State of Hawaii, Department of Health
HEER Office

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APPENDIX 21-C

DEFINING ECOLOGICALLY-BASED DECISION UNITS

An important step in the DQO process is to define the study boundaries, which includes defining decision units (DUs). A general discussion of DUs is presented in Subsection 3.4 of the Hawaiʻi HEER TGM. As discussed above, The HEER Office has adopted the use of Multi Increment sampling (MIS) sampling for specific applications and suggests that the size and shape of a DU is primarily controlled by the environmental concerns posed by the contaminants present at the site. (HDOH 2018, ITRC, 2012) Ecological DUs should be based on: (1) the phase of ecological risk assessment being planned (SLERA or BERA); (2) the assessment endpoints and receptors of interest; and (3) the available habitat and its contiguity with site.

Ecological DUs must be defined both laterally and vertically. The approach to defining the lateral extent of a DU should consider the following factors:

- **The ERA process, particularly problem formulation, conceptual site model (CSM) development, and the resulting assessment endpoints** The assessment endpoints selected for the site, and the receptors selected to represent them, are the critical first step in defining the lateral extent of a DU.
- **Population versus individual exposures.** With the exception of special status species (those listed as rare, threatened, or endangered) or migratory birds, risk management decisions for vertebrates should be based upon protecting local receptor populations. Lower trophic level receptors, such as benthic invertebrates, are typically assessed at the community level. However, ERAs for upper trophic level wildlife species (e.g., birds and mammals) are typically based on effects to individuals. Individual-level responses are then used to estimate population-level responses for management purposes (Sample et al. 1996). It can be assumed that there is a distinct (local) population of the receptor of interest on the site so that the exposure of the population is represented by the exposure of all of the individuals, which are assumed to experience equivalent exposure. This assumption is appropriate for organisms with relatively small home ranges.
  It is thus critical to define the population and address questions of scale. The size of a typical sediment site is generally too small to support viable populations of most upper trophic level receptors. However, many sites can support populations and communities of lower trophic level species such as sediment invertebrates, coral, and aquatic plants. Confined aquatic habitats (Anchialine Pools, tidepools, etc.) may support distinct populations and communities of benthic invertebrates and fish. For tidal creeks, bays, harbors, etc., portions of the water body may be capable of supporting populations or communities of receptors, but they are not isolated and may "exchange" organisms with off-site areas. This may con-

found attempts to determine if there are impacts, since immigration from surrounding, un-contaminated areas may mask the effects of site-associated contaminants.

Fish and other aquatic communities in streams and rivers should be generally be defined by reach, which is the appropriate scale at which to address effects (Suter 2007). The size of the reaches (which could correspond to DUs) may be defined based upon changes in physical attributes (such as habitat shifts represented by sediment grain size distribution, marine influence, and wave energy) and habitat attributes.

For mobile vertebrates, such as birds and mammals, the population is generally defined as a function of individual spatial use patterns (home range). Sites sufficiently large to contain multiple home ranges for a given species can be said to support a "local population" of that species provided that the habitat is suitable. Home ranges can be defined in a number of ways, depending upon receptor. During the breeding season, some species defend territories that contain all life requisite needs (food, breeding sites, etc.). Others may defend small breeding sites but forage (nonexclusively) over larger areas. Because ingestion of food is the greatest exposure pathway for these receptors, the foraging range strongly influences site-related exposure. For species with home ranges smaller than the area of suitable habitat present on a site, it is typically assumed that exposures (on a spatially averaged basis) of individuals can be extrapolated to the population level. For species whose home range size exceeds the area of suitable habitat at a site, a site use factor (SUF), calculated as the area of suitable habitat on the site divided by the home range, is typically used to adjust the exposure.

- **Seasonal considerations**. Some species are migratory and only spend a portion of the year in an area. Upper trophic level receptors are typically selected and exposures calculated based upon the breeding season. This is because reproduction is often emphasized as the toxicological endpoint in ERAs, and reproductive effects are generally most relevant to population-level effects (especially when extrapolated from individual-level responses).
- **Bioaccumulation and bioavailability considerations.** Bioaccumulation and bioavailability may vary across the site based upon variability in factors that influence these functions, such as pH, total organic carbon (TOC), grain size, and acid-volatile sulfide/simultaneously extracted metals (AVE/SEM). The influence may be direct (through binding or otherwise limiting bioavailability) or indirect (by influencing the form of the chemical to a species that is less toxic). Although most receptors are not expected to perceive or respond directly to differences in bioavailability of chemicals, they will respond to physical or chemical features of the habitat known to influence bioavailability. For example, a given receptor may prefer a certain range of pH, TOC, or grain size, and so may indirectly increase or decrease exposure to chemicals in microhabitats.
- Depositional or Accretional Areas. The processes of erosion and deposition of sediment creates a patchwork of unconsolidated substrates throughout coastal Hawaiʻi. Physical characteristics of the sediment particles, such as grain size and associated organic carbon, play a substantial role in the fate and transport, bioavailability, and toxicity of contaminants in the marine environment. Many chemicals that cause ecological effects (such as metals,

pesticides, PCBs) are known to be associated most strongly with finer-grained sediment, especially silts and clays (also called “muds”) (Morrison et al. 2011). Fine-grained sediments generally accumulate in coastal bays and other sites where wave energy is low or absent. Contaminant concentrations are expected to be highest in such depositional areas where particles smaller than 62.5 µm accumulate (NRC 1989, Grabe and Barron 2004). In contrast, sites with predominantly sand or gravel are less likely to contain toxic levels of contaminants (Morrison et al. 2011). The U.S. Geological Survey (USGS) has conducted numerous studies of natural processes that affect erosion and deposition in Hawaiʻi. Geophysical processes affect not only where sediments accumulate, but also how receptors are exposed to contaminated sediments. See (Fletcher et al. 2012) for a summary of discussion of depositional and erosional areas in Hawaiʻi.

The vertical extent of a DU is defined by the depth to which ecological receptors are typically exposed (HDOH 2018). For sediment, the depth of samples to evaluate ecological exposures should generally be from the sediment surface down to the redox boundary, which generally defines the biologically active zone. This is generally no deeper than 5 to 15 cm in marine systems.

[Additional guidance on defining DUs for ERAs in Hawaiʻi is under development.]