FACT SHEET #19 – TECHNICAL SUPPORT MEMORANDUM 3: STEP 3 ECOLOGICAL SCREENING ASSESSMENT

This memorandum supplements the Department of Environmental Quality (DEQ) Voluntary Remediation Program (VRP) Fact Sheet #19, *Ecological Risk Assessment - Steps 3 and 4 Screening and Baseline Ecological Risk Assessment Under the Voluntary Remediation Program*. VRP Fact Sheet #8 (*Site Characterization)*, VRP Fact Sheet #14 (*Ecological Risk Assessment – Steps 1 and 2 Ecological Exclusion and Scoping Assessments*), and VRP Fact Sheet #28 (*Data Quality Objectives [DQOs]*) should be referred to in order to develop an adequate, complete data set for use in the Ecological Screening Assessment. This memorandum should be used for VRP sites that screen through Steps 1 (Ecological Exclusion Assessment) and 2 (Ecological Scoping Assessment). The ecological risk assessment process is presented on Figure 1 of Fact Sheet #19.

Step 3. Ecological Screening Assessment Instructions

The Ecological Screening Assessment should be completed by, or under the supervision of, a biologist, ecologist, or other qualified environmental professional who is familiar with ecological risk assessment (ERA) and site assessment processes. Prior to conducting the Step 3 assessment, the volunteer should provide a work plan to the DEQ that describes the methods and procedures that will be used to complete the Step 3 screening assessment. It may also be appropriate to include a demonstration of data adequacy in the work plan. As described under Step 3d, the results of the Step 3 screening should be submitted to the DEQ as a technical report or memorandum that includes a detailed data evaluation and medium (Step 3b) or receptor (Step 3c) screen in accordance with the work plan. The volunteer should obtain prior approval from the DEQ if they choose not to submit a Step 3 screening assessment work plan.

The procedures to guide volunteers through a VRP Step 3 Ecological Screening Assessment are described below. The objectives of the screening assessment are to determine the adequacy of the data collected to-date, select the site-specific contaminants of interest (COI) (Step 3a), and conduct risk-based screening procedures to provide preliminary numeric risk estimates. Either a medium-specific (Step 3b) and/or a receptor group-specific (Step 3c) screening may be conducted. The medium-specific risk-based screening is simpler to conduct, but is intended to be more conservative than the receptor group-specific screening. The receptor group-specific screening will be more helpful in determining the media (e.g., soil, surface water, or sediment) and ecological receptors that should be included if more complex ecological risk assessment (i.e., Step 4 Baseline Ecological Risk Assessment) is to be conducted for the site.

Site-specific wetland delineation, critical habitat/species surveys, or other detailed field efforts are not required for Step 3. However, the results of a rare, threatened, or endangered (T&E) species search conducted in Step 1 should be incorporated into Step 3.

Step 3a. Data Evaluation

The goal of Step 3a is to develop the COI list and corresponding screening criteria to conduct medium-specific screening (Step 3b) and/or receptor group-specific screening (Step 3c). A prerequisite to developing the COI list is a demonstration by the volunteer that site data have been collected in sufficient quantity and quality to adequately identify COIs. Step 3a should include the following components: Data

Adequacy Evaluation (Step 3a-1), Selection of COIs (Step 3a-2), Relationship to Background (Step 3a-3), Reporting Limit Screening (Step 3a-4), Contaminant Frequency Screening (Step 3a-5), and Identification of Applicable ERBSCs (Step 3a-6). These steps do not necessarily need to be done as described in the order below, but each step should be considered as part of the data evaluation.

STEP 3a-1: DATA ADEQUACY EVALUATION

As part of Step 3a, available analytical data for the site should be summarized by medium (i.e. soil, surface water, and sediment). Text, tables, and figures should be used to demonstrate whether the data adequately characterize the nature and extent of contamination at the site. The site should be subdivided based on knowledge of habitats and/or exposure areas to verify that there are no data gaps within each key habitat at the site. A demonstration should be made as to whether data are adequate to characterize key habitats and relevant exposure area(s). An evaluation should be conducted to determine whether the data are of adequate quality and verify that the method detection limit (MDL) for each constituent is low enough to predict potential ecological effects. The Step 3a-1 Data Adequacy evaluation should ensure that data are adequate across the entire site (i.e. Step 3b) as well as within each exposure area and habitat (i.e. Step 3c).

The data for each medium within each habitat and/or exposure area should be summarized in tables showing the number of samples, minimum and maximum detected values, minimum and maximum reporting limits (if variable due to dilutions or use of multiple methods), the frequency of detection, and the number of samples where the maximum detected value and the maximum reporting limit has exceeded the medium-specific ecological risk-based screening concentration (ERBSC). The data summary tables and any other supporting information should be provided to DEQ for concurrence on the adequacy of the data to proceed forward to Step 3a-2.

The summary tables and supporting information mentioned above should focus on the quality of the data and its adequacy for defining the nature and distribution of the contamination as it pertains to the habitat and/or exposure areas. VRP Fact Sheet #8*, Site Characterization*, and VRP Fact Sheet #28, *Data Quality Objectives* should be referred to in order to determine the data set is adequate and complete to conduct Steps 3b and/or 3c. If the site analytical data for each medium is complete (i.e., adequately represents the COIs in each affected environmental medium, achieves MDLs lower than ERBSCs, etc.), then the volunteer may proceed to Step 3a-2. If the data set is determined by the volunteer and/or DEQ to be too limited in quantity or quality, then the volunteer may need to develop a sampling and analysis work plan for further data collection at the site. The volunteer should discuss the results of Step 3a-1 with DEQ prior to proceeding to the next step (Step 3a-2).

STEP 3a-2: SELECTION OF COIs

Once the data have been determined to be of adequate quality and quantity under Step 3a-1, then the volunteer can proceed to Step 3a-2. The purpose of Step 3a-2 is to select the COIs in each medium that are to be included in the ecological screening assessment. If the Exclusion Assessment (Step 1) or the Scoping Assessment (Step 2) were conducted, the volunteer should use the information from these steps to list all contaminants that are known or suspected to have been released to the environment at the site. If Steps 1 and 2 were not completed, the volunteer should review the site uses and history to identify potential COIs that may be present due to releases at the site. COIs should be retained using the following three criteria:1) those listed as bioaccumulative; 2) contaminants that were detected in any

medium; and 3) contaminants where the MDL exceeds the ERBSC. It is recommended that the list of COIs be subdivided by medium (i.e., soil, groundwater, sediment pore water, surface water, and sediment), chemical class (e.g., metals or other inorganics, volatile organic compounds [VOCs], semi-volatile organic compounds [SVOCs], polychlorinated biphenyls [PCBs], etc.), and alphabetized within each class. This order will be helpful in subsequent screening steps. The volunteer should document Step 3a-2 by briefly describing the available analytical data for the site and the rationale for the selection (and if applicable, the elimination) of contaminants as COIs.

STEP 3a-3: RELATIONSHIP TO BACKGROUND

A comparison of site concentrations to background concentrations should be conducted. If the maximum detected concentration of a potentially naturally-occurring metal is greater than the concentration determined as naturally-occurring background, the COI should be carried forward to Step 3b and 3c. Constituents with maximum detected concentrations lower than DEQ-approved background values may be dropped from further evaluation if reporting limits are adequate to meet screening criteria. If the volunteer has not established approved background levels, they may skip this step or they may choose to submit a work plan (or technical memorandum if background data has been collected but not yet approved) to DEQ to collect background data and establish site specific background concentrations. A description of procedures for determining naturally-occurring background concentrations is described in VRP Fact Sheet #24.

STEP 3a-4: REPORTING LIMIT SCREENING

Provided that an adequate data set is available, contaminants that were not detected in any previously collected samples may be removed from the list of COIs for a given medium if the laboratory's maximum reporting limits for each are lower than their respective medium-specific ERBSCs. Contaminants with reporting limits that are greater than the medium specific ERBSC should be retained for further screening procedures at the reporting limit concentration, unless there is evidence that the COI would not occur at the site and DEQ approval is obtained. The DEQ-approved ERBSCs are provided in Table 1, and the process used to develop the ERBSCs is described in Appendix A to this technical memorandum.

STEP 3a-5: CONTAMINANT FREQUENCY SCREENING

Provided that an adequate data set is available, contaminants that are infrequently detected may not represent a significant threat to ecological receptors or may be artifacts in the data due to sampling, analytical, or other procedures. Thus, a five percent contaminant frequency screening is conducted for data to remove these contaminants and allow Step 3b and 3c screening to focus on contaminants that present a high potential for exposure. The volunteer should use site data to conduct the contaminant frequency screening for each COI in each exposure medium. The frequency screening is simply the number of samples where the COI was detected, or was not detected but had a reporting limit greater than the medium specific ERBSC, divided by the total number of samples in which the COI was analyzed and multiplied by 100 to express as a percentage. With DEQ agreement, the volunteer may eliminate from further consideration the COIs in each medium with frequencies that are less than or equal to five percent, unless the COI is a bioaccumulative chemical listed in Table 2. Also, COIs may not be eliminated without DEQ approval if detections or non-detections as described above are clustered or at high concentrations within an exposure area such that a risk may be present in a portion of the site. Because the number and location of samples may vary greatly from site to site, the results of the five percent

frequency screening should be discussed and approved by DEQ prior to its inclusion in the Step 3c risk-based screening process.

STEP 3a-6: IDENTIFICATION OF APPLICABLE ERBSCs

The recommended process used to develop the ERBSCs is described in Appendix A. If the volunteer believes that an alternative ERBSC is more appropriate for their site, the volunteer may propose an alternative ERBSC, for approval by DEQ. Application of an ERBSC for a chemically-similar surrogate or development of an ERBSC utilizing toxicity data from the scientific literature are quantitative approaches that may be considered and proposed to DEQ for a COI that lacks an ERBSC. If no toxicity information is available, a weight of evidence analysis considering the contaminant's bioaccumulative potential, adequacy of the laboratory MDL, site history, representativeness of the samples, and any other pertinent information, may be used to remove the contaminant from further consideration for that medium. However, in general, and in the absence of a compelling weight of evidence analysis, if no ERBSC is available for a particular contaminant in a given medium, DEQ requires that the COI be retained for further evaluation.

Step 3b. Medium-Specific Screening

Step 3b is a simple, conservative, risk-based screening that provides an opportunity to remove the site from further ecological assessment. However, if the list of medium-specific COIs developed during Step 3a includes any of the bioaccumulative chemicals listed in Table 2, the volunteer will be required to complete Step 3c or Step 4.

To complete Step 3b, the volunteer should list the maximum detected concentration of each COI or the highest reporting limit for a constituent that was not detected by the laboratory in each contaminated medium present across the entire site. The volunteer should then calculate medium-specific hazard quotients (HQs) by dividing the maximum COI concentrations in a given medium by the appropriate medium- and contaminant-specific ERBSCs listed in Table 1.

$$HQ_{xy} = [COI]_{xy} / ERBSC_{xy}$$

Where:

HQ_{xy} is the hazard quotient for a COI (x) in a given medium (y) (unitless).

$[COI]_{xy}$ is the higher of the maximum detected concentration or the highest reporting limit of non-detected constituents of the COI in a given medium (milligram per kilogram (mg/kg) or milligram per liter (mg/L))

$ERBSC_{xy}$ is the COI-specific and medium-specific ecological risk-based screening concentration listed in Table 1 (mg/kg or mg/L).

Where groundwater and/or sediment pore water data exist, and the groundwater and/or sediment pore water may discharge to surface water, then HQs for sediment pore water or groundwater should be calculated using surface water ERBSCs.

The hazard quotients for each medium should be summed to obtain medium-specific hazard indices (HIs):

$$HI_y = HQ_{x1y} + HQ_{x2y} + HQ_{x3y} + HQ_{\infty y}...$$

Where:

HI_y is the medium-specific hazard index for a given medium (y),
HQ_{x1y} is the hazard quotient for COI 1 (x1) in a medium (y), and
HQ_{x2y} is the hazard quotient for another COI (x2) in the same medium (y), etc.

The results of these calculations are HIs for surface or subsurface soil, groundwater, sediment pore water, surface water, and/or sediment. Summation of HQs to estimate HIs assumes that the exposure to, and effects of, each COI are additive. If information suggests that the COI toxic effects are not additive, this may be presented to DEQ for consideration in Step 3, or may be considered in the Step 4 analysis.

Conservative assumptions utilized in this analysis include: 1) the use of the lowest of the available ERBSCs for any given medium, and 2) the use of the maximum COI concentrations (i.e., both detected and non-detected as described above) as exposure point concentrations (EPCs). Therefore, for non-bioaccumulative COIs, this medium-specific risk-based screening is considered to be protective of ecological receptors. As noted in Step 3a-6, if a volunteer believes that a different ERBSC is more appropriate for a COI at their site, they may use an alternative ERBSC, subject to approval by DEQ. These conservative procedures result in a likely overestimation of potential for ecological effects and reduce the potential for contaminants to be removed from further evaluation.

ERBSCs are provided for constituents that have been found to commonly occur at Wyoming sites (Table 1). Additional contaminants may be on the COI list for a site; therefore, the volunteer should derive ERBSCs using the methods in Appendix A for all potential site COIs. If an alternative ERBSC cannot be derived using the methods in Appendix A for the contaminants at a site, the volunteer should discuss with DEQ potential options for evaluation of ecological risk. For those constituents for which ERBSCs exist, if all of the medium-specific HIs are less than or equal to 1 and there are no bioaccumulative COIs, then there are no unacceptable ecological risks associated with COIs at the site. In this case, following documentation as describe in Step 3d and with DEQ concurrence, ecological risk screening for the site is complete. If any medium-specific HI is greater than 1, or if bioaccumulative COIs (Table 2) were detected at the site, then a potential for ecological risks is predicted and the volunteer should proceed to Step 3c or Step 4.

Step 3c. Receptor Group-Specific Screening

Step 3c is a refinement of Step 3b that includes preliminary problem formulation and a receptor group-specific ecological risk-based screening. Step 3c is performed either if: 1) the list of medium-specific COIs developed during Step 3a includes any of the bioaccumulative chemicals listed in Table 2; or 2) Step 3b results indicate any medium-specific hazard index is greater than 1. Step 3c serves to identify receptors that may potentially be at risk at a site, and allows development of a preliminary conceptual ecological exposure model (CEEM). Step 3c is a more site-specific risk-based screening procedure than Step 3b, and may result in the conclusion that no further ecological assessment is necessary for a contaminated site. In the event that further ecological assessment is required, Step 3c may allow particular receptors, exposure pathways, or media to be eliminated, thus streamlining further ecological risk assessment requirements. Also, the information and results derived during Step 3c will support the development, if necessary, of an ecological risk assessment work plan for the Step 4 baseline ERA. Table 3 presents receptor group-specific ERBSCs. Example calculations for these ERBSCs are provided in Appendix A.

STEP 3C-1: PRELIMINARY PROBLEM FORMULATION

The preliminary problem formulation includes the following components, which are described in detail below:

- Characterization of site habitats and receptors;
- Preliminary ecological exposure assessment;
- Development of a CEEM;
- Qualitative ecological effects characterization; and
- Development of preliminary assessment endpoints and measures.

If information supporting the preliminary problem formulation was gathered during Steps 1 or 2 of the ecological risk assessment process, then that information can be referred to, inserted, or updated as necessary for Step 3c. The information summarized in the preliminary problem formulation is used to develop the assessment endpoints and measures. These provide the focus and scope of the receptor group-specific screening.

The results of the Step 3c screening are summarized and evaluated in the Step 3d report. If HQs exceed 1 for any COI for a particular receptor group, then those COIs are considered constituents of potential ecological concern (COPECs) for the media to which those receptor groups are exposed. These COPECs and exposure media are then presented as the focus of a baseline ecological risk assessment (Step 4). If no COPECs are identified, then with DEQ concurrence, no further ecological risk assessment will be required for the site.

Step 3c-1-1. Preliminary Problem Formulation: Characterization Of Site Habitats And Receptors

The first step of the preliminary problem formulation is to characterize habitats and receptors at the site. This is a qualitative description of site habitats and a listing of key receptors or species that occupy or may occupy the site. Habitat and site information documented during Steps 1 and/or 2 should be presented here. If this information was previously documented and provided to the DEQ, the volunteer should work with the DEQ to determine to what extent the habitat and receptor characterization should be updated or restated.

Based on the information documented in Steps 1 and/or 2, the exposure medium and receptor groups should be categorized into the following receptor groups based primarily on the media that would be contacted due to their predominant foraging strategy (e.g., terrestrial, benthic, aquatic, or aquatic-dependent):

Exposure Medium of Concern	Receptor Group
Soil	Terrestrial plant community
	Terrestrial invertebrate community
	Terrestrial birds
	Terrestrial mammals
Surface Water	Aquatic life community (plants, invertebrates, and fish)
	Aquatic dependent birds
	Aquatic dependent mammals
	Amphibians and aquatic dependent reptiles
Bulk Sediment	Benthic (sediment-dwelling) invertebrate community
	Benthic (sediment-dwelling) fish
	Aquatic dependent birds
	Aquatic dependent mammals
	Amphibians and aquatic dependent reptiles
Sediment Pore Water or Groundwater	Benthic (sediment-dwelling) invertebrates

The receptors at the site that are potentially exposed to more than one medium should be listed in one of the receptor groups above that represents their most likely dominant exposure (e.g., foraging) medium at the site. Appendix A (Table A-10) lists some common Wyoming ecological receptors, and assigns them to habitat type. Other receptors may be used following consultation with the DEQ.

The receptor groups should be further characterized by predominant feeding guild (e.g., herbivore, carnivore, omnivore). Within terrestrial birds and mammals, aquatic-dependent birds and mammals, and fish receptor groups, the volunteer should list whether carnivores or piscivores (fish-eating species) are present. Reptiles and amphibians should be listed to document their presence at the site. However, due to a general lack of ERBSCs for these species, they are not included in the quantitative risk-based screening process. Rather, it is assumed that the risk-based screening for other receptor groups is protective of reptiles and amphibians.

Based on the information documented in Steps 1 and/or 2, special protections may be required for rare, threatened or endangered (T&E) species or sensitive habitats present at the site. In general, it is assumed that the receptor group-specific risk-based screening will account for potential risks to T&E species. However, if COI exposure to T&E species is likely to be more than intermittent or if acute risk is likely, the volunteer should consult with DEQ and wildlife management agencies/trustees to develop an acceptable risk assessment approach for these species. This may include conducting a baseline ecological risk assessment (Step 4).

Step 3c-1-2. Preliminary Problem Formulation: Preliminary Ecological Exposure Assessment

The next step of the Preliminary Problem Formulation is the preliminary exposure assessment. The purpose of the preliminary exposure assessment is to determine which, if any, ecological receptors identified above are likely to be exposed to the COIs at the site, which exposure pathways are likely to be complete, and how the data should be aggregated to predict exposure.

Based on the list of COIs in each medium developed in Step 3a-2, and the receptor groups listed above, a table known as the exposure matrix, with a row for each medium (e.g., soil, surface water, etc.) that contains COIs and a column for each receptor group, should be developed. An ***EXAMPLE*** of an exposure matrix for a hypothetical site is presented as Figure 1 to this technical memorandum. Based on observations made during site visits, information gathered during the Exclusion Assessment

(Step 1) or Scoping Assessment (Steps 2a and 2b), previous site investigations and/or the known habits of the ecological receptors that inhabit or are likely to inhabit the site, the volunteer should place an ***X*** or list the potential exposure routes (e.g., direct contact/uptake, ingestion, inhalation) in each box within the matrix representing contaminated media likely to be contacted by the listed receptor groups (i.e., where the receptors could be exposed to COIs in that medium). Each ***X*** represents an exposure pathway for an ecological receptor that should be assessed in the ecological risk-based screening procedures.

If only one dominant habitat type is present across the site and the ecological receptors of concern are likely to be exposed to similar COI concentrations across the site, then the entire site is considered one exposure area. At some sites with a number of different habitat types where COI exposure is variable, separate exposure areas should be designated. Exposure areas should be based primarily on habitat types and site history or usage patterns. Data should be organized by exposure area to be used in the receptor group-specific ecological risk-based screening. In addition, if there are particularly important habitats located within the boundaries of the site, these should be defined as separate exposure areas.

Step 3c-1-3. Preliminary Problem Formulation: Development Of A Conceptual Ecological Exposure Model (CEEM)

Using information from the previous preliminary problem formulation steps, the volunteer should create a preliminary CEEM similar to the ***EXAMPLE*** in Figure 2 to this technical memorandum. This figure is an expansion of the site conceptual model developed for site characterization (VRP Fact Sheet #8: *Site Characterization*). Similar to the site conceptual model, it qualitatively summarizes the source of COIs and their release and transport mechanisms. Given the information developed in the preliminary problem formulation, it also includes a listing of the media to which ecological receptors may be exposed (i.e., the exposure media), the ecological receptor groups that are likely to be exposed to those media, and the complete (or potentially complete) and quantifiable exposure pathways for each receptor group. The CEEM should also show incomplete or insignificant transport or exposure pathways described in the preliminary problem formulation. The CEEM is a graphical summary that expresses, at a glance, which receptor groups, exposure routes, and exposure media are present at the site, and which of these are most likely to be at risk due to site-related contamination. The CEEM should clearly indicate the receptor groups and exposure pathways that are to be assessed in the ecological risk assessment and those that are not.

Step 3c-1-4. Preliminary Problem Formulation: Qualitative Ecological Effects Characterization

The next step in the preliminary problem formulation is to determine the potential toxic effects and type of adverse effects that might be expected due to exposure to the COIs. This is called the qualitative ecological effects characterization. This qualitatively identifies particular contaminant-specific ecological effects that might be particularly relevant and important at a site. The following should be completed:

- Summarize the physical and chemical characteristics and toxic mechanisms of particular COIs;
- Identify contaminant-specific toxic effects such as eggshell thinning caused by organochlorine pesticides (e.g., DDT, aldrin, dieldrin) when ingested by carnivorous/piscivorous birds;
- Identify any well-known susceptibilities of particular ecological receptors to a COI; and
- Identify the potential for bioaccumulation/bioconcentration of COIs in the CEEM (Table 2).

Particular adverse effects should be noted for COIs that may not be accounted for by the use of the ERBSCs or where ERBSCs are lacking. Additionally, unless it can be clearly justified that adverse effects are unlikely for a particular COI in a particular medium, such COIs should be retained.

Step 3c-1-5. Preliminary Problem Formulation: Development Of Preliminary Assessment Endpoints And Measures

The final step of the preliminary problem formulation is to identify appropriate assessment endpoints and measures. Assessment endpoints and assessment measures define what is to be evaluated during the ecological risk assessment and the measures that are to be used to make that assessment. For Step 3c, these endpoints and measures are purposefully broad to reflect the simplified nature of the receptor group-specific risk-based screening. Assessment endpoints are explicit expressions of environmental values, including definition of an ecological entity and its attributes that are to be protected at the site. The assessment endpoints should be ecologically relevant, reflect a potential site-related impact, and be relevant to management goals for the site.

The assessment endpoints should be clearly stated by the volunteer for each receptor group to be included in the risk-based screening. Additionally, assessment endpoints and measures should reflect how site data are evaluated by an ecological exposure area as described in Step 3c-1-2. Assessment endpoints should reflect the range of variations in habitat types across the site (i.e. terrestrial versus aquatic).

Assessment measures are parameters that can be estimated or measured to determine the potential for the adverse effects highlighted by the assessment endpoints. Assessment measures may be related to quantifying the exposure, effects, and/or ecosystem and receptor characteristics. In Step 3c, where groups of receptors are assessed using default receptor group ERBSCs, the assessment measures are limited to the measured concentrations of the COIs in each of the potential exposure media and the receptor group ERBSCs selected for the screening.

STEP 3C-2. RECEPTOR GROUP RISK-BASED SCREENING

This component of Step 3c involves comparing the site data to the receptor group ERBSCs. The Step 3c risk-based screening procedure incorporates the use of statistical methods to estimate site-wide and/or exposure area-specific Reasonable Maximum Exposure Point Concentrations (RMEPCs) for use in the screening process. These EPCs may be lower than the maximum concentrations required in Step 3b and better reflect concentrations over an area of exposure. The Step 3c procedure also allows the use of receptor group-specific ERBSCs rather than sole use of the more conservative medium-specific ERBSC required in Step 3b. Use of receptor-group ERBSCs often result in the elimination of some contaminants and receptor groups from the need for further ecological consideration in a Step 4 baseline ecological risk assessment. For sites with few COIs and/or few exposed ecological receptors, Step 3c may altogether eliminate the need for further ecological risk assessment. Receptor-group ERBSCs are provided in Table 3 for constituents and receptors that have been found to commonly occur at Wyoming sites. If a receptor-group ERBSC is lacking for a COI at a site, the volunteer should discuss with DEQ potential options for evaluation of ecological risk.

There are two steps in the Receptor Group Risk-Based Screening:

- Development of RMEPCs
- Concentration-Risk Evaluation

These steps are described in detail below.

Step 3c-2-1. Receptor Group Risk-Based Screening: Development of Reasonable Maximum Exposure Point Concentrations (RMEPCs)

For each COI remaining after the initial screening procedures in Step 3a or Step 3b (if performed), the volunteer should calculate reasonable maximum exposure point concentrations (RMEPCs) for each medium and exposure area. The RMEPCs are the lower of the 95 percent upper confidence limit (95UCL) on the mean or the maximum detected value. DEQ recommends that the volunteer utilize statistical software (e.g., USEPA ProUCL) to test the data distribution and calculate the 95UCL based on the actual data distribution, which includes both detected and non-detected samples. The statistical output to support information for the 95UCLs should be provided to DEQ as part of the reporting requirements identified in Step 3d.

Step 3c-2-2. Receptor Group Risk-Based Screening: Concentration-Risk Evaluation

The remainder of the screening process consists of dividing the RMEPCs for each medium and exposure area by the receptor-group ERBSCs provided in Table 3. Next, hazard quotients for each COI and hazard indices for each receptor identified in the CEEM are calculated. The ERBSCs listed in Table 3 are recommended values for ecological receptors that may be encountered at Wyoming sites. The volunteer may choose to use only those ERBSCs for receptors that are expected to occur at their facility. For example, if there are no COIs in sediment or surface water, the volunteer does not need to consider receptor group-specific ERBSCs for aquatic-dependent birds or mammals. In addition, the volunteer may use choose to use alternate ERBSCs with approval by DEQ.

Receptor group-specific hazard quotients for each COI are calculated first by dividing the RMEPC for each COI by the appropriate contaminant- and receptor-group ERBSCs as follows:

$$HQ_{xyr} = [COI]_{xy} / ERBSC_{xyr}$$

Where:

HQ_{xyr} is the hazard quotient for a given COI (x), medium (y), and receptor group (r) (unitless),

$[COI]_{xy}$ is the RMEPC (lower of the 95UCL or maximum concentration) of the COI in a given medium (y) (mg/kg or mg/L), and $ERBSC_{xyr}$ is the COI-specific, medium-specific, and receptor group-specific ecological risk-based screening concentration from Table 3 (mg/kg or mg/L).

If groundwater and/or pore water data exist and these media may discharge to surface water, then HQs for freshwater dependent aquatic life, freshwater dependent birds, and freshwater dependent mammals should also be calculated using the groundwater or pore water data as the basis of the RMEPC. These HQs should be presented in addition to (or, with DEQ approval, as a substitute for) HQs for surface water.

If an HQ_{xyr} is greater than 1 for any of the COIs and receptor groups for a given medium, then that chemical becomes a COPEC for that medium and is carried forward to Step 4. If a receptor group ERBSC is not available for a particular receptor group, then that COI also becomes a COPEC and must be evaluated in Step 4.

If the HQ_{xyr} based on the RMEPC is less than 1 but the maximum sample-specific reporting limit for a non-detected sample is greater than an ERBSC, then that COI may need to be listed as a COPEC. This could happen if there are matrix interferences that elevate the reporting limit for an individual sample or group of samples. This could indicate the presence of a potential hot spot and should be discussed with the DEQ.

For each receptor group (including those potentially exposed to COIs in groundwater and sediment pore water), the hazard quotients for each medium, exposure area, and receptor-group should be summed to obtain medium-specific and receptor group-specific hazard indices for each exposure area, as follows:

$$HI_{yr} = HQ_{x1yr} + HQ_{x2yr} + HQ_{x3yr} + ...HQ_{\infty yr}.$$

Where:

HI_{yr} is the hazard index specific to a given medium (y) and receptor group (r),

HQ_{x1yr} is the hazard quotient for a receptor group (r) exposed to a contaminant (x1) in a given medium (y), and

HQ_{x2yr} is the hazard quotient for the same receptor group exposed to another contaminant (x2) in the same medium, etc.

If the hazard indices are less than or equal to 1, then there are no unacceptable ecological risks associated with COIs at the site. In this case, following documentation (Step 3d below) and DEQ concurrence with the documentation, the screening assessment is complete and no further ecological risk assessment is necessary.

If any COPECs are selected during Step 3c, then a potential for ecological risks exists due to the COPECs and further assessment via Step 4 or remedial actions are required at the site. The preliminary problem formulation, risk-based screening procedures, and COPECs for each medium should be documented in a report (Step 3d).

Step 3d. Report

Each part of the ecological screening assessment process that is undertaken should be documented in an Ecological Screening Assessment report with site-specific information that clearly supports the conclusions reached and recommendations made. If previously completed, the information gathered and documented during ecological risk assessment Steps 1 and 2 should be used to provide documentation for Step 3. At a minimum, the Ecological Screening Assessment report should include a rationale for the approach used in each step, a rationale for selecting COIs, and the methods used and results of Step 3b and/or 3c. If Step 3c was conducted, then the rationale for selection or exclusion of COIs, the rationale and selections made during the preliminary problem formulation, and the process employed and results of the risk-based screening should be presented. In addition, the risk estimates calculated during either Step 3b and/or 3c should be discussed. The volunteer should present conclusions for Step 3 and list recommendations for ending or continuing ecological assessment at the site. Information that was previously submitted in the Step 3 work plan, need not be repeated in the Step 3 Ecological Screening Assessment report (e.g. problem formation language, CEEM, etc.).

Figure 3 to this technical memorandum provides a sample outline that can be used to organize the documentation for Step 3. Key sections to this outline are discussed below. Note that only the applicable sections need to be included in documentation developed for a given site. The components of the outline are described as follows:

- **Introduction** – The volunteer should describe the location of the site, provide a brief explanation/history of the site and how it became contaminated, and present the objectives of the ecological screening assessment. A map of the site should be provided and referenced in this section. The map should show the site's location, and identify important surface features, such as legal boundaries, roads and buildings, hydrological features, important habitats, etc.

- **Data Evaluation –** The report should include tables, figures and documentation that support the results of the data evaluation, including a section on data adequacy, the results of the COI screening, the background comparison (if applicable), the results of the reporting limit screening, and the results of the contaminant frequency screening. In addition, if alternative ERBSCs were developed, the volunteer should describe the methods used to develop the ERBSCs.

- **Medium-Specific Ecological Risk-Based Screening** – This section should include the results of the medium-specific ecological risk-based screening assessment. Tables reporting the maximum detected concentrations of each COI, the maximum reporting limits, the number of samples that exceed the ERBSCs for each medium and the HQs should be compiled and presented.

- **Receptor Group-Specific Ecological Risk-Based Screening –** This section should include the results of the receptor group-specific ecological risk-based screening assessment. Tables reporting maximum detected concentrations of each COI, the maximum reporting limits, and the number of samples that exceed the ERBSCs for each medium within each exposure area should be provided. The calculated RMEPCs for each COI in each medium in each exposure area (i.e., the maximum detected value or the 95UCL) should be provided. If statistical software is used to calculate 95UCLs, include the distribution identified by the software, the maximum detected concentrations, and the 95UCL values. The statistical results (i.e. raw output) should be provided as an appendix. The volunteer should provide tables showing the results of the screening evaluation, including the RMEPCs used, the receptor-group ERBSCs, and the HQ and HI values.

- **Preliminary Problem Formulation** – The volunteer should describe current site habitats and receptors that occupy or may occupy the site. The volunteer should list or tabulate site ecological receptors by receptor group and present the rationale for eliminating any ecological receptors or receptor groups from further consideration. Exposure media and exposure pathways for the listed receptor groups should be discussed. A brief explanation should be included for each insignificant or incomplete exposure pathway (i.e., any blank boxes in the exposure matrix table). These explanations should rely on site-specific conditions. Exposure-limiting factors should be described to justify why particular exposures were not chosen for assessment in the risk-based screening. An exposure matrix and CEEM should be provided in a similar format to the examples provided in Figures 1 and 2 to this technical memorandum, respectively. The volunteer should document particularly important physical and chemical properties, toxic mechanisms, and/or site-specific ecological effects of the COIs for the most likely affected receptors. The volunteer should list the assessment endpoints based in the exposure media, exposed ecological receptor groups, and ecological effects of particular concern.

- **Risk Characterization** – Risk characterization includes risk estimation, risk description, uncertainty assessment, and an assessment of the potential for significant ecological risks to be posed at the site. The risk characterization section need only report on those portions of Step 3 that were completed. If predicted, ecological risks may be examined in regard to the likely site use of the contaminated area by species within a receptor group, the areal extent of contamination at the site, or other modifying factors pertinent to the likelihood of significant ecological risks occurring at the site. Step 3 HQs should be in consideration of assessment measurements and endpoints. The uncertainties associated with the assessment of ecological risks should be listed along with a qualitative assessment of whether they result in an over- or underestimation of the potential for ecological risks to be posed by COIs at the site. Finally, the contaminants for which significant ecological risks are predicted (i.e. COPECs) should be listed.

- **Conclusions and Recommendations –** The conclusions should reflect the CEEM, summarize predicted risks, describe the risk characterization procedures, and list the COPECs. Pertinent information reported and discussed in the preliminary problem formulation, risk-based screening, and risk characterization sections of the report should be reiterated as needed to strengthen the conclusions and recommendations made in this section.

For any predicted risks, the volunteer may recommend remediation using the receptor group-specific ERBSCs in Table 3 as preliminary remediation goals (PRGs), develop a sampling and analysis or risk assessment work plan to fill any data gaps, and/or refine the ecological screening assessment and PRGs with a baseline ecological risk assessment (Step 4). If risks are predicted for ecological receptor groups due to COIs in groundwater, the information in VRP Fact Sheet #13: *Groundwater Cleanup Levels* should be consulted prior to identifying groundwater remediation and/or ecological risk-based PRGs for groundwater.

Acronym List

BAF	Bioaccumulation Factor
BAFp	Bioaccumulation Factor for COI (x) in Plants
BCF	Bioconcentration Factor
BSAF	Biota Sediment Accumulation Factor
BW	Body Weight
CEEM	Conceptual Ecological Exposure Model
COI	Contaminant of Interest
COPEC	Contaminants of Potential Ecological Concern
Cplant	Concentration of COI (x) in Plant Tissue
Csoil	Concentration of COI (x) in Soil
DEQ	Department of Environmental Quality
DIR	Dietary Ingestion Rate
DQO	Data Quality Objectives
EcoSSL	USEPA Ecological Soil Screening Level
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ERBSC	Ecological Risk-Based Screening Concentration
g	Gram
ha	Hectare
HI	Hazard Index
HMW	High Molecular Weight
HQ	Hazard Quotient
HR	Home Range
IRIS	Integrated Risk Information System
Kg	Kilogram
Kow	Octanol -Water Partition Coefficient
L	Liter
LC50	Lethal Concentration for 50 Percent of the Test Population
LD50	Lethal Dose for 50 Percent of the Test Population
LMW	Low Molecular Weight
MDL	Method Detection Limit
mg	Milligram
mg/kg	Milligram per Kilogram
mg/kg bw/d	Milligram per Kilogram Body Weight per Day
mg/L	Milligram per Liter
MW	Molecular Weight
NOAA	National Oceanic and Atmospheric Administration
Nxy	Number of COIs (x) in Medium (y)
ORNL	Oak Ridge National Laboratory
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
Pi	Proportion of Prey or Forage Item (i) in Diet of Higher Trophic Level
PRG	Preliminary Remediation Goal

RAIS	Risk Assessment Information System
RMEPC	Reasonable Maximum Exposure Point Concentration
SFD	Solid (Soil or Sediment) Fraction in Diet
SQUIRTS	Screening Quick Reference Tables
SUF	Site Use Factor
SVOC	Semi-Volatile Organic Compound
T&E	Threatened and Endangered
TRV	Toxicity Reference Value
95UCL	95th Percent Upper Confidence Limit on the Mean
ug/kg	Microgram per Kilogram
ug/L	Microgram per Liter
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VOC	Volatile Organic Compound
VRP	Voluntary Remediation Program
WIR	Water Ingestion Rate

FACT SHEET #19 – TECHNICAL SUPPORT MEMORANDUM 3

APPENDIX A. DEVELOPMENT OF ECOLOGICAL RISK-BASED SCREENING CONCENTRATIONS (ERBSCS)

1.0 INTRODUCTION

Medium-specific and receptor group-specific ERBSCs were developed by review of the regulatory literature. The analytes that were included in the update are shown in Table A-1. These are analytes that are commonly found to be of concern by DEQ at various sites in Wyoming. This does not mean that other analytes are not of concern and should not be evaluated if found at a volunteer's site by review of historic information or by sampling.

The goal of the ERBSC update was to obtain conservative (i.e. protective) values to use as ERBSCs. Therefore, if a volunteer's site has measured concentrations that fall below these values, DEQ is reasonably certain that there is little likelihood of the potential for adverse ecological effects to any ecological receptor at the site. The methodology for deriving the ERBSCs is described by medium below.

2.0 MEDIUM-SPECIFIC ERBSCS

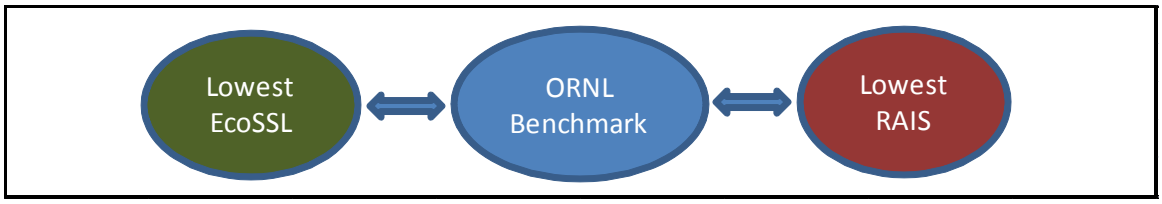
2.1 Medium-Specific ERBSCs for Soil

Soil ERBSCs are based on protection of terrestrial plants, terrestrial invertebrates, birds, and mammals as data are available. Numerous sources were utilized to obtain medium-specific ERBSCs for soil. In alphabetical order, these included:

- Efroymson, R.A., M.E. Will, G.W. Suter II, and A. C. Wooten. 1997a. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, N.ES/ER/TM-85/R3. November 1997.
- Efroymson, R.A., M.E. Will, G.W. Suter II. 1997b. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Processes: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, N.ES/ER/TM-126/R2. November 1997.
- Efroymson, R.A., G.W. Suter II, B.E. Sample and D.S. Jones. 1997c. Preliminary Remediation Goals for Ecological Endpoints. Oak Ridge National Laboratory, Oak Ridge, TN.ES/ER/TM-162/R2. August 1997.
- Risk Assessment Information System (RAIS). 2011. Ecological Benchmark Tool. http://rais.ornl.gov/tools/eco_search.php (This source includes information from USEPA Regions 4 and 5, Oak Ridge National Laboratory, and other citations).
- United States Environmental Protection Agency (USEPA). 2005a. Ecological Soil Screening Levels for Arsenic. Interim Final. Office of Solid Waste and Emergency Response. Washington D.C. March 2005. http://www.epa.gov/ecotox/ecossl/.
- United States Environmental Protection Agency (USEPA). 2005b. Ecological Soil Screening Levels for Barium. Interim Final. Office of Solid Waste and Emergency Response. Washington D.C. February 2005. http://www.epa.gov/ecotox/ecossl/.

- United States Environmental Protection Agency (USEPA). 2005c. Ecological Soil Screening Levels for Cadmium. Interim Final. Office of Solid Waste and Emergency Response. Washington D.C. March 2005. http://www.epa.gov/ecotox/ecossl/.
- United States Environmental Protection Agency (USEPA). 2005d. Ecological Soil Screening Levels for Cobalt. Interim Final. March 2005. http://www.epa.gov/ecotox/ecossl/.
- United States Environmental Protection Agency (USEPA). 2005e. Ecological Soil Screening Levels for Lead. Interim Final. Office of Solid Waste and Emergency Response. March 2005. http://www.epa.gov/ecotox/ecossl/.
- United States Environmental Protection Agency (USEPA). 2006. Ecological Soil Screening Levels for Silver. Interim Final. Office of Solid Waste and Emergency Response. September 2006. http://www.epa.gov/ecotox/ecossl/.
- United States Environmental Protection Agency (USEPA). 2007a. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs). Interim Final. http://www.epa.gov/ecotox/ecossl/.
- United States Environmental Protection Agency (USEPA). 2007b. Ecological Soil Screening Levels for Copper. Interim Final. February 2007. http://www.epa.gov/ecotox/ecossl/.
- United States Environmental Protection Agency (USEPA). 2007c. Ecological Soil Screening Levels for Selenium. Interim Final. Office of Solid Waste and Emergency Response. July 2007. http://www.epa.gov/ecotox/ecossl/. United States Environmental Protection Agency (USEPA). 2008. Ecological Soil Screening Levels for Chromium. Interim Final. March 2005. Revised April 2008. http://www.epa.gov/ecotox/ecossl/.

The reported soil benchmarks for plants, soil invertebrates or soil microfauna, birds, and mammals that were expressed as mass contaminant per mass soil (percent (%), milligram per kilogram (mg/kg) or microgram per kilogram (ug/kg)) were tabulated and converted to mg/kg if expressed otherwise. Data for toxicity of soil solutions (mg/L) to plants were not used because bulk soil data would not be comparable to the benchmark. The lowest overall value (comparing the lowest EcoSSL to the ORNL benchmark and the Lowest RAIS value) was then selected to use as the ERBSC as shown below:



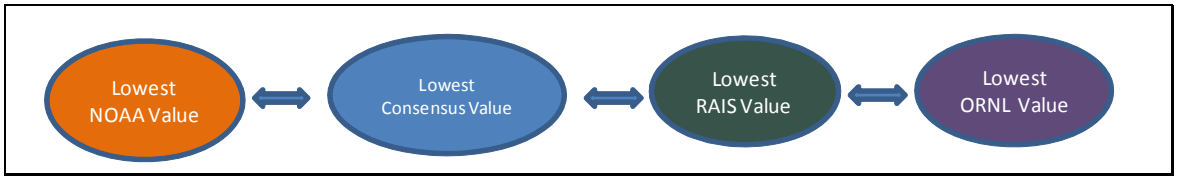
DEQ recognizes that there are other analytes that the volunteer may encounter at their site that may not be listed in Table A-1. For some, and possibly many, contaminants at a site there is little information available. The Dutch Intervention Values or other values associated with significant toxic effects were not considered appropriate for ERBSCs. Benchmarks may need to be derived from laboratory animal toxicity data associated with acute oral or inhalation lethal effects (e.g. lethal dose for 50 percent of the test population (LD50) or lethal concentration for 50 percent of the test population (LC50) data, respectively). If the volunteer desires to propose toxicity values, these should be associated with significant adverse effects and the approach discussed with DEQ. Uncertainty factors will need to be applied. An uncertainty factor value of 1000 for significant lethal effects, and a value of 100 for significant nonlethal effects, would be the point of departure; however, the volunteer may derive a chemical-specific uncertainty factor based on information from the scientific literature and present this to DEQ for consideration.

2.2 Medium-Specific ERBSCs for Sediment

Sediment ERBSCs are based on protection of the benthic invertebrate community. Several sources were reviewed for potential sediment ERBSCs. Sediments are by nature heterogenous, and toxicity may vary due to site-specific conditions such as particle size, oxygenation, and organic matter. Sediment benchmarks therefore vary widely. The sources reviewed for this ERBSC update (in alphabetical order) were as follows:

- Efroymson, R.A., G.W. Suter II, B.E. Sample and D.S. Jones. 1997c. Preliminary Remediation Goals for Ecological Endpoints. ES/ER/TM-162/R2. Oak Ridge National Laboratory, Oak Ridge, TN.
- MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.
- National Oceanic and Atmospheric Administration (NOAA). 2008. Screening Quick Reference Tables (SQUIRTS). OR&R Report 08-1.
- Risk Assessment Information System (RAIS). 2011. Ecological Benchmark Tool. http://rais.ornl.gov/tools/eco_search.php
- United States Environmental Protection Agency (USEPA) . 1977. Guidelines for the Pollution Classification of Great Lakes Harbor Sediments. United States Environmental Protection Agency. Region V. Chicago, Illinois. (As cited in MacDonald and USGS 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters, Technical Report, January 2003) (Barium only)

The lowest available sediment benchmark was selected as the ERBSC as shown below:



The volunteer may consider providing DEQ with site-specific data such as sediment toxicity tests and field population information in conjunction with bulk sediment chemistry compared to ERBSCs. This approach should be discussed with DEQ prior to incorporating into a site data collection work plan.

2.3 Medium-Specific ERBSCs for Surface Water

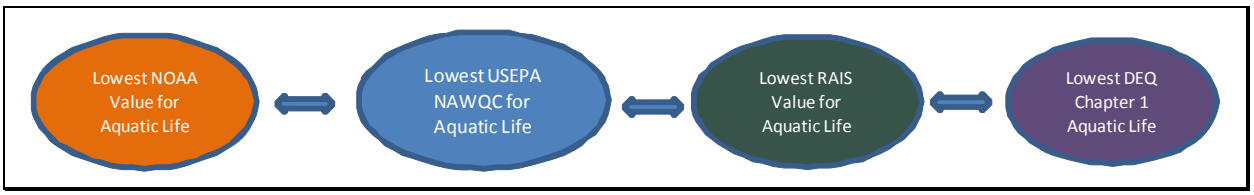
Several sources were reviewed for appropriate values to use as surface water ERBSCs. Surface water ERBSCs are designed to be protective of most species or communities of aquatic life, including plants, invertebrates, and fish. It is assumed that surface water ERBSCs are protective of the larval (tadpole) and adult life- stages for amphibians as well. If T&E amphibian species are present at the site, this assumption should be re-evaluated by the volunteer and discussed with DEQ.

Surface water ERBSCs include the following sources:

- NOAA. 2008. Screening Quick Reference Tables (SQUIRTS). OR&R Report 08-1.
- Risk Assessment Information System (RAIS). 2011. Ecological Benchmark Tool. http://rais.ornl.gov/tools/eco_search.php

- United States Environmental Protection Agency (USEPA). 2011. National Recommended Water Quality Criteria. http://water.epa.gov/scitech/swguidance/standards/current/index.cfm#appendxb. November 6, 2011.
- Wyoming Department of Environmental Quality (WDEQ). 2011. Water Quality Rules and Regulations. Chapter 1. Wyoming Surface Water Standards. Appendix B-1.

The lowest available acute or chronic surface water benchmark was selected as the ERBSC as shown below:



3.0 RECEPTOR GROUP SPECIFIC ERBSCS

Receptor group specific ERBSCs were developed for birds and mammals that are common to the State of Wyoming and that could be expected to occur at a volunteer's site. These ERBSCs were developed for the following media and exposure pathways:

- Soil - Incidental soil ingestion, dietary ingestion
- Surface Water - Surface water ingestion
- Sediment - Incidental sediment ingestion, dietary ingestion

The receptor group soil ERBSCs were calculated by rearranging the following equation from USEPA (2007d) which accounts for incidental soil ingestion as well as the dietary ingestion pathway assuming that the diet is only contaminated by exposure to soils:

$$HQ_{i+1} = \frac{[(C_{soil} * SFD * DIR_{i+1}) + (\Sigma\ (C_{soil} * P_i * DIR_{i+1} * BAF_i)]}{TRV_{i+1}} \qquad \text{[Eq. A-1]}$$

Where:

HQ_{i+1} = Hazard quotient for receptor group in trophic level ***i+1***
DIR_{i+1} = Food ingestion rate (kg dw/kg bw-d) for trophic level ***i+1***
Csoil = Site soil concentration (mg/kg) for HQ calculation
SFD = Proportion soil in diet of tropic level ***i+1***
P_i = Proportion of dietary item ***i*** in diet of trophic level ***i+1***
TRV_{i+1} = Toxicity reference value (mg/kg body weight/day) for animal eating dietary item ***i+1***
BAF_i = Dietary item ***i*** bioaccumulation factor

3.1 Receptor Group ERBSCs for Soil and Sediment

The following equation was applied to estimating ERBSCs for both soil and sediment. For estimation of ERBSCs, it was assumed that each COI exhibited 100% absorption. A site use factor (SUF) was not applied. The SUF is typically used to adjust the proportion of the animals home range relative to the site

area such that exposure for an animal with a home range or feeding territory larger than the site is reduced proportionally, and an animal with a home range smaller than the site is assumed to obtain 100% of their exposure within the site. A SUF of 1 consistent with an assumption of 100% site use was applied for developing screening levels. Although application of SUF and absorption of less than 1.0 is not considered appropriate for screening under Step 3c, the volunteer may apply these factors based on site-specific considerations in the Step 4 baseline ERA.

To solve for the ERBSC, equation A-1 above was rearranged to solve for Csoil. The HQ was set to a value of 1. The soil concentration is then the soil ERBSC when the HQ is 1:

$$ERBSC = \frac{(HQ_{i+1} * TRV_{i+1})}{[DIR_{i+1} * (SFD + \Sigma(P_i * BAF_i))]} \qquad \text{[Eq. A-2]}$$

Where:

HQ_{i+1} = Hazard quotient for trophic level ***i+1***
DIR_{i+1} = Food ingestion rate (kg dw/kg bw-d) for trophic level ***i+1*** (Table A-2)
ERBSC = Soil or sediment ERBSC (mg/kg)
SFD = Proportion soil or sediment in diet of tropic level ***i+1*** (Table A-2)
P_i = Proportion of dietary item ***i*** in diet of trophic level ***i+1*** (Table A-2)
TRV_{i+1} = Toxicity reference value for animal eating dietary item ***i+1*** (Table A-3)
BAF_i = Dietary item ***i*** bioaccumulation factor for uptake from soil or sediment (Table A-4)

3.1.1 Toxicity Reference Values

The toxicity reference values (TRVs) are presented in Table A-3. These are dose-based toxicity values for birds and mammals expressed in units of milligrams COI per kilogram receptor body weight per day (mg/kg bw/d). They represent a daily chronic or lifetime exposure dose that would not have toxic effects significantly elevated above those in control populations or non-exposed receptors. They are therefore considered conservative because it is unlikely that most receptors in the site environment would be exposed daily throughout the entire lifetime to this dose. The minimum TRV for birds was selected to represent all avian receptors, and the minimum TRV for mammals was used to represent all mammalian species. The supporting information, considered in compiling the receptor-specific TRVs is presented in Table A-8.

TRVs are typically not available for the wildlife receptors in Wyoming, but are derived from laboratory toxicity tests with animals known to be amenable to laboratory procedures such as rats, mice, and poultry. It is strongly recommended that TRVs for birds not be substituted for mammals, and vice versa due to the differing physiology between these classes of vertebrate organisms. The TRVs were obtained from the following source:

- United States Environmental Protection Agency (USEPA). 2013. Ecological Soil Screening Level (EcoSSL) Reports and Guidance Documents. http://www.epa.gov/ecotox/ecossl/.

The USEPA EcoSSLs were considered to be the most current, well-documented, and rigorously peer-reviewed summaries of wildlife toxicity information. If TRVs were not available from the EcoSSL reports, the following sources were reviewed for TRVs:

- Eisler, R. 1987. Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Patuxent Wildlife Research Center, MD. U.S. Fish and Wildlife Service Biological Report 85(1.11). Contaminant Hazard Reviews. Report No. 11. May 1987.
- Sample, B.E., D.M. Opresko, and G.W. Suter. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. Oak Ridge National Laboratory. ES/ER/TM-86/R3. June 1996.
- United States Environmental Protection Agency (USEPA). 2011c. Integrated Risk Information System (IRIS). http://cfpub.epa.gov/ncea/iris/

3.1.2 Bioaccumulation Factors

Bioaccumulation factors (BAFs) that relate prey or forage concentrations to soil or sediment concentrations are also required for estimating soil or sediment ERBSCs. BAFs may be constants or may vary with media concentrations or physical parameters and expressed as a regression equation in the literature. An example of a BAF that is a constant value is that for arsenic for plants:

$$BAFp = 0.214 \qquad \text{[Eq. A-3]}$$

Where:
BAFp = Bioaccumulation factor for plants (Cplant/Csoil)
Cplant = Plant tissue arsenic concentration (mg/kg)
Csoil = Soil arsenic concentration (mg/kg)

The BAFp above indicates that predicted plant tissue arsenic concentrations are 0.214 times less than those in soils (i.e. that arsenic bioattenuates rather than bioaccumulates in plants). However, because the amount of plant material ingested by an herbivore exceeds the fraction of soil in diet, the dietary pathway still may contribute a significant dose and is an important component of the ERBSC.

An example of a BAF that varies with soil concentration is that for arsenic for terrestrial invertebrates, where the BAF is the slope of the exponential regression line relating tissue concentration soil concentration as follows:

$$Cb=e^{(0.706*Ln(Csoil)-1.421)} \qquad \text{[Eq. A-4]}$$

Where:
Cb = Invertebrate tissue concentration of arsenic (mg/kg)
Csoil = Soil concentration of arsenic (mg/kg)

The slope of the line is not a constant, and therefore soil concentrations must be selected at which to predict the tissue concentration. This equation predicts higher uptake rates at lower soil concentrations. This can occur for many reasons, including the following: 1) at low soil concentrations there are active physiological uptake mechanisms, 2) at high soil concentrations receptors exhibit adverse effects and stop feeding or die, 3) receptors at the cellular level exist to absorb the chemical that become saturated at high soil concentrations, and/or 4) because the animal may not consistently use the area of high concentration.

Bioaccumulation of lipophilic chemicals is often predicted as dependent on the log of the octanol-water partition coefficient, Kow. The Kow is a measured property that states the fraction of a chemical dissolved in octanol and the fraction that would be dissolved in co-occurring water. Octanol is considered to represent biological lipids or fats. Chemicals that dissolve in octanol are typically attracted to fat cells in an organism and have higher Kow values than chemicals that are lipophobic or more highly water

soluble. An example of a BAF that is based on a chemical-specific log Kow is the biota sediment accumulation factor (BSAF) for benthic or aquatic invertebrates for benzene:

$$BSAF = 10^{(0.819*\text{Log Kow}-1.146)} \qquad \text{[Eq. A-5]}$$

Where:

BSAF = Biota sediment accumulation factor (unitless)
Log Kow = Log of the octanol water partition coefficient for benzene (unitless)

The BAFs that would be observed at soil or sediment concentrations equivalent to the medium-specific ERBSCs are summarized in Table A-4. These BAFs were used to derive the receptor group ERBSCs. BAFs for birds were unavailable in the literature reviewed; therefore, uptake for mammals was assumed to be similar to that for birds. This adds uncertainty to the BAFs and resulting ERBSCs for birds. In general, estimating dietary concentrations is an uncertain process, and conservative assumptions made include:

- BAFs for mammals are representative of uptake for birds. This may or may not be true, and would be expected to vary seasonally and by species.
- Assuming that BAFs and tissue concentrations modeled from these BAFs are static and not dynamic. Many bird species in Wyoming are migratory, and therefore could potentially depurate (lose) tissue concentrations during periods away from the site. Larger mammal species also may have seasonal migration patterns that could reduce tissue concentrations.
- Assuming that birds would have similar levels of fat as mammals. This may or may not be true, and would be expected to vary seasonally and by species. Some authors adjust BAFs for mammals before applying them to birds. This would only influence predicted dietary uptake for lipophilic (i.e., attracted to fat) COIs such as the volatile organic compounds (VOCs) or semi-volatile organic compounds (SVOCs). Metals typically do not bioaccumulate on a lipid weight basis.

The volunteer may choose to sample tissue concentrations rather than relying on bioaccumulation modeling. The volunteer may also elect to perform an in-depth literature review for current scientific information regarding bioaccumulation factors and uptake modeling. Any such approach should be discussed with DEQ prior to implementation.

If a BAF is a constant value, it is multiplied by the media concentration to obtain an estimated tissue concentration. If the BAF or uptake rate varies with media concentration, a regression equation is used. These equations typically predict higher uptake rates at lower media COI concentrations. The lowest medium-specific ERBSC for each COI was used to calculate the BAFs for dietary items using equation A-2 above.

3.1.3 ERBSC Values for Soil and Sediment

The receptor group specific ERBSCs are reported in Table A-5 for each of the receptors expected to contact soils. The ERBSCs for each of the receptors expected to contact sediments are reported in Table A-6.

3.2 Receptor Group ERBSCs for Surface Water

The receptor group ERBSCs for surface water include the assumption that birds and mammals utilize the water body as the sole drinking water source, and that they feed in the surrounding aquatic or riparian area where the prey and forage items are contaminated by contact with surface water. The equation to predict the ERBSC for surface water is as follows:

$$ERBSC = \frac{(HQ_{i+1} * TRV_{i+1})}{[WIR_{i+1} * (\Sigma(P_i * BCF_i)]} \qquad \text{[Eq. A-6]}$$

Where:

HQ_{i+1} = Hazard quotient for trophic level ***i+1*** (unitless)
ERBSC = Surface water ERBSC (mg/L)
P_i = Proportion of dietary item ***i*** in diet of trophic level ***i+1*** (Table A-2)
TRV_{i+1} = Toxicity reference value for animal eating dietary item ***i*** (mg/kg-d) (Table A-3)
BCF_i = Dietary item ***i*** bioconcentration factor for uptake from water (unitless) (Table A-4)
WIR_{i+1} = Water ingestion rate (L/kg bw-d) for trophic level ***i+1*** (Table A-2)

For uptake from water, the term bioconcentration is typically applied, and the bioconcentration factor (BCF) (concentration in tissue divided by the concentration in water) is used as opposed to BAF. Fish were the only receptor group for which BCFs were obtained. Aquatic plants and invertebrates were modeled as obtaining contaminants from sediment only. This is because the proportion contributed by sediment pore water or groundwater is often an unknown. This assumption simplifies the calculation of the ERBSCs and is expected to be appropriate because many of the bioaccumulative organic COIs are not highly water soluble. In addition, studies have shown that metal bioaccumulation from all sources in the field tends to be higher than laboratory derived BCFs based on water exposure only (DeForest et al., 2007). Receptor group ERBSCs for surface water are provided in Table A-7.

4.0 Raw Data Used to Generate Summary Tables

The raw toxicological data and the sources used to generate the TRV summary table are reported in Table A-8. The bioaccumulation data, equations, and sources used to generate the summary of BAFs and BCFs are reported in Table A-9. The life history information for each of the receptors is reported in Table A-10.

5.0 Conclusions

Receptor group ERBSCs were developed for each of the Wyoming receptors identified in Table A-2 if TRVs, and BAFs or BCFs were available.

The receptor group ERBSCs that are inclusive of dietary ingestion as well as direct ingestion of abiotic media for sediment are lower than the medium specific ERBSCs for metals. Using the minimum receptor group ERBSC for inorganics or metals would be protective of benthic communities. The benthic community is more sensitive than birds and mammals for many of the SVOCs, and using the ERBSCs based on freshwater sediments would be protective of birds and mammals. A consistent pattern for soil is not apparent.

The receptor group ERBSCs for surface water include bioconcentration from surface water by fish and dietary ingestion of fish by birds and mammals. The medium-specific ERBSCs for metals and inorganics are lower than those receptor group ERBSCs for birds and mammals. However, the polynuclear aromatic hydrocarbons (PAHs) are predicted to bioconcentrate in fish tissue, and the receptor group ERBSCs for birds and mammals for many of the individual high molecular weight (HMW) PAHs are lower than the medium-specific ERBSCs that are values based on direct exposure to aquatic life.

The receptor group ERBSCs may be lower than the medium-specific ERBSCs if the receptor group is particularly sensitive to a given COI and/or the COI is bioaccumulative. Use of the medium-specific ERBSC could then potentially screen out a COI that would in fact potentially have adverse effects for avian or mammalian wildlife. To effectively remove COIs that do not present ecological risk, the DEQ prefers that the lowest receptor-group ERBSC for each COI be cross-checked with the medium-specific ERBSC.

REFERENCES:

DeForest, D.K., K.V. Brix, and W.J. Adams. 2007. Assessing metal bioaccumulation in aquatic environments: the inverse relationship between bioaccumulation factors, trophic transfer factors, and exposure concentration. *Aquatic. Toxocol*. 84: 236-246.

Efroymson, R.A., M.E. Will, G.W. Suter II, and A. C. Wooten. 1997a. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, N.ES/ER/TM-85/R3. November 1997.

Efroymson, R.A., M.E. Will, G.W. Suter II. 1997b. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Processes: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, N.ES/ER/TM-126/R2. November 1997.

Efroymson, R.A., G.W. Suter II, B.E. Sample and D.S. Jones. 1997c. Preliminary Remediation Goals for Ecological Endpoints. Oak Ridge National Laboratory, Oak Ridge, TN.ES/ER/TM-162/R2. August 1997.

Eisler, R. 1987. Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Patuxent Wildlife Research Center, MD. Biological Report 85(1.11). Contaminant Hazard Reviews. Report No. 11. May 1987.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

MacDonald, D.D., and USGS. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters, Technical Report, January 2003.

Risk Assessment Information System (RAIS). 2011. Ecological Benchmark Tool. http://rais.ornl.gov/tools/eco_search.php.

Sample, B.E., D.M. Opresko, and G.W. Suter. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. Oak Ridge National Laboratory. ES/ER/TM-86/R3. June 1996.

USEPA. 1977. Guidelines for the pollution classification of Great Lakes Harbor sediments. United States Environmental Protection Agency. Region V. Chicago, Illinois. (As cited in MacDonald and USGS 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters, Technical Report, January 2003).

USEPA. 2005a. Ecological Soil Screening Levels for Arsenic. Interim Final. Office of Solid Waste and Emergency Response. Washington D.C. March 2005. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2005b. Ecological Soil Screening Levels for Barium. Interim Final. Office of Solid Waste and Emergency Response. Washington D.C. February 2005. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2005c. Ecological Soil Screening Levels for Cadmium. Interim Final. Office of Solid Waste and Emergency Response. Washington D.C. March 2005. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2005d. Ecological Soil Screening Levels for Cobalt. Interim Final. March 2005. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2005e. Ecological Soil Screening Levels for Lead. Interim Final. Office of Solid Waste and Emergency Response. March 2005. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2006. Ecological Soil Screening Levels for Silver. Interim Final. Office of Solid Waste and Emergency Response. September 2006. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2007a. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs). Interim Final. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2007b. Ecological Soil Screening Levels for Copper. Interim Final. February 2007. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2007c. Ecological Soil Screening Levels for Selenium. Interim Final. Office of Solid Waste and Emergency Response. July 2007. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2007d. Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). Attachment 4-1. Revised April 2007. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2008. Ecological Soil Screening Levels for Chromium. Interim Final. March 2005. Revised April 2008. http://www.epa.gov/ecotox/ecossl/.

USEPA. 2011. National Recommended Water Quality Criteria. http://water.epa.gov/scitech/swguidance/standards/current/index.cfm#appendxb. November 6, 2011.

USEPA. 2011c. Integrated Risk Information System (IRIS). http://cfpub.epa.gov/ncea/iris/.

USEPA. 2013. Ecological Soil Screening Level (EcoSSL) Reports and Guidance Documents. http://www.epa.gov/ecotox/ecossl/.

Wyoming Department of Environmental Quality (). 2011. Water Quality Rules and Regulations. Chapter 1. Wyoming Surface Water Standards. Appendix B-1.