.g. ponds, lakes, rivers, estuaries). The information provided in the basic information checklist, along with any information collected during site-visits, is used to complete the exposure pathway assessment in Appendix A2.

The results of the exposure pathway assessment are documented in a scoping report (Appendix A2, Attachment 3). These results are used to either 1) document the absence of complete exposure pathways, or 2) identify potentially complete pathways where further evaluation is needed. In cases where exposure pathways are incomplete, no further action is necessary. For simple sites, such as those in urban environments with a high degree of impervious cover

(pavement, buildings), the completion of the basic site information checklist may be sufficient to demonstrate the absence of complete pathways. If complete exposure pathways are identified, further evaluation is needed to determine if a site-exclusion is appropriate or if a risk assessment is necessary. The evaluation process for ERA exclusions and associated documentation are described below. If complete exposure pathways are identified and exclusionary criteria are not met, a risk assessment is required.

## 2.2 Exclusion

There are circumstances under which exposure pathways are potentially complete, but unacceptable ecological risk is unlikely. DEQ's intent is to provide an off-ramp from the ERA process by excluding those sites with LOFs that contain small, isolated exposure areas (e.g., such as those that may occur within highly urbanized areas) where the *de minimis* size of the site results in a low potential for meaningful exposure. Exclusions are not intended to apply to 1) aquatic and sensitive environments[1] (due to the complexity of these environments), 2) areas where threatened or endangered (T&E) species are likely to be present, and 3) areas where high concentrations of contaminants are known or suspected to be present that could represent acute toxicity or an ongoing source to other environments.

In order to qualify for a size exclusion the area must meet the following criteria:

- There is less than 0.5 acre of exposure area[2] in the LOF and the area adjacent (contiguous) to the LOF does not contain a terrestrial exposure area greater than 0.5 acre[3]. The combination of the exposure area in the LOF and any area immediately adjacent should be 1 acre or less.

- T&E species and their critical habitat are not present within a ¼ mile radius from the LOF boundary. This includes sensitive or high value environments where hazardous substances could pose a greater threat such as locations where T&E species are known or expected to be present, areas with local zoning intended to protect natural resources, wildlife refuges, wetlands, riparian zones, habitat for culturally important species, or aquatic environments.

Documentation should include the completion of the exposure pathway assessment as described in Appendix A2

[1] Sensitive environment is defined in Oregon rule and means an area of particular environmental value, such as riparian or wetland habitat, where a hazardous substance could pose a greater threat than in other non-sensitive areas. The complete definition is provided in OAR 340-122-0045.
[2] The *de minimis* exposure area considers the size of an exposure area needed to support wildlife receptors if habitat fragmentation within urban environments is present based on the average home range of the breeding female vagrant shrew (*Sorex vagrans*) (Hawes, 1977).
[3] The presence of additional exposure area adjacent to the contaminated area increases the probability of ecological exposure to the LOF.

If the terrestrial exposure area is determined to be *de minimis* based on the information above, no further evaluation of terrestrial risk is likely to be necessary. However, while the exclusionary criteria are intended to apply to most sites and conditions, there may be cases where additional ERA is necessary to ensure site conditions are protective of ecological receptors.[vii]

# 3. Risk Assessment

A risk assessment is conducted to determine the probability of adverse effects resulting from ecological exposure to hazardous substances within the LOF. The complexity of the risk assessment may be scaled to the site; however the technical underpinnings of the assessment are comprised of the same basic elements:

1 **Problem Formulation**, consisting of a **conceptual site model** (CSM) describing complete exposure pathways and identifying **assessment endpoints**
2 **Exposure Analysis** that includes the development of **exposure point concentrations** that represent likely exposure to selected assessment endpoints;
3 Selection of risk-based concentrations **(RBCs)** protective of assessment endpoints
4 **Risk Calculations** that involve either a screening-type evaluation where EPCs are compared with RBCs (Tier I – Generic and Tier II - Refined), or utilize additional measurement endpoints (Tier III - Advanced)
5 **Risk Characterization** consisting of evaluating the information developed in the previous elements using a lines-of-evidence approach to judge the **likelihood and ecological significance** of the risk and support a **risk determination**

DEQ identified three different types (called Tiers) of risk assessments that can be conducted and represent different levels of effort related to the complexity of site. Tiers are briefly described below.

**Tier I – Generic Screening Level Risk Assessment**:
A Tier I ERA is the simplest type of risk assessment and involves comparing site concentrations to default ecological RBCs developed by DEQ. The only site-specific element associated with Tier I ERAs is development of the exposure point concentration (EPC).

**Tier II – Refined Screening Level Risk Assessment**:
A Tier II ERA relies on the standard assessment framework of comparing exposure concentrations (EPCs) to RBCs, but allows for adjustments to RBCs to account for site-specific conditions or receptors.

**Tier III – Advanced Risk Assessment**:
Advanced risk assessments use additional measurement endpoints within the exposure or effects assessment. Examples include biological surveys, toxicity testing, body burden analysis, and probabilistic estimates.

The type and degree of supporting documentation recommended for each Tier differs. For each risk assessment element described in the sections below, a text box summarizes the type of information expected for each Tier to properly document risk assessment conclusions.

# 3.1 Problem Formulation

Problem formulation further evaluates complete exposure pathways identified during Scoping, identifies assessment endpoints associated with specific media and pathways, and culminates in a conceptual site model summarizing these relationships.

### 3.1.1 Assessment Endpoints

Assessment endpoints are 1) explicit expressions of a specific ecological receptor and an associated function or quality that is to be maintained or protected (what is the subject of protection, for example local populations of avian ground insectivores), and 2) the characteristic or level of protection (effect level, for example survival, growth and reproduction). Assessment endpoints are often developed from regulatory management goals. According to Oregon statute, the goal is to maintain the health and viability of populations of plants and animals exposed in the (LOF)[viii]. For populations of species listed as threatened and endangered, the goal is to protect each individual plant or animal. Every individual of non-listed species do not need to be protected, as long as the set of individuals (i.e., the local population) is not adversely affected.

It is difficult to evaluate the risk to all populations of species that may be present at Oregon cleanup sites. Therefore, it is common to identify receptor groups, or guilds, that use similar food types and environmental media, are physiologically similar, and share the same biological classification. For example, while different species of ground feeding mammals may be found across different habitat types (e.g. shrew, moles, voles, rodents) exposure parameters such as soil and prey ingestion are similar within this guild (EPA, 2003). These are termed default (or generic) assessment endpoints because they are selected to represent broad groups of plants and animals rather than one individual species[ix]. Exposure parameters and toxicity information that are representative of these guilds are used to generate default RBCs (Section 3.3)

In addition to the default assessment endpoints, it may be appropriate to add site-specific assessment endpoints that are not adequately covered by general feeding groups. Examples of a specific group relevant at a site might include shorebirds, amphibians, or reptiles. Site-specific assessment endpoints should not consider domestic or once-domesticated animals (e.g., pets, livestock, or feral animals) or any plant or animal whose existence is maintained by continuous human intervention (e.g., plants grown as agricultural crops).

Assessment endpoints for threatened and endangered species should include the specific species of concern and biological endpoint for protection of individuals. An example of assessment endpoints for specific threatened endangered species is:

- Protection of survival, growth and reproduction of the Streaked horned lark, Columbian white-tailed deer, or Lower Columbia River Coho Salmon.

For non-T&E species, the same biological endpoints such as survival, reproduction and growth are used to estimate the potential for effects on populations of plants and animals. A Tier III risk assessment may propose additional endpoints to evaluate site-specific effects. DEQ's default assessment endpoints for non-T&E species are listed below:

*Aquatic Species and Aquatic-Dependent Wildlife*

- Survival, growth and reproduction of aquatic species exposed to sediment, pore water and surface water. The group of aquatic species may include plants, benthic invertebrates, amphibians and reptiles, and fish and shellfish.
- Survival, growth and reproduction of local populations of aquatic-dependent wildlife exposed to sediment and surface water and feeding on aquatic biota.

*Terrestrial Species*

DEQ selected default assessment endpoints representative of four guilds of terrestrial wildlife that get a significant portion of their diet or physiological needs from soil, as follows:

- Survival, growth and reproduction of local populations of plants exposed to soil.
- Survival, growth and reproduction of local populations of soil invertebrates exposed to soil.
- Survival, growth and reproduction of local populations of avian ground insectivores, herbivores, and carnivores exposed via ingestion of prey and incidental ingestion of soil.
- Survival, growth and reproduction of local populations of mammalian ground insectivores, herbivores, and carnivores exposed via ingestion of prey and incidental ingestion of soil.

For Tier I ERAs, the assessment endpoint portion of the ERA will indicate that DEQ default assessment endpoints are selected, in addition to any threatened and endangered species known or suspected to be present.

For Tier II and III ERAs, any additional site-specific assessment endpoints should be identified. A site visit should be conducted, the scope of which should reflect the complexity of the site. It is likely that a habitat survey and discussions with DEQ will be needed to identify assessment endpoints.

### 3.1.2 Conceptual Site Model

Assessment endpoints associated with the complete exposure pathways should be summarized in a conceptual site model similar to the example provided below. The CSM can be a table or a visual representation of these relationships. If bioaccumulative chemicals are COIs, exposure pathways should consider accumulation in tissue and prey items. Oregon's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (DEQ, 2007) should be consulted for additional detail. Example of a portion of a CSM table:

| Contaminated Media | Exposure Route | Receptor | Assessment Endpoint |
|---|---|---|---|
| Soil | Ingestion | Ground feeding mammals ground (shrew) | Survival and reproduction of local populations of ground feeding mammals exposed via incidental ingestion of soil and prey items. |

For Tier I ERAs, the CSM need only identify any threatened and endangered species present, and the default assessment endpoints associated with complete pathways identified during scoping.

For a Tier II or III ERAs, the CSM should be expanded to include a site-specific list of media, exposure routes, receptors, and assessment endpoints.

# 3.2 Exposure Analysis

An exposure analysis is conducted to estimate the current and potential future environmental exposure of each ecological receptor. An exposure analysis includes 1) an estimate or measure of the environmental concentration (EPC) to which the organism is exposed, and 2) the exposure factors used to estimate the rates of ingestion of media such as soil, water, and food. Taken together, these two components of exposure analysis represent an upper bound or high end exposure[x], or a reasonable maximum exposure (RME). Considerations for the development of the environmental exposure point concentrations (EPCs) are discussed below, while exposure factors representative of default assessment endpoints are discussed in the context of RBC development in Section 3.3 and Appendix B.

### 3.2.1 Background Evaluation

Common inorganic COIs such as arsenic and lead may be naturally present at a cleanup site. To distinguish anthropogenic sources of inorganic COIs from natural ones, concentrations that represent background need to be determined before exposure to site-related contamination are evaluated. Several approaches can be used to assess background concentrations of COIs. Assuming adequate site characterization, the simplest background evaluation involves comparing the maximum detected concentration to DEQ's upper prediction limits (UPLs) provided in *Development of Oregon Background Metals Concentrations in Soil*, 2013. A UPL represents an upper limit of a population of discrete concentrations that fall within the background sample population. Therefore, if any discrete sample concentration from the site is greater than this limit, site concentrations are determined to be greater than the background level (EPA, 2015a). Background and site data comparisons should be made using the same sample type (e.g. discrete, composite, ISM). For example, mean concentrations from incremental samples at a site should be compared with ISM mean concentrations from background areas. The background areas should be similar in geology to the site, sampling protocols should be similar to those used to characterize site conditions (e.g., depth, particle size, number of increments), and would ideally include ISM results from three different background areas (EPA, 2015a). Alternative approaches may be acceptable, and should be developed in coordination with DEQ.

If the concentration of a COI at a site is determined to be below background levels, the results of evaluation should be documented in the deliverable. Note that background screening is intended for naturally-occurring substances only[xi], and does not apply to organic chemicals during the risk assessment phase of a remedial investigation/feasibility study. However, the determination of "ambient" concentrations of organic chemicals within the area surrounding the site, but not

impacted by site releases, can be helpful in the feasibility study stage to support remedial action selection. An evaluation of ambient concentrations is site specific and should be done in conjunction with DEQ.

### 3.2.2 EPC Data Requirements

One of the most important aspects of risk assessment is to ensure that the site is adequately characterized and that an EPC can be estimated with a high level of confidence. Minimum recommended data requirements to generate EPCs are listed below.

**Data Requirements**
Analytical data used in ecological risk assessment should, at a minimum:

- Include all site contaminants of interest (COIs) known or suspected to be present.
- Have method detection limits below DEQ RBCs, or be the lowest reasonably achievable detection limit.
- Adequately characterize decision units.

Please see the **Decision Unit Characterization IMD** for DEQ-recommended approaches and methods.

It is DEQ's intent to facilitate efficient, well-supported decision making by minimizing errors and uncertainties in the estimates of EPCs. In order to achieve this goal, DEQ recommends using incremental sample methodology to characterize contaminant levels in decision units[4]. ISM minimizes sampling and statistical errors inherent in the use of limited discrete data to estimate an EPC based on a 90$^{th}$ percentile upper confidence level on the arithmetic mean. Variability in concentrations detected at discrete sample locations can result in a high or low bias in the calculated EPC, confounding the risk assessment process by inappropriately screening in or out site COIs, i.e., screening in COIs that should not be identified as chemicals of potential concern (false positives), or screening out COIs that do contribute to unacceptable risk (false negatives). Both types of errors lead to incorrect decisions and/or time consuming risk assessment iterations. Therefore, DEQ strongly encourages robust characterization early in the process to support all risk assessment tiers. Please see the *Decision Unit Characterization* IMD for additional discussion on DEQ-recommended approaches and methods to developing EPCs.

### 3.2.3 EPC Calculation Methods

EPCs are developed to represent exposure of individuals (T&E species) or local populations[5] of plants and animals that reside within, or are exposed to, a portion of the LOF[xii]. The LOF is defined as the environmental extent of where site-related contamination has come to be located,

[4] Decision units (DUs) are the defined volume (area and depth) of sample media (such as soil) where a contaminant can be sampled and represented by a mean and for which a decision is to be made (see DEQ's Decision Unit Characterization IMD for additional information).
[5] Local populations share the LOF as a common environment, and have the potential to interbreed within this area (Hanski & Simberloff, 1997; Mayr, 1970; Wells & Richmond, 1995).

or may migrate to in the future. EPCs are developed for each decision unit, i.e., an exposure area over which a decision regarding ecological risk is made for each assessment endpoint. EPCs are plausible upper-bound or high-end estimates of exposure[xiii] and may be represented by discrete sample results, a 90$^{th}$ percentile upper confidence limit on the arithmetic mean, or measurements using rigorously collected incremental samples. EPCs are generated for each COI and decision unit.

The use of point-by-point exposure evaluation methods are typically used in the evaluation of sediment and water where exposure to receptors such as benthos is discrete, but may also be used to evaluate terrestrial exposure areas. In these cases, the use of many decision units (i.e., discrete points) for risk evaluation is intended to either 1) demonstrate that there are no exceedances of ecological RBCs by comparing a maximum detected concentration to the lowest applicable ecological RBC, or 2) identify RBC exceedances on a point basis in lieu of refined exposure analysis. The use of point-by-point methods are contingent on the assumption that enough samples have been taken to represent an upper bound exposure over the range of concentrations that may be present, including high concentration source areas.

For Tier I, II, or III terrestrial ERAs, the ERA should identify whether EPCs are based on a point-by-point evaluation, 90$^{th}$ percentile on the arithmetic mean, or ISM results. For aquatic sites, the default screening is typically point-by-point unless a site-specific EPC is developed in coordination with DEQ.

For each exposure pathway, the available site data should be evaluated to determine if it is adequate to develop EPCs for the pathways and receptors identified in the CSM, or if additional data collection is necessary (see Section 3.2.2). Conditions that affect exposure, such as source area delineation, contaminant distribution, receptor home ranges, changes in habitat type, and physical barriers are important when selecting representative data for calculations. See Section 3.2.4 for further discussion on exposure assumptions.

### 3.2.4 Exposure Depth and Spatial Scale

Spatial scale assumptions for use in developing EPCs for terrestrial and aquatic assessment endpoints are provided as follows.

### *Terrestrial Exposure*

#### *Spatial Scale Assumptions*

If T&E species and sensitive environments are absent, DEQ's default exposure area (decision unit) for the protection of local populations of ecological receptors is the *de minimis* area of 0.5 acres, representing the smallest home range of interest for wildlife guilds (see Section 2.2). The LOF should be divided into 0.5 acre decision units and characterized according to Section 3.0 of the *Decision Unit Characterization IMD*. Incremental sampling methodology is strongly recommended. If ISM samples are collected, this DU size will also be used to evaluate immobile plants and invertebrates due to the rigorous spatial coverage of these samples. Plants and invertebrates carry out important ecosystem services such as biological production and nutrient cycling, and also represent a food source for wildlife. If incremental methods are not used, exposure for immobile receptors should be evaluated on a point by point basis.

> For Tier I terrestrial ERAs the exposure area default is 0.5 acres. Risk determinations will be based on each 0.5 acre decision unit for all guilds.
>
> Tier II terrestrial ERAs assume all exposure occurs within the LOF (AUF = 1). Plant and invertebrate exposure areas remain at 0.5 acres (ISM), but EPCs for mobile receptors may be calculated over an area up to 5 acres. If the home range is larger than the LOF for predator species, an AUF may be applied. Exposure assumptions should be developed in coordination with DEQ.
>
> Tier III terrestrial ERAs may use alternative methods for estimating exposure such as habitat weighting or probabilistic methods and should be developed in coordination with DEQ.

In a Tier I risk assessment, the LOF is divided into 0.5 acre decision units for characterization, EPC calculation, and comparison to RBCs for a risk determination. As the size of an exposure area increases, it may be applicable to combine 0.5 acre decision units to calculate mean exposure for mobile wildlife ecological receptors within a Tier II evaluation. Tier II assessments should be conducted in conjunction with DEQ through a work plan.

For Tier II risk assessments, DEQ considers LOF of 5 acres as an upper bound to define local populations of ground feeding species. If the LOF is larger than 5 acres, several local populations may exist, and separate exposure areas should be considered. For top predator birds and mammals with home ranges larger than 5 acres, the EPCs may be adjusted with area use factors (AUF) to account for LOFs that are smaller than total exposure. If the home range is entirely within the LOF, as is the case with small home range species, the AUF will equal 1.0. When the home range exceeds the LOF, the AUF is calculated as the ratio of the contaminated area to the home range and will have a value less than 1.0. Recommended exposure assumptions are summarized below:

- LOF < 0.5 acres: If the exposure area within the LOF is not adjacent to or is itself a sensitive environment, and T&E species are not present, this area is considered *de minimis*. Known or suspected significant source areas or hot spots should be absent.

- LOF ≥ 0.5 acres up to 5 acres: Plants and invertebrates should be assessed in 0.5 acre units (ISM only). The size of the LOF is within the foraging range for ground feeding birds and mammals and therefore home range adjustments are unnecessary. For large home range receptors such as carnivorous birds and mammals the LOF may be smaller than the foraging range and exposure estimates from the LOF may be adjusted using an AUF.
- LOF ≥ 5 acres: If the LOF is greater than or equal to 5 acres, the exposure area is larger than the foraging range for local populations of ground feeding birds and mammals. Therefore, DEQ recommends breaking up the exposure areas into separate units. For large home range receptors such as carnivorous birds and mammals, the size of the LOF is consistent with an applicable home range and an AUF may be unnecessary.

If site-specific assessment endpoints are identified that are not represented by DEQ's default assessment endpoints, e.g., survival, growth, and reproduction of shorebirds (see Section 3.1.1), home range information should be presented in a work plan. Sources of home range information include EPA's Wildlife Exposure Factor Handbook (EPA, 1993), or Oregon-specific resources such as Oregon State University's Oregon Explorer Database (https://oregonexplorer.info/topics/Animals-and-Plants), the Atlas of Oregon Wildlife (Csuti *et al*., 2001), and Land Mammals of Oregon (Verts & Carraway, 1998).

***Depth***

The default soil exposure depth considered for ERAs in Oregon is generally 0 to 3 feet below ground surface (bgs) in order to characterize the range of potential soil exposures for a variety of receptors. This default range includes surface soil exposure to which most species are exposed, and deeper depths most applicable to burrowing mammals (shrew, moles and voles), birds (owls, swallows), plant species, and reptiles. However, if site-specific observations indicate burrows deeper than 3 feet bgs, a deeper exposure depth should be used.

The soil sampling approach should consider characterizing variability in concentrations within the depth of exposure (i.e., typically 0 to 3 feet bgs). The site CSM and mechanism of release can be used to guide vertical soil sampling, identify the contaminated soil horizon, and generate representative EPCs. For example, if site data indicate that site contamination does not penetrate the soil horizon below a depth of 12 inches, then data collected from 0 to 12 inches bgs may be used to estimate EPCs. Alternatively, if the contamination is the result of a subsurface release, for example at 2 feet bgs, this deeper horizon should be included in EPC calculations.

Generally speaking, surface soil characterization should always be prioritized (e.g. the top 6 inches to 1 foot), due to the significant exposure to this interval to a large number of ecological receptors. Depth averaged soil concentrations, or vertical composites, which extend over large depth intervals (e.g. 0 to 3 feet bgs) may dilute surface concentrations and underestimate risk.

### *Aquatic Exposure*

Aquatic receptors include immobile receptors, fish, and aquatic-dependent wildlife such as birds and mammals that dwell partly or entirely in bodies of water. These species are exposed to a complex mix of surface water, sediment, pore water, and sometimes contaminated prey; therefore, exposure assumptions should be developed on a site-specific basis in coordination with DEQ.

For sediment and porewater, the vertical extent of exposure should represent the zone where the largest abundance and biomass is located, typically referred to as the biological active zone. The biological active zone in sediment varies with habitat type, bottom substrate, and sediment transport and mixing characteristics. Therefore, site-specific delineation of the depth of this zone is preferred. In absence of site-specific data, habitat type can be used to estimate appropriate depths. EPA, developed the following guide using information on organism abundance (EPA, 2015b):

- Lentic (still, fresh water) - 0 to 15 centimeters (cm)
- Lotic (rapidly moving fresh water)
    - Coarse sand without fines (<20 percent by weight) - 0 to 35 cm
    - Coarse sand with substantial fines (≥20 percent by weight) - 0 to 15 cm; consider sampling to 35 cm to represent seasonal variability
- Estuarine and Tidal freshwater environments - 0 to 15 cm
- Marine:
    - Mud (silt plus clay) - 0 to 15 cm
    - Mixed (mud or sandy mud)) - 0 to 10 cm
    - Sand - 0 to 5 cm; consider sampling deeper to represent seasonal variability

**All aquatic ERAs fall into Tier II or III ERA categories.**
Exposure assumptions associated with site-specific assessment endpoints should be developed in coordination with DEQ.

Given the above information, characterization of a 0 to 15 cm exposure depth should be considered in most cases. However, careful consideration should be given to seasonal or diurnal sediment movement and resulting temporal variability in concentrations representative of exposure. For example, if the top 15 cm of sediment erodes seasonally, exposing subsurface sediment, both the top 15 cm and the underlying sediment should be characterized. Similarly, groundwater discharge and recharge and how these conditions affect aquatic exposure, should be understood before conducting sampling so that samples representative of ecological exposure are collected.

## 3.3 Risk-Based Concentrations

The likelihood for ecological adverse effects resulting from exposure to contaminants (represented by EPCs, as described in the previous section) is typically evaluated using RBCs. RBCs are receptor- and media-specific concentrations that represent acceptable risk to plants, invertebrates, fish, birds and mammals within terrestrial and aquatic environments. RBCs are generated using toxicity reference values (TRVs) and reasonable maximum estimates of exposure factors for representative receptors within a feeding guild. RBCs represent chemical concentrations protective of the assessment endpoints described in Section 3.1. Soil and water RBCs are provided in Tables 1 and 2, respectively, and Appendices B (soil) and C (water) describe the selection and generation of the RBCs. In addition to the RBCs compiled in these

appendices for DEQ's default assessment endpoints, RBCs for the protection of burrowing mammals from chemicals in air (vapor phase), and sediment RBCs for the protection of aerial avian and mammalian insectivores are available from LANL, 2017. Sediment RBCs were not updated as part of this IMD, and therefore sediment screening levels from DEQ's Ecological Risk Assessment Guidance (ODEQ, 2001) are provided in Table 3. If bioaccumulative chemicals are present in sediment, RBCs[6] from Oregon's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (DEQ, 2007) should be used to evaluate fish, shellfish, and piscivorous wildlife.

RBCs for T&E and non-T&E species correspond to the assessment endpoints and primary routes of exposure that occur at most cleanup sites in Oregon. Generally, these are considered protective of additional species where the scientific literature are insufficient to develop RBCs, such as for amphibians and reptiles. The RBCs used by DEQ are "no observed effect" levels for T&E species (NOAELs) and "lowest observed effect" levels (LOAELs) for non-T&E species.

Oregon Statute establishes the acceptable risk level for ecological exposures to hazardous substances for T&E and non-T&E species:

*For protection of ecological receptors, if a release of hazardous substances causes or is reasonably likely to cause significant adverse impacts to the health or viability of a species listed as threatened or endangered pursuant to 16 U.S.C. 1531 et seq. or ORS 496.172, or a population of plants or animals in the locality of the facility, the acceptable risk level shall be the point before such significant adverse impacts occur.*

Oregon Administrative Rule interprets this statute to mean that the acceptable risk level for ecological receptors are protected at a **population level** (low effect levels to some individuals within a species), except for threatened and endangered species that are protected at an **individual level** (no effect levels to all individuals within a species). The rule goes on to say that risk is acceptable for populations of non-T&E receptors if there is only a small chance (10 percent or less) that more than 20 percent of individuals within the local population are exposed to an EPC above the median lethal dose or concentration (LD50 or LC50), considering health and viability. A Tier III risk calculation may be conducted to assess the probability of exposure described in the rule using distributions of site concentrations consistent with Oregon rule. In addition, DEQ has determined that it is functionally equivalent to conduct a Tier I or II risk calculation, involving a simpler comparison of reasonable maximum exposures, i.e., EPCs, with LOAEL-based RBCs.

Toxicity information used to generate RBCs has undergone rigorous evaluation by EPA and/or DEQ, and represents the best available science at the time of development. DEQ intends to use this information unless new science or site-specific toxicity information is available; DEQ rarely allows use of alternate toxicity values, particularly for wildlife. The Los Alamos National Laboratory ECORISK Database and EPA's ECOTOX databases provide ongoing updates to toxicity information, and should be incorporated into DEQ RBCs as they become available.

[6] RBCs are termed screening level values (SLVs) in the *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment*

These sources should be consulted when evaluating additional site-specific pathways or hazardous substances for which DEQ has not developed RBCs.

For Tier I Terrestrial ERAs, default RBCs provided in Table 1 are selected.

For Tier II or III ERAs, default or refined RBCs may be used for each assessment endpoint relevant to the site. If RBCs are refined, parameters modified to reflect site-specific conditions or receptors should be presented, along with documentation to support the refinement. Tier III ERAs may also evaluate effects using site-specific toxicity testing as compared to literature values.

Exposure assumptions used to generate wildlife RBCs have also undergone rigorous evaluation by EPA and/or DEQ for default receptor guilds. If additional or other assessment endpoints are evaluated, site- or receptor-specific RBCs may be developed using refined exposure assumptions. Refinements may include replacing default with site-specific exposure uptake parameters and recalculating RBCs for use in Tier II risk estimates. Examples of site-specific exposure parameters are site-specific biota-sediment accumulation factors or bioaccumulation factors, organic carbon, pH, hardness, or prey consumption rates. Additional information on how to develop site-specific RBCs is provided in Appendix B. Any modifications to default RBCs should be conducted in coordination with DEQ.

# 3.4 Risk Calculation

In Tier I and II assessments, the risk calculation involves a screening-type evaluation where site-specific exposures (EPCs) are compared with default or refined RBCs in a deterministic assessment to calculate a risk ratio or quotient. In Tier III assessments, probabilistic methods may be used to calculate risk from estimates of exposure and effects, or additional measurement endpoints may be used such as site-specific toxicity testing. Risk calculation methods are described below.

## 3.4.1 Tier I and II Risk Calculation

Tier I and II risk calculations compare EPCs with RBCs to identify chemicals that have the potential to cause unacceptable risk, i.e., chemicals of potential concern (COPCs). The risk calculations must consider risk from exposure to: (a) individual COIs within each complete pathway exposure medium (e.g. soil), (b) multiple COIs occurring simultaneously within one exposure medium (e.g. multiple metals in soil), and (c) both individual and multiple COIs occurring within one or more exposure media (e.g. metals in soil and surface water). To address cumulative risk, a hazard index (HI) is calculated by "totaling" the hazard quotients (HQs) for each receptor and media associated with each complete pathway. A COI must be retained as a COPC if the EPC exceeds the RBC (i.e., the HIs greater than or equal to 1.0) for an individual COI[7]. In addition, if the HI ≥ 1.0 for cumulative risk identified for an assessment endpoint, COIs

[7] DEQ has clarified the definition of chemical substances to include chemical classes such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls, chlorinated dibenzo-p-dioxins and chlorinated dibenzofurans, chlordanes, and endosulfans. These chemical classes should be evaluated as a single

with hazard quotients greater than or equal to 0.10 are retained as cumulative COPCs. Calculation details for individual and multiple chemicals are provided below.

#### 3.4.1.1 Individual Chemical Calculation

To identify individual COPCs in a given exposure medium, the EPC of each COI is compared to the relevant RBC.

$$\text{Hazard quotient (HQ)} = \frac{\text{EPC}}{\text{RBC}}$$

Where:

**Hazard quotient (HQ)** = the ratio of the EPC to the RBC for each hazardous substance and pathway.
**EPC** = Exposure point concentration of a given COI in soil, sediment or water
**RBC** = Risk-based concentration for the COI, receptor class, and media

Chemicals for which the HQ is greater than or equal to 1.0 for a receptor class and pathway are individual COPCs. Note: individual chemical screening comparisons are rounded to one place past the decimal point (e.g. an HQ of 0.98 rounds to 1.0 and screens in; an HQ of 0.91 rounds to 0.9, and screens out).

Site-specific COIs not detected in a media of concern should be screened against their corresponding method detection limits (MDLs) to evaluate whether the MDLs are below RBCs. COIs with MDLs above RBCs should be retained as COPCs and their potential ecological impacts should be identified as data gaps.

Site-specific COIs for which RBCs are not available should be retained in a separate category of COPCs for the purposes of performing an evaluation of uncertainty. Contaminants of interest that fall into this category may require a literature search for the identification of additional toxicity information or RBCs in order to reduce this uncertainty. Additionally, these COPCs may be evaluated further through toxicity or bioaccumulation testing.

#### 3.4.1.2 Cumulative Risk Calculation

In order to evaluate total exposure, the cumulative risk posed by the presence of multiple COIs within one or multiple exposure pathways (or environmental media[xiv]) are evaluated. The evaluation of cumulative risk in Tier I assessments initially assumes additive toxicity. Total acceptable cumulative risk is found when the sum of the COI hazard quotients for individual chemicals and classes, or the hazard index (HI), is below 1.0. The assumption of additivity in the evaluation of cumulative risk may be refined in a Tier II assessment by identifying and grouping chemicals with similar toxicological endpoints.

If the HI is ≥ 1.0, DEQ's preference is to retain COIs with quotients ≥ 0.10 as COPCs associated with potential unacceptable cumulative risk unless another approach is acceptable to the department. The intent is to identify a meaningful subset of cumulative COPCs within the larger

hazardous substance for determining risk and the acceptable risk level for individual hazardous is applied, i.e., a risk quotient of 1.0 applies to each chemical class.

list of COIs contributing to the HI (e.g. see example #2 below). The additional step of identifying COPCs ≥ 0.10 may be unnecessary if the objective is the delineation of point by point RBC exceedances identified for removal (see text box below). Chemicals that screen in for cumulative risk, but are less than a hazard quotient of 1.0 on an individual basis, should be retained for any future site characterization or monitoring events, and considered within the lines of evidence evaluation in risk characterization.

A COPC screens in for cumulative risk if:

$$\text{SUM}\left(\frac{\text{EPC}}{\text{RBC}}\right) \geq 1.0 \text{ and } \frac{\text{EPC}}{\text{RBC}} \geq 0.10$$

Based on the equation above, the approach to screen for cumulative effects associated with exposure to multiple COIs in one environmental medium is as follows:

- Add hazard quotients for multiple COIs in one medium as shown in Example 1. If the hazard index is greater than or equal to 1.0, there is a potential for cumulative risk. Note: When adding hazard quotients, retain all digits for the sum calculation and then round to one significant digit (e.g. a risk index of 0.98 screens in).

- If the cumulative hazard index is greater than or equal to 1.0, identify COPCs contributing to cumulative risk as any HQ for a COI greater than or equal to 0.10. Note, in this case, round the result to two places past the decimal point (e.g. 0.092 will screen out; 0.096 will screen in).

For terrestrial Tier I point-by-point screening evaluations, only the $\text{SUM}\left(\frac{\text{EPC}}{\text{RBC}}\right)$ need be calculated for each location in the assessment of cumulative risk. In this case, COPCs are identified as chemicals with HQs ≥ 1.0 due to the discrete nature of the decision unit. This method may be used if the intent is to identify discrete locations of RBC exceedances in lieu of refined exposure estimates. This approach assumes an adequate number of samples are available to represent the exposure area.

If the receptor could potentially contact multiple media, the COI must be retained as a COPC if the sum of individual medium hazard quotients is greater than 1.0. Complete pathways to more than one medium should be reflected in the conceptual site model. For example, if soil, water, and sediment pathways are complete, then the equation would be:

$$\text{Multi Media Risk Index} = \text{HQsoil}\left(\frac{\text{EPC}}{\text{RBC}}\right) + \text{HQwater}\left(\frac{\text{EPC}}{\text{RBC}}\right) + \text{HQsediment}\left(\frac{\text{EPC}}{\text{RBC}}\right)$$

Examples 1 and 2 illustrate cumulative risk calculation for receptors with one complete exposure pathway at the site (one environmental medium). Example 3 shows a cumulative calculation example for multiple exposure media. Hazard quotients for each individual COI and medium are summed across all the media with complete pathways to calculate a total exposure hazard index for a receptor class (e.g. mammal HQs for soil and surface water). If the sum of the HQs, or hazard index (HI), is greater than or equal to 1.0 for single or multiple media, the cumulative

exposure of contaminants could be a threat to ecological receptors. The following tables present examples of cumulative risk calculations by receptor guild (assessment endpoint), which should be provided in a Tier I or II ERA.

**Cumulative Screening Example 1:**

**Multiple chemicals in one medium for one receptor class (e.g. ground feeding birds)**

Three individual hazard quotients are ≥ 1.0. In this case, the COPCs are Chemicals A, C and D. In this example, the cumulative HI is also greater than 1.0, but no additional COPCs are identified because the remaining HQs < 0.10.

| COI | Medium EPC (mg/kg) | Receptor Class RBC (mg/kg) | EPC / RBC | HQ ≥1.0? | HQ≥0.10? | COPC? | |
|---|---|---|---|---|---|---|---|
| | | | | | | Individual | Cumulative |
| Chemical A | 1.12 | 1.14 | **0.98** | **Yes** | **Yes** | **Yes** | **Yes** |
| Chemical B | 0.1 | 3 | 0.092 | No | No | No | No |
| Chemical C | 20 | 15 | **1.3** | **Yes** | **Yes** | **Yes** | **Yes** |
| Chemical D | 40 | 20 | **2.0** | **Yes** | **Yes** | **Yes** | **Yes** |
| Chemical E | 0.05 | 1.1 | 0.05 | No | No | No | No |
| **Hazard Index** | | | **3.4** | | | | |

**Cumulative Screening Example 2:**

**Multiple chemicals in one medium for one receptor class**

In this example, the hazard quotients for individual chemicals in one medium are less than 1.0, but the cumulative risk index is greater than 1.0. Chemicals A, B, and E are identified as COPCs on the basis of cumulative risk (HQ ≥ 0.10).

| COI | Medium EPC (mg/kg) | Receptor Class RBC (mg/kg) | EPC / RBC | HQ ≥1.0 ? | HQ ≥ 0.10? | COPC? | |
|---|---|---|---|---|---|---|---|
| | | | | | | Individual | Cumulative |
| Chemical A | 52 | 60 | **0.87** | No | **Yes** | No | **Yes** |
| Chemical B | 0.5 | 3.1 | **0.16** | No | **Yes** | No | **Yes** |
| Chemical C | 1.0 | 15 | 0.067 | No | No | No | No |
| Chemical D | 1.1 | 20 | 0.06 | No | No | No | No |
| Chemical E | 0.11 | 0.23 | **0.48** | No | **Yes** | No | **Yes** |
| **Hazard Index** | | | **1.6** | | | | |

**Cumulative Screening Example 3:**

**Cumulative Screening for Chemicals in Multiple Media**

In the example below, multi-media cumulative risk for Chemicals A and B are evaluated for three different complete exposure pathways. Multi-media cumulative risk is calculated by summing the medium specific hazard quotients. In this example, the multi-media sum for Chemical A is less than 1.0, and therefore not identified as a COPC. Chemical B is identified as a COPC because the multi-media cumulative risk is greater than 1.0.

| | Medium EPC / RBC | COPC? |
|---|---|---|
| **Chemical A** | | |
| Soil | 0.35 | |
| Sediment | 0.24 | |
| Surface Water | 0.11 | |
| **Multi-Media Sum** | **0.70** | **No** |
| **Chemical B** | | |
| Soil | 0.40 | |
| Sediment | 0.85 | |
| Surface Water | 0.75 | |
| **Multi-Media Sum** | **2.0** | **Yes** |

### 3.4.2 Tier III Calculation

Tier III ERAs are those that use additional endpoints to complete the risk assessment for site – specific receptors. Measures of the associated endpoints may include biological surveys, toxicity testing or body burden analysis (such as sampling and analyzing tissue). Estimation of an exposure-response relationship may be attempted using a correlation, or by identifying ecological impacts along a concentration gradient using toxicity testing. Site-specific toxicity, tissue concentrations, and/or field studies will feed back into the lines of evidence identified in risk characterization. Tier III ERA methods are evaluated on a site-specific basis. The proposed methods should be submitted and approved by DEQ in advance of conducting site-specific work.

Due to the level of site-specific information needed to conduct DEQ's acceptable exposure probability calculation for non-T&E species, these assessments fall into the Tier III ERA section. Updated methods and details for conducting "Level III analysis," previously included in DEQ's 1999 *Guidance for Ecological Risk Assessment: Levels I, II, II, IV*, can be found in Appendix D of this IMD. Additionally, probabilistic risk assessment may be used in place of deterministic exposure parameters discussed in Appendix B.

## 3.5 Risk Characterization

Risk characterization is the final phase of the risk assessment where information from the scoping, problem formulation, and risk calculation steps are further evaluated using additional

data presentation and lines of evidence to determine the likelihood of adverse effects. If it is concluded that unacceptable risk is probable, contaminants of concern (COCs) are identified relative to specific assessment endpoints. Risk characterization includes the following components in order to support a risk determination:

- **Risk Estimation**: Presentation of the magnitude, extent, and spatial distribution of risk
- **Risk Uncertainty**: Description of uncertainties, assumptions, strengths, and limitation of the analysis
- **Risk Description**: Lines of evidence are used to support a determination of observed or predicted adverse effects
- **Risk Determination:** Identification of ecological risk associated with identified COCs

Risk characterization culminates in a conclusion regarding ecological risk. A risk conclusion may 1) determine that there is no unacceptable ecological risk and need not be considered in site remediation; 2) unacceptable risk exists, and ecological effects and risk based concentrations are identified for consideration in a feasibility study, or 3) additional characterization or risk analysis is needed for COPCs, media, and receptors of concern identified.

### 3.5.1 Risk Estimation

Risk estimation provides the information needed to assess the likelihood of unacceptable risk by presenting (1) magnitude and nature of individual and cumulative risk, and (2) the spatial distribution of risk in the environment. The submission of specific data presentations are requested to support a lines of evidence evaluation concluding in a risk determination; these data presentations are described below. In cases where a Tier III ERA has used probabilistic methods to evaluate exposure-response relationships, or used additional measurement endpoints such as site-specific toxicity testing, this information should be presented in addition to deterministic HQs and HIs.

#### 3.5.1.1 Presentation of Magnitude and Extent of Ecological Risk

HQs for each COPC and each assessment endpoint and complete exposure pathway should be summarized in table form. These tables should include a summary of hazard quotients for individual COPCs (HQ $\geq$ 1.0), total hazard index, and cumulative COPCs (HQ $\geq$ 0.10) for each assessment endpoint. This summary is intended to inform the risk determination in two ways:

1. **Magnitude.** High magnitude exceedances of RBCs (hazard quotients and hazard indices) increase the likelihood of effects occurring at the site. Additionally, because RBCs are derived on the basis of chronic toxicity, the magnitude of an exceedance ratio may also indicate the potential for acute (e.g., lethal) effects.

2. **Ecological Extent.** The degree to which COPCs potentially adversely affect multiple receptors (assessment endpoints), through one or multiple exposure pathways, indicates a greater potential for adverse effects within multiple levels of biological organization (trophic levels).

**Example Table:**

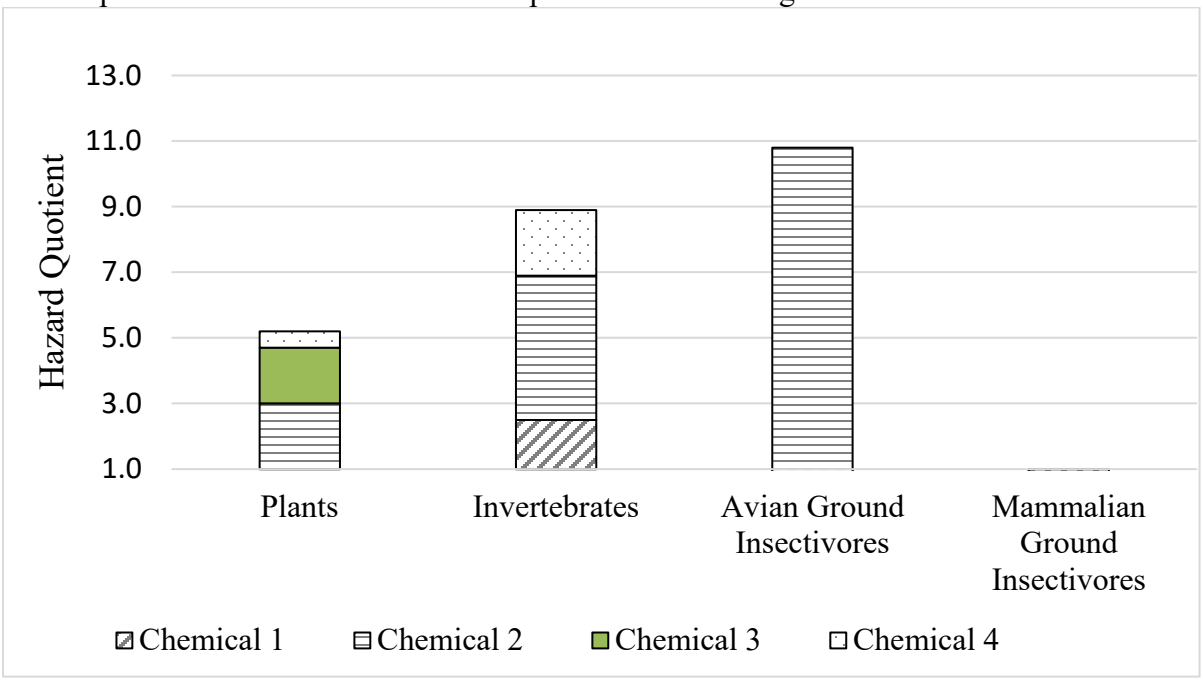
**COPC Hazard Quotient Summary [by Assessment Endpoint]/Assessment Endpoint COPC Summary Table**

In addition to HQs, indicate where an RBC was unavailable to evaluate risk. To aid in cross media evaluations, indicate if a COI was not analyzed in a given medium.

Note: HQs shown in italics screened out during risk calculation, and are not COPCs (HQ<0.1), and are shown for illustrative purposes only

| Exposure Pathway: List Medium (sediment, soil, or water). | | | | | | |
|---|---|---|---|---|---|---|
| COPC (Example) | **HQs by Assessment Endpoint (Example, Upland Soil, Exposure Area 1)** | | | | | |
| | Plants | Inverte-brates | Ground Feeding Birds | Top Feeding Birds | Ground Feeding Mammals | Top Feeding Mammals |
| COPC A (Lead) | 1.1 | *0.08* | 5.7 | 0.81 | 0.76 | *0.08* |
| COPC B (Zinc) | 2.8 | 3.7 | 3.7 | 0.75 | 0.45 | *0.01* |
| COPC C (Chromium) | No RBC | No RBC | 4.8 | 0.63 | *0.06* | *0.01* |
| COPC D (DDX) | No RBC | No RBC | 15.4 | 5.2 | 28.6 | 63.6 |
| Total LPAHs / Total HPAHs | --Not Analyzed-- | | | | | |
| **Receptor Specific Total Hazard Index** | 3.8 | 3.7 | 25.5 | 7.4 | 29.9 | 63.7 |

Summary figures should also be included to illustrate the magnitude of COPC exceedances for each exposure media and assessment endpoint such as the Figure illustrated below.



### 3.5.1.2 Spatial Distribution of Ecological Risk

In addition to the presentation of COPCs by assessment endpoint, the spatial (or areal) extent of the risk should be shown by presenting the distribution of RBC exceedances by sample location. This presentation is intended to relay the following information:

- Distribution of COPC exceedances in the environment.
- Spatial scale of exceedances, which is related to the number of organisms potentially at risk.
- Proximity of exceedances to ecologically important features such as sensitive or critical environments.
- Locations of high magnitude cumulative risk.

Tables and maps should present hazard indices (HIs) for each sample location by assessment endpoint (e.g. plants, invertebrates, birds and mammals) to illustrate the distribution of total risk. While mobile receptors are typically assessed using an average exposure point concentration, the location specific presentation identifies locations contributing most significantly to risk. Examples of summary tables for spatial distribution are provided below. COPCs with the highest magnitude hazard quotient contributing to the hazard index at each location should be noted. The sample specific hazard indices summarized in the tables can then be used to create maps of the exceedance ratios. The maps should show sample locations on a satellite overlay in order to illustrate risk indices relative to relevant environmental features. In addition to total hazard indices, the inclusion of tables and maps illustrating the spatial distribution of hazard quotients for individual COPCs contributing significantly to total risk should be included.

**Example Table:**

**Spatial Distribution of Total Risk by Assessment Endpoint**

Tabulate the total hazard (HI) for each sample location by assessment endpoint. The dataset used to complete these tables may include discrete, composite, or incremental samples. List the COPC with the highest magnitude hazard quotient at the sample location.

**Total Hazard Indices (HI) by Sample Location**

Exposure Area Complete Pathway: Example, Upland Soil Exposure Area 1

| Exposure Area 1 Sample Locations | Assessment Endpoint | | | | | |
|---|---|---|---|---|---|---|
| | Plant | Invertebrates | Ground Feeding Birds | Top Feeding Birds | Ground Feeding Mammals | Top Feeding Mammals |
| Sample 1 | 2.2 Lead | 1.1 Zinc | 18.0 Lead | 1.1 Lead | 5.0 DDX | 11.1 DDX |
| Sample 2 | 9.4 Zinc | 7.7 Zinc | 20.0 Lead | 2.9 Lead | 20 Lead | 0.51 DDX |
| Sample 3 | 0.6 Zinc | 0.7 Zinc | 16.8 DDX | 5.3 DDX | 27.5 DDX | 60.6 DDX |
| Sample 4 | 0.7 Zinc | 0.7 Zinc | 2.9 Lead | 0.5 Chromium/ Zinc | 0.5 DDX | 0.5 DDX |

### 3.5.2 Risk Uncertainty

The risk uncertainty evaluation should focus on sources of uncertainty that are reducible within the exposure analysis and risk-based concentrations. The sections below describe uncertainty related to Tier I and II evaluations. Tier III methods to evaluate uncertainty should be developed in coordination with DEQ.

#### 3.5.2.1 Exposure Analysis Uncertainty

The EPC is intended to represent chemical exposure to receptors generated using sampling data representative of the areas that receptors are anticipated to occupy. Understanding whether and to what degree the data collected represent what is actually in the environment – and what the receptors are exposed to – is of utmost importance in using the conclusions of the risk assessment for decision making. Sample representativeness can be a significant source of uncertainty in ecological risk assessments, and one that can be most easily reduced through additional data collection. As a result, the uncertainty section should explicitly evaluate the rigor of the data used in the exposure assessment as follows:

- **Representativeness of the Sampling Methodology:** Discuss the representativeness of the sampling methodology. There is typically greater confidence in exposure represented by incremental sampling as compared to discrete samples. The use of discrete data will likely require more conservative decision-making using risk screening conclusions.

- **COI Characterization:** Discuss the adequacy of analytical data to represent site COIs known or suspected to be present, and the degree to which method detection limits are below relevant RBCs.

- **LOF Delineation:** Discuss the degree to which the analytical dataset and exposure characterization represents the current and potential future locality of the facility. Outline any unknowns in the chemical distribution in all environmental media that may affect exposure, such as groundwater discharge or fish movement in interpreting tissue concentrations, etc.

- **Site-Specificity:** Discuss the degree to which direct measurements or adjustments were made to represent the exposure assessment.

If desired, and to support decision making, a sensitivity analysis may be provided to evaluate how changes to the EPC would impact the significance of identified risk.

#### 3.5.2.2 Uncertainty in Risk-Based Concentrations

Effects thresholds presented in this guidance are point estimates of no observed (NOAECs / NOAELs) and lowest observed effect (LOAECs / NOAELs) levels extracted from national and scientific literature. These values are developed from the test concentrations used in toxicity studies, and do not report or estimate the nature and magnitude of effects across a full concentration range. The use of Effective Concentration or Dose (ECx or EDx), defined as the point on the dose response curve where x% of the test population is affected, improves confidence that the selected threshold is biologically significant. However, toxicity data in this form are not available in national literature compilations (EPA or other databases). Site-specific

toxicity testing could utilize this methodology to reduce uncertainty in the effects assessment. In cases where testing is infeasible, such as those for wildlife, EC10 or EC20 toxicity thresholds could be calculated by extracting dose response information from the literature.

An additional source of uncertainty is whether, and to what extent, the effects identified using literature values would occur under site-specific conditions in the field. This uncertainty can be reduced by conducting Tier III testing under more realistic or field conditions. Most site-specific evaluations are limited to species that can be easily tested, such as soil, sediment or water tests with plants and invertebrates. Biological surveys may also be useful tools to provide direct estimates of effects.

### 3.5.3 Risk Description

Risk description involves assembling and evaluating information generated for the risk estimate and risk uncertainty as lines of evidence to determine the likelihood and relevance of unacceptable risk. In addition, modifying factors, such as assessment endpoint social or ecological relevancy and ecological function, are used to further evaluate significance. Risk description lines of evidence and modifying factors are described below.

**Lines of Evidence Summary**

Generally, DEQ uses the following lines of evidence to judge the likelihood and significance of identified COPC risk: risk magnitude, nature of risk, spatial distribution of risk, and adequacy of chemical characterization. The risk identified in the estimation section should be described in the context of the following lines of evidence.

| Lines of Evidence | Supporting Information | Example | Risk Description |
|---|---|---|---|
| Magnitude of Risk | HQs and HIs: Degree of exceedance of RBC COPC(s) Risk Estimation Tables / maps | Examine magnitude of HQ(s) and HI(s) in one or more media | Increased HQs and HIs increases the likelihood of adverse effects. If HQ(s) ≥5 consider potential for lethal effects |
| | Severity of Toxicological Effects | COPC has steep dose response curve (for example, lead toxicity to birds) | Increased likelihood of adverse effects |
| Nature of Risk (Ecological Extent) | Multiple COPCs identified within one assessment endpoint | Lead, copper, chromium COPCs to ground feeding birds | Increased likelihood and significance of adverse effects |

| | | | |
|---|---|---|---|
| | COPC(s) identified across multiple assessment endpoints and biological levels of organization | Lead a COPC for plants, invertebrates, birds and mammals | Increased likelihood and significance of adverse effects across multiple species and trophic levels |
| | | Bioaccumulative COPC Food Chain Effects | |
| Spatial Distribution of Risk | Measure of area representing risk for each assessment endpoint | Calculations of area (e.g. acres) of risk areas; maps | Larger area increases the number of organisms impacted |
| | Number of exposure media identified for COPC(s) | COPC identified in multiple media (water, soil and / or sediment) | RBCs evaluate single media exposure; likelihood of adverse effects increases |
| Adequacy of Chemical Characterization | Incremental or discrete sampling? | If discrete sampling used, false negatives probable | Consider all potential adverse effects likely until additional data collected |

**Lines of Evidence Modifying Factors**

In addition to the lines of evidence identified above, exceedance of acceptable risk levels should be evaluated further with respect to the significance of the risk to determine if the COPCs in one area could pose a greater threat than other areas. Modifying factors include the social or ecological importance of the area or species identified, the ecological function of the area, or whether the ecological importance of the area is expected to increase in the future. An example of modifying factors that should be described are presented below.

| Lines of Evidence | Supporting Information | Example | Risk Description |
|---|---|---|---|
| Social or Ecological Species Relevancy | Non-T&E, but sensitive, special status, or culturally important species present | Lamprey, Benthic Fish Native Mussels Wapato Plant | Increases significance of identified risk to public, tribal or other stakeholders |
| Relative Ecological Function | Maps showing proximity to sensitive environments (wetlands, riparian | RBC exceedances | Increases the likelihood of effects to additional species such as amphibians and reptiles |

| | | | |
|---|---|---|---|
| | zones, migratory corridors) | | |
| Anticipated Change in Ecological Function | Zoning information, Presence of Ecological Overlay Zones | Biological succession increases habitat value over time | Significance of risk to increase over time |

### 3.5.3 Risk Determination

Interpreting and balancing the risk estimation and risk description lines of evidence described in the above sections culminates in a risk determination. The risk determination uses the lines of evidence and modifying factors to classify COPCs on the basis of both the likelihood and the significance of the estimated risks (EPA, 1997) and to make remedial action decisions. There are no default or national guidelines available for these determinations, and therefore every evaluation is site-specific and requires professional judgement and consultation with DEQ. These guidelines are not intended to cover all criteria that may need to be considered, but rather provide a framework for lines of evidence that should be consistently used to interpret the relative importance of identified adverse effects. This summary is intended to serve as an important risk communication tool for risk managers and other interested parties.

All COPCs have a probability of posing unacceptable risk and should be considered in future characterization, site monitoring, and cleanup actions. COPCs identified as having a high likelihood of adverse effects or posing significant risk are identified as chemicals of ecological concern (COCs) and are recommended for primary consideration in remedial action decision making. Risk determinations form the basis for COC identification, and also, if warranted, 1) recommendation(s) for additional characterization where uncertainty prevents a definitive conclusion, or 2) identification of areas where remedial action to protect ecological receptors is appropriate. The following information should be presented to support the risk determination:

- COPCs identified for each receptor and exposure pathway, with associated exposure areas as outlined in the risk estimation and description sections, and rationale for inclusion or exclusion as a COC.
- COCs identified for each receptor and exposure pathway, with associated exposure areas.
- Decision units that exceed cumulative risk thresholds. Acceptable risk levels may be achieved in these cases by: 1) developing cleanup criteria for individual COCs such that the total cumulative hazard indices are less than 1.0, or 2) evaluating the degree of spatial co-location of COPCs to demonstrate that remedial actions focused on COCs will effectively eliminate cumulative risk.
- Lines of evidence and modifying factors presented in the risk estimation and description sections used to identify COCs.
- Key uncertainties in the exposure and effects estimates.

# 4. Potential Ecological Hot Spot Identification

Potential hot spots of contamination should be identified in the ERA[xv]. Potential hot spots are defined as those COCs present in concentrations exceeding RBCs corresponding to 10x the acceptable risk level for exposure to individual hazardous substance[xvi]. COCs with sample locations exceeding an HQ of 10 should be identified as potential hot spots in the ERA. A final determination of hot spots, for which there is a preference for removal or treatment, is made in the feasibility study. This determination is made after considering factors other than toxicity, such as how likely COCs are to migrate, and the extent to which they may be reliably contained.

# 5. References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# 6. Record of Revisions to IMD

| Revision | Date | Changes | Editor |
|---|---|---|---|
| New IMD | 9-14-2020 | N/A | N/A |

# 7. Endnotes

[i] ORS 465.315(2)(a)
[ii] OAR 340-122-0084(3)
[iii] ORS 465.315 & OAR 340-122-0010 to -0115
[iv] OAR 340-122-0115(35)
[v] OAR 340-122-0080(5)
[vi] OAR 340-122-0080(2)
[vii] OAR 340-122-0090(1)(a) and OAR 340-122-0115(1)
[viii] ORS 465.315
[ix] OAR 340-122-0115(7)
[x] OAR 340-122-0084 (1)(f)
[xi] OAR 340-122-0040(2)(c)
[xii] ORS 465.315(1)(b)(A)
[xiii] OAR 340-122-0084 (1)(f)
[xiv] OAR 340-122-0084(1)(i)
[xv] ORS 465.315(2)(b)
[xvi] OAR 340-122-0115(32)(b)(A)(iii)