Division of Water
Water Quality Program

DRAFT LINGERING OIL LISTING METHODOLOGY
Technical Support Documentation

Prepared for

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

%	percent
µg/L	microgram(s) per liter
AAC	Alaska Administrative Code
DEC	Alaska Department of Environmental Conservation
ARCS	Assessment and Remediation of Contaminated Sediments
ASTM	ASTM International
BaP	benzo(a)pyrene
CALM	Consolidated Assessment and Listing Methodology
cm	centimeter(s)
ECCC	Environment and Climate Change Canada
ERM	effects range medians
EVOS	*Exxon Valdez* Oil Spill
HOR	heavy oil residue
HMW	high molecular weight
km	kilometer(s)
LM	listing methodology
LMW	low molecular weight
LOEC	lowest observable effects concentration
LOR	light oil residue
m	meter(s)
MEP	maximum extent practicable
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
MOR	moderate oil residue
NEC	no effect concentrations
NOAA	National Oceanic and Atmospheric Administration
PAH	polycyclic aromatic hydrocarbon
PCL	protective concentration levels
PEC	probable effects concentrations
PEL	probable effects level
PWS	Prince William Sound
SCAT	Shoreline Cleanup Assessment Technique
SPAR	Division of Spill Prevention and Response
SQuiRTS	Screening Quick Reference Tables
USEPA	United States Environmental Protection Agency

1. OVERVIEW AND BACKGROUND

This document presents the supporting data and rationale for the Lingering Oil Listing Methodology (LM). This LM is a data-driven approach that the State of Alaska Department of Environmental Conservation (DEC) will use to evaluate areas affected by Lingering Oil (LO). The unique characteristics of LO and the cold climate of Alaska necessitated this effort. Unless disturbed, LO has limited interaction with water and biota and may persist in the environment indefinitely. DEC recognized a need to be able to evaluate if areas with LO are meeting state water quality criteria. Various data types were integrated, and thresholds were established based on widely accepted practices and the current state of knowledge. While the extensive data from the *Exxon Valdez* Oil Spil (EVOS) were used to develop multiple lines of evidence (tiers), it is designed to be applied across the State of Alaska.

DEC uses listing methodologies (LM) to assess if waters are attaining Alaska water quality standards. The LMs outline the magnitude, frequency, and duration of pollution and describe what data and information is necessary, how the data are used, the analytics performed, quality assurance requirements, and the process or thresholds for determining attainment. DEC currently follows a consolidated assessment and listing methodology (CALM) unless LMs for specific pollutants, such as pathogens, and turbidity, have been developed.

DEC has reviewed EVOS information regarding the presence of subsurface (greater than 5 centimeters [cm] below surface) lingering oil (consisting of petroleum hydrocarbons); however, DEC has not historically had a LM specifically addressing lingering oil. DEC has prepared the LM for lingering oil to evaluate attainment of water quality standards. This document supports the technical basis for the LM. The LM does not alter the authorities under 18 Alaska Administrative Code (AAC) 75 Article 3 allowing DEC under management of the Division of Spill Prevention and Response (SPAR) to require a release of a hazardous substance be investigated, contained, and cleaned up.

1.1 Lingering Oil Definition

The following definition has been developed to support this LM. It has undergone review by the DEC, DEC internal counsel, and the EVOS Trustee Council.

Definition: Lingering oil is an oil[1] residue deposited in shoreline sediment[2] from an anthropogenic release that is generally not bioavailable unless disturbed.

The components of this definition are detailed as follows:

> **"Lingering oil is an oil residue"** defines oil per Alaska Statutes (AS) 46.04.900.

[1] Definition per AS 46.04.900
[2] Definition per 18 AAC 70.990

“deposited in shoreline sediment” indicates that this definition is focused on oil entrained in sediments along a shoreline, which excludes floating oil and sheens, which are generally indicative of newly spilled oil.

“from an anthropogenic release” specifies the origin of this oil is not from a natural source such as seeps.

“that is generally not bioavailable unless disturbed.” A key characteristic of lingering oil is that organisms are not exposed to it when it is buried, and further weathering or biodegradation is likely to be very slow without the input of oxygen and nutrients made available when it is disturbed by storm action or other events.

This definition of lingering oil provides a basis for interacting with the Alaska water quality standards. The definition also clearly separates lingering oil from freshly oiled locations due to anthropogenic releases so that lingering oil can be managed separately from freshly spilled oil and naturally occurring seeps.

1.2 Background

The *Exxon Valdez* Oil Spill released 11 million gallons of oil into Prince William Sound (PWS) and approximately 10% was recovered (National Oceanic and Atmospheric Administration [NOAA] 2014), with the remainder naturally degrading or becoming trapped along the shorelines of PWS. Based on studies since the spill, it is estimated there is significant mass of residual oil sequestered in stony/gravelly sediment near and below mean sea level. This mass of oil is not being biodegraded, generally because (1) these sediments are not oxygenated, which impedes aerobic microbial hydrocarbon degradation; (2) the temperature in these sediments is cold enough to slow microbial enzyme systems; (3) the tidal energy is relatively low; and (4) any readily biodegradable or readily volatilizable fractions have already been consumed or volatized.

The areal extent of lingering oil on the shorelines in PWS is not well defined because beaches are widely distributed and only a small fraction of shoreline has been explored and characterized for lingering oil. Modeled information has identified areas where lingering is most likely to occur. The most recent assessment of beaches within PWS was performed in 2010 and relied primarily on the concentrations of petroleum hydrocarbons in shoreline sediments and modeled data, which predicted the probability that a beach would be oiled (i.e., contained lingering oil). Since that time, studies conducted to assess the presence and extent of lingering oil have determined that oil from the *Exxon Valdez* Oil Spill is buried within the sediments of PWS, remains in the same state of degradation as it has been for last two decades, and is not bioavailable until it is disturbed (Aderhold et al. 2018).

1.3 Existing DEC Water Quality Standards

Initial receptors and pathways most likely at risk from lingering oil were evaluated to identify designated uses and water quality standards to be incorporated in the LM. **Table 1-1** provides the list of receptors and pathways considered.

Table 1-1: Receptors and Pathways Most Likely at Risk from Lingering Oil

Human Health	• Ingestion of fish and shellfish contaminated by lingering oil • Water supply for aquaculture or seafood processing • Contact recreation and secondary recreation (swimming, water skiing, boating, camping, wading, and recreational fishing)
Aquatic Life	• Direct contact with lingering oil in sediment • Direct contact with soluble fractions of lingering oil • Ingestion of water and sediment contaminated by lingering oil • Ingestion of other organisms contaminated by lingering oil
Economic	• Growth, propagation, and harvest of fish, shellfish, or other aquatic life

Current exposures of sensitive, rare, threatened, endangered, or previously harmed species (such as Pacific herring, pigeon guillemots, marbled murrelets, and orcas) are likely to be via the food web and ingestion of prey items.

1.3.1 Designated Uses

DEC has designated uses applicable to the various receptor pathways for freshwater and marine shoreline environments. The designated uses are found at 18 AAC 70.020(a) and provided in **Table 1-2** along with whether the designated use is relevant to lingering oil.

Table 1-2: Designated Uses Relevant to Lingering Oil

Designated Use	Relevant to Lingering Oil
(1) Fresh water	Yes
(A) Water supply	Yes
(i) Drinking, culinary, and food processing	Yes
(ii) Agriculture, including irrigation and stock watering	Yes
(iii) Aquaculture	Yes
(iv) Industrial	Yes
(B) Water recreation	Yes
(i) Contact recreation	Yes, such as swimming, diving
(ii) Secondary recreation	Yes, such as boating, camping, hunting, hiking, wading, and recreational fishing, but not consumption of fish
(C) Growth and propagation of fish, shellfish, other aquatic life, and wildlife	
(2) Marine water	Yes

Designated Use	Relevant to Lingering Oil
(A)Water supply	Yes
(i) Aquaculture	Yes
(ii) Seafood processing	Yes
(iii) Industrial	Yes
(B) Water recreation	Yes
(i) Contact recreation	Yes, such as swimming, diving
(ii) Secondary recreation	Yes, such as boating, camping, hunting, hiking, wading, and recreational fishing, but not consumption of fish
(C) Growth and propagation of fish, shellfish, other aquatic life, and wildlife	Yes
(D) Harvesting for consumption of raw mollusks or other raw aquatic life	Yes

1.3.2 Numeric and Narrative Water Quality Standards

Narrative and numeric water quality standards were considered during the development of the LM to determine if a waterbody is attaining or impaired due to lingering oil, including petroleum hydrocarbons, which can affect watercolor or dissolved oxygen or cause floating solids and other residues. The criteria that were considered are as follows:

- Color (18 AAC 70.020[b][1] and [13]) must meet the following:
  - May not exceed a certain number of color units or the natural condition (whichever is greater).
  - Surface waters must be free of substances that produce objectionable color.
  - Color or apparent color may not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life.
- Dissolved oxygen (18 AAC 70.020[b][3] and [15]) may not be as follows:
  - Less than 6.0 milligrams per liter (mg/L) for a depth of 1 meter (m) except when natural conditions cause this value to be depressed.
  - Reduced below 4.0 mg/L at any point beneath the surface.
  - Less than 5.0 mg/L in tributaries and estuaries except where natural conditions cause this value to be depressed.
  - Higher than 17 mg/L and the concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.

- For residues (18 AAC 70.020[b][8] and [20]), floating solids, debris, sludge, deposits, foam, scum, or other residues may not do as follows:
  - Make water unfit or unsafe for designated uses.
  - Detrimentally affect established water supply treatment levels.
  - Make the water unfit or unsafe for use.
  - Cause a film, sheen, or discoloration on the surface of the water or adjoining shorelines.
  - Cause leaching of toxic or deleterious substances.
  - Cause sludge, solid, or emulsion to be deposited beneath or upon the surface of the water, within the water column, on the bottom, or upon adjoining shorelines.

DEC water quality standards provide specific numeric and narrative criteria for petroleum hydrocarbons (18 AAC 70.020[b][5] and [17]) that were considered:

- They may not make the water unfit or unsafe for its designated use.
- Total aqueous hydrocarbons in the water column may not exceed 15 micrograms per liter (µg/L).
- Total aromatic hydrocarbons in the water column may not exceed 10 µg/L.
- There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life.
- Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.
- Petroleum hydrocarbons may not cause a film, sheen, or discoloration on the surface or floor of the waterbody or adjoining shorelines.
- Surface waters must be virtually free from floating oils.
- Petroleum hydrocarbons may not exceed concentrations that individually or in combination impart odor or taste as determined by organoleptic tests.

DEC narrative criteria for toxic and deleterious substances (18 AAC 70.020[b][11] and [23]) also include protective language that was evaluated for applicability to lingering oil:

- Substances may not be introduced that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on designated uses.
- Concentrations of substances that pose hazards to worker contact may not be present.
- There may be no concentrations of substances in water that alone or in combination with other substances make the water unfit or unsafe for the use.

- Concentrations of substances that pose hazards to incidental human contact may not be present.
- The concentration of substances in water may not exceed the numeric criteria for aquatic life for marine water and human health for consumption of aquatic organisms or any Alaskan chronic and acute criteria.
- Concentrations must protect sensitive and biologically important life stages of resident species of Alaska.
- There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, adverse effects on aquatic life or produce undesirable or nuisance aquatic life.
- Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests.

Additionally, there are fresh water and marine sediment narrative criteria (18 AAC 70.020[b][9] and [21]). Given that the lingering oil is entrained in the sediment, these criteria were also considered. The sediment narrative criterion states that marine sediments *"May not pose hazards to incidental human contact or cause interference with use."*

1.3.3 Decision on Designated Uses and Water Quality Standards for Lingering Oil

After review of the existing DEC water quality standards, the decision has been made to rely on narrative criteria when considering lingering oil. **Table 1-3** summarizes which of the standards are relevant to lingering oil. The specific narrative criteria for the three relevant standards are presented in Table 1-1 and Appendix A of the LM.

Table 1-3: Water Quality Standards Relevant to Lingering Oil for Fresh and Marine Water

Standard Number	Standard Name	Applicable to Lingering Oil?
(1) / (13)	Color	Yes, although lingering oil is sequestered, lingering oil has the potential to affect color
(2) / (14)	Bacteria	No, fecal coliforms are not relevant to lingering oil
(3) / (15)	Dissolved Gas	No, standards are only numeric, not narrative, and therefore not relevant to lingering oil
(4) / (16)	Dissolved Inorganics	No, dissolved inorganics (e.g. total dissolved solids, salinity) are not relevant to lingering oil
(5) / (17)	Petroleum Hydrocarbons, Oils and Grease	Yes, lingering oil is a petroleum or oil
(6) / (18)	pH	No, standards are only numeric, not narrative, and therefore not relevant to lingering oil
(7) / (19)	Radioactivity	No, radiation is not relevant to lingering oil

Standard Number	Standard Name	Applicable to Lingering Oil?
(8) / (20)	Residues	Yes, lingering oil could be considered a residue
(9) / (21)	Sediment	Yes, lingering oil is entrained in sediment, and has potential to affect sediment
(10) / (22)	Temperature	No, standards are only numeric, not narrative, and therefore not relevant to lingering oil
(11) / (23)	Toxic and Other Deleterious Organic and Inorganic Substances	Yes, lingering oil could be considered a toxic substance
(12) / (24)	Turbidity	No, lingering oil is sequestered and unlikely to cause a turbidity concern in the water

1.4 Waterbody Categories

Waterbodies and adjoining shoreline assessment units are assigned to one of five categories in Alaska's Integrated Water Quality Monitoring and Assessment Report (**Table 1-4**). The assignment of a category is based on the data assessment and attainment determinations described in the LM. Assignment of a waterbody to categories 1 and 2 indicates designated uses are being attained, while assignment to category 5 indicates the water is impaired and will be placed on the 303(d) list. The data categories used in this LM are consistent with those listed in DEC's CALM (2021).

Table 1-44: Category Definitions

Category	Description
Categories 1 and 2	Waters for which there is enough information to determine that water quality standards are attained for all or some of their designated uses.
Category 3	Waters for which there is not enough information to determine their status.
Category 4	Waters that are impaired but have one of several different waterbody recovery plans.
Category 5	Waters that are impaired and do not yet have waterbody recovery plans. Also known as 303(d) list impaired waters.

1.5 Other Relevant DEC Regulations Considered

DEC's SPAR division handles fresh oil spills and emergency response to spills. SPAR spill regulations for cleanup of hydrocarbons are driven by human health exposure pathways (dermal, inhalation, ingestion). SPAR states that *"Cleanup levels are the concentrations of a hazardous substance that may be left in soil or water without posing a threat to human health, safety or welfare, or to the environment"* (DEC 2022). SPAR regulations are set out in 18 AAC 75, which indicates a consideration of environmental protection carried out via water quality criteria, cleanup goals, and other Alaska guidance.[3] During development of the LM, regulations under 18 AAC 75 were evaluated for applicability. Details of those can be found in Appendix A.

After evaluation of the existing DEC regulations that could apply to lingering oil, it was decided that none are specific to lingering oil impairment of water bodies and/or shorelines. While SPAR could be helpful for obtaining test pit and observational data if a shoreline is within a contaminated site, the contaminated sites cleanup criteria are not specific to bioavailability of lingering oil for assessing water quality for designated use attainment or impairment.

1.6 EVOS

The development of the LM was informed by the behavior of crude oil in natural systems and understanding of the fate of large oil releases, specifically the EVOS. Crude oil has naturally existed as part of the marine environment for millions of years. Some life, such as microbes, have evolved to use crude oil as an energy source and exist in seawater, sediment, and shorelines around the world. PWS was found to have other sources of hydrocarbon residues from Californian tar imported to PWS for construction, diesel and diesel soot from anthropogenic activities, and refined oil products (like fuels; Bence et al. 1996).

Following an oil spill and cleanup efforts, small amounts of stranded oil will degrade under natural conditions. In contrast, concentrated oil that becomes entrained in anerobic sediments will be degraded by bacteria several orders of magnitude more slowly. Additional factors that influence beached oil persistence include the size of the spill, the extent and rapidity of cleanup efforts, climate, and tidal energy. For example, coastal environments recovered rapidly (within a few years) following the 2007 *Hebei Spirit* oil spill in South Korea (13 million liters of crude oil, approximately one-third the size of EVOS) due to massive shoreline cleanup activities and the high tidal energy of the area (approximately 9 m of tidal range; Barron et al. 2020).

Thus, spilled crude oil can become lingering oil if it is a large spill, cleanup efforts are insufficient or delayed, in colder climates, and in environments with low tidal energy. Additionally, for oil to persist it needs to be able to penetrate deeply into the sediment into low-nutrient anoxic zones. The large pore spaces in cobble/gravel beaches allow for oil movement deeper into the sediment and are more likely to host lingering oil than sandy beaches. Generally, lingering oil in PWS is found under 10 to 20 cm of clean sediment and is 5 to 20 cm thick (Lindeberg et al. 2017). Oil in PWS has persisted for over 30 years following the oil spill because it is sequestered from hydrological washing and other natural weathering processes. Additionally, the low oxygen and nutrient levels inhibit biodegradation. Lingering oil also differs chemically from crude oil because it will be weathered to some degree; it is generally low in n-alkanes and has fewer polycyclic aromatic hydrocarbons (PAHs). While not as toxic as crude oil, weathered oil still retains high concentrations of phenanthrenes and chrysenes relative to crude oil, and it maintains toxic potential if disturbed and reintroduced into the environment.

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[3] See DEC's Contaminated Sites website for more guidance: https://dec.alaska.gov/spar/csp/guidance-forms/.

The EVOS occurred on March 24, 1989, in PWS. Since then, hundreds of scientific investigations have looked at the long-term fate, transport, and effects of the EVOS on the ecological communities of PWS. More than 30 years of research have provided a great deal of information on the persistence of oil and the responses of different species to both acute (short-term) and chronic (long-term) effects of exposure to oil, as well as the role the ecosystem plays in the recovery of affected species. EVOS data forms the bulk of the oil spill data for the state of Alaska and will make up the majority of the initial dataset used by this LM.

At the time of the EVOS, approximately 10% of the released oil was recovered from beaches and surface water. During the last 36 years, much of the unrecovered oil has degraded through natural processes. For example, microorganisms that can break down oil exist in all marine environments, including cold, deep, and high-pressure settings (Hazen and Prince 2015). Marine half-lives of dispersed oil can range from days to months, while undispersed oil has longer half-lives due to the reduced surface area. Despite the cleanup efforts and action of natural processes, a portion of the initial EVOS oil spill persists in the aquatic environment as sequestered subsurface oil and surface oil patches (Aderhold et al. 2018).

The intertidal zones of some beaches in PWS impacted by the EVOS are still considered water quality impaired. These beaches have been assessed as impaired since 1990 due to petroleum hydrocarbons exceeding Alaska's water quality standards. The EVOS Trustee Council has executed multiple projects focusing on the long-term fate and transport of lingering oil and long-term monitoring of marine conditions and injured resources, harbor protection and marine restoration, and habitat acquisition and protection.

1.6.1 Expert Interviews Regarding EVOS

Experts on lingering oil in Alaska were interviewed to identify key resources, reports, and studies. These interviews provided insights into how experts from different agencies and sectors studying the effects of lingering oil in PWS opine on the subject. Based on expert interviews, seven documents were identified for inclusion in a literature review. Critical documents included reports from the EVOS portal, studies from the *Deep Sea Research Part II* special issue, and reports from the Alaska Department of Fish and Game.

1.6.2 Existing Literature Review Regarding EVOS

DEC conducted a literature review for documents published since 2015 relevant to the study objective. An initial 53 peer-reviewed journal articles and/or reports were identified for preliminary consideration. The list was reduced to the 25 most relevant to the project by evaluating each paper for inclusion of relevant species and data as well as those recommended by experts. Projects that had recent data as well as geolocations of lingering oil were prioritized. An annotated bibliography was prepared and published online (Geosyntec Consultants, Inc., 2023).

These are some of the main points that drove the need for developing a new LM:

- There is significant mass of residual oil from EVOS left in stony/gravelly sediment near and below mean sea level.
- This mass of oil is not being biodegraded, generally because (1) these sediments are not oxygenated, which impedes aerobic microbial hydrocarbon degradation; (2) the temperature in these sediments is cold enough to slow microbial enzyme systems; and (3) any readily biodegradable or readily volatilizable fractions have already been consumed or volatized.
- Only a small fraction of shoreline has been surveyed on foot and characterized for lingering oil.
- Important wildlife receptors (particularly populations of Pacific herring, pigeon guillemots, marbled murrelets, and orcas) have not recovered since the EVOS for a multitude of factors and are indicative of long-term challenges to the environment in PWS. Populations of ecological receptors are important to consider in the context of lingering oil but might not rebound due to other factors than EVOS.
- Subsistence harvesters in PWS who catch chinook, pink, chum, and sockeye salmon, king and Tanner crabs, halibut, rockfish, herring, and shrimp could also be exposed to hydrocarbons via the food web. Human receptors (via ingestion pathway) are important to consider in the context of lingering oil.
- A significant amount of research has occurred following the EVOS, and this research can be used to determine the status of EVOS-impacted beaches with remaining lingering oil.

1.7 Review of Other Jurisdiction Approaches

An initial review of lingering oil approaches used by other states and countries was conducted. The states of Texas, Louisiana, Maine, Washington, and Oregon were targeted for their coastal locations, climate, and/or oil production. The northern countries of Canada, Norway, and the United Kingdom were targeted for their similar climate and coastlines. None of the states and countries researched had information specifically related to lingering oil. However, many states and countries had narrative and/or numeric criteria that directly or indirectly include petroleum hydrocarbons or PAHs, such as the following:

- A water quality criterion for phenanthrene for aquatic life
- Water and sediment toxicity testing
- Sediment contaminant screening levels for individual PAHs, low and high molecular weight PAHs, and total PAHs
- Fish and benthic community assessments
- Assessment of aquatic habitat quality, habitat suitability
- Percent (%) acceptable taxa or faunal loss in a specific locale

Many countries including the United States, Canada, and the United Kingdom have published Shoreline Cleanup Assessment Technique (SCAT) guidelines. The primary United States SCAT guidelines originate from NOAA. The United States Environmental Protection Agency (USEPA) Region 10 also has its own SCAT guidelines. These SCAT guidelines were considered for developing LM for the evaluation of shorelines impacted by oil. However, in general, SCAT guidelines do not provide specific values for assessing shorelines and making attainment or impairment determinations.

The 2013 NOAA SCAT provides some general guidelines/suggestions that specify cleanup termination endpoints that are decided on a case-by-case basis, involving public/stakeholder input as well as considering other factors. However, there are documents specifically outlining cleanup endpoints for coastal oil spills such as the 2007 Environment and Climate Change Canada (ECCC) guidelines (2018), the 2002 International Tanker Owners Pollution Federal Limited white paper (2002), or the 1999 guidelines by Michel and Benggio. These termination endpoints were evaluated as part of the LM's attainment thresholds for lingering oil. The 2011 Deepwater horizon oil spill completion plan (Deepwater Horizon Unified Command Group 2011) provides shoreline cleanup endpoints that were also evaluated for development of the LM. Ultimately, these endpoints were not considered appropriate for lingering oil because they assume some level of degradation will continue to occur in the future.

1.8 Shoreline Segments/SCAT Relating to Development of Assessment Units

Waterbodies are segmented in smaller units for the purpose of evaluating the attainment of designated uses, called assessment units. These assessment units can vary in scale depending on the natural characteristics of the waterbody being evaluated. For developing the LM, the SCAT guidelines and associated PWS beach segmentation were reviewed to understand if a common shoreline segment length could be used to help define an assessment unit's length and sample density.

SCAT guidelines recommend that a shoreline be segmented into sections 0.2 to 2 kilometers (km) long, averaging 500 m, based on geological features (such as a headland or change in shoreline type), a change in oiling conditions, a river mouth, or jurisdictional boundaries. The section lengths are based on a goal to create lengths that are small enough to be effectively clean but large enough to provide meaningful data. Although the objective of the shoreline segments for SCAT differs slightly from determining if a waterbody is attaining or impaired due to lingering oil, the scale remains effective for decision-making. Importantly, because shoreline segments lengths are often first defined by SCAT in spill response, using the same segments can be effective to gauge changes over time.

The density of data per assessment unit was considered. There are no specific guidelines for the number of test pits to be dug per shoreline segment, because this can be influenced by many factors such as accessibility, degree of oiling, suspicion of buried oil, etc. The criterion of at least 10 test pit data points per shoreline segment is a reasonable minimum number from a statistical perspective, providing a resolution of 20 to 200 m. Oil spill impacts to shorelines can vary widely from a spatial perspective. The type of oil, wind, waves, currents, and shoreline morphology can affect the area of a shoreline that is oiled. These factors should be considered and provide a basis for having a lower resolution of data on longer segments and a higher resolution of data on shorter segments.

Surveys conducted in PWS from 2001 to 2021 average one test pit dug for every 2 m of shoreline segment where repeat surveys were conducted to characterize known impacted shoreline segments. For the recent efforts, the median shoreline segment length is 84 m with a median of 48 test pits per segment. Although SCAT and recent PWS test pit surveys provide an appropriate basis for sizing assessment units within PWS, due to variability in waterbodies across Alaska, it was decided that assessment units for lingering oil would follow DEC's current process for consistency and are based on a hydrologic unit code.

1.9 Assessment Level Data Requirements

Assessment level data requirements presented in the CALM (DEC 2021) were reviewed for application to data used for determining if a waterbody is attaining or impaired due to lingering oil. Generally, these data requirements are appropriate with respect to data quality, spatial coverage/density, and technical components. Where the CALM and the lingering oil LM diverge is related to the age of the data. Due to the various data types considered for the lingering oil LM, the rationale for the data age considerations is discussed in the Sections 2 through 6 by data type. The conditions applied for assessment level data are provided in Table 1-3 of the LM.

1.10 Preferred Data Type Approach

Multiple options were evaluated for the LM approach to lingering oil. DEC decided an integrative approach that allows inclusion of multiple data types through a hierarchy would provide a thorough, data-driven approach. A hierarchy was developed for each of three potential approaches based on (1) most recent data, where the data are ranked based on most recent availability; (2) weight of evidence, where the full body of data is considered holistically; or (3) preferred data, where the data are evaluated in order of preference. After careful consideration, the selected option was preferred data. The preferred data types were then assigned to tiers as shown in **Table 1-2** of the LM, with Tier 1 given the highest priority. This approach prioritizes direct measurements over indirect measurements and provides DEC with flexibility to use various data types available for any given assessment unit, while also providing preference for new data.

2. TIER 1: TEST PIT DATA

The most preferred data for lingering oil determinations is direct observations through test pits, which are generally defined as holes dug in the sediment. The data most critical to lingering oil is subsurface oiling, which has been historically measured through visual observations in dug pits and trenches. This is because surface oil will generally be weathered, degraded, and will not become lingering oil.

Test pit observations can become standardized, creating comparable data over time by using a standardized framework such as SCAT. SCAT provides guidelines to use test pits to create a quantitative evaluation of the presence, depth, and thickness of oil entrenched in sediment. SCAT data are the basis for the development of shoreline treatment recommendations and provide a detailed record of changes in shoreline oiling conditions over time due to cleanup and natural cleaning.

In North America, SCAT techniques are documented and updated by NOAA (2013), and ECCC (2018). Following the SCAT guidelines provides decision-making level data by having field teams conduct surveys on affected areas to collect accurate documentation on the oiling conditions using standardized methods and terminology. This information provides a scientifically credible and sound foundation for the decision-making process.

Subsurface oiling is measured by three main factors: its depth, thickness, and categorization. Subsurface is considered at 5 cm or greater below the surface. Lingering oil is evaluated as subsurface oil. The SCAT terminology for categorization is provided in **Table 2-2** of the LM. The terminology is based on a visual estimate of oiling using guidance such as that shown in **Figure 2-1**. If photographs are difficult to view due to document resolution, higher resolution images are available in the SCAT Handbook (NOAA 2013).

Oil Character		Description	Example Photographs
OP	Oil-Filled Pores	Pore spaces in the sediment matrix are completely filled with oil; often characterized by oil flowing out of the sediment when disturbed	
PP	Partially-Filled Pores	Pore spaces are filled with oil, but it generally does not flow out when exposed or disturbed	
OR	Oil Residue	Cover (0.1–1 cm) or coat (0.01–0.1 cm) of oil residue on sediment and/or some pore spaces partially filled with oil	
OF	Oil Film or Stain	<0.01 cm stain or film oil residue on the sediment surfaces. Non-cohesive. Often determined by sheen type (see A2.d)	
TR	Trace	Discontinuous film or spot of oil on sediment, or an odour or tackiness with no visible evidence of oil	Difficult to see in a photograph
NO	No Oil	No visible or apparent evidence of oil	

Figure 2-1: Examples of Oiling Categorization (modified from ECCC SCAT 2018)

Although there has been an effort to standardize the oiling categorization, test pit data collected generally following SCAT guidelines might not use the exact same terminology. The historical SCAT data of EVOS from 1989 to 1991 in the database include heavy, moderate, light, or very light categorizations but no further information. The 2001 to 2023 EVOS test pit data have the number of test pits dug; the number that were clean, with surface oiling, and with subsurface oiling; and the maximum subsurface oiling type (which differs from SCAT classifications) and include the following:

- Oil pore: Pore spaces are completely filled with oil resulting in oil oozing out of sediments; water cannot penetrate the oil pore zone.
- Heavy oil residue (HOR): Pore spaces are partially filled with oil residue but not generally flowing out of sediments.
- Moderate oil residue (MOR): Sediments are heavily coated and pore spaces are not filled with oil; pore spaces could be filled with water.
- Light oil residue (LOR): Sediments are lightly coated with oil.
- Oil film: There is a continuous layer of sheen or film on sediments; water might bead on sediments.
- Trace: There is discontinuous film, spots of oil on sediments, and an odor or tackiness with no visible evidence of oil.

More recent test pit data (from 2015 to 2021) typically include the number of pits dug, the number of pits that are clean, LOR, MOR, and HOR.

For example, Green Island Site GR103B was categorized in 1989 by the original SCAT survey as "Light," in 1990 as "Moderate," and in 1991 as "Very Light." In 2001 the site was reassessed by having 84 test pits dug, of which 14 were listed as clean, 1 as surface oiled, and 4 as subsurface oiled, and the maximum subsurface oiling type was HOR. This site was visited again in 2015 with 50 test pits dug, with 46 listed as clean, 1 LOR, 1 MOR, and 2 HOR. Finally, this site was visited in 2021 with 40 test pits dug; 39 were listed as clean, and 1 was listed as LOR.

If the test pit data are generally in line with SCAT guidelines, and comparisons can be made between the categorizations such as LOR being equal to light, the data can be used for Tier 1. If the test pit data do not provide enough information to quantify the finding in a comparable way to SCAT guidelines, the data will be used as Tier 5 observations instead.

2.1 Age

In the context of lingering oil, SCAT test pit data will likely be the oldest data collected from a known oil spill. While the data might not reflect current conditions, these data can still be helpful to contextualize the oil spill, determine how shoreline areas have been segmented and know which segments were identified as unrecovered after the oil spill response. Additionally, the SCAT process for quantifying test pit data provides a basis for temporal evaluation, particularly when the same assessment units are evaluated repeatedly. If test pit data have been collected from the same shoreline segment over multiple years, the most recent 10 years of data are preferred and considered representative of the current site conditions, and data older than 10 years will be considered when more recent data are not available. This approach is both reasonable and conservative due to the nature of lingering oil and, unless more recent data demonstrate attainment, it is likely that an impairment remains.

2.2 Data Requirements

A minimum of 10 representative test pits per assessment unit are required for this tier. This is based on SCAT guidelines and the normal number of samples collected during SCAT historically in the state of Alaska. Additionally, the requirement of at least 10 test pit data points per assessment unit is a reasonable minimum number to provide statistical power to attainment decisions.

2.3 Test Pit Thresholds

Assessment units will be considered impaired if they are not virtually free of oil; assessment units will be considered attaining if less than or equal to (≤) 10% of test pits exhibit light to moderate oil, greater than (>) 90% of test pits are clean or very light, and there is no pit with heavy oil in the most recent test pit survey of the assessment unit (**Table 2-3** in the LM). These thresholds are consistent with the USEPA LM guidance of less than (<) 10% of test pits with a presence of oil (USEPA 2002) as well as the NOAA SCAT handbook.

3. TIER 2: SEDIMENT CHEMISTRY

PAH concentrations in water and sediment can be used to assess cleanup goals and potential long-term effects. Water data can change significantly over time as the concentrations of petroleum residuals in water are rapidly diluted, biodegraded, or entrained into sediment. Therefore, water chemistry data used to characterize lingering oil are not applicable to current conditions. Sediment data are more stable over time and are therefore more reliable for lingering oil evaluations.

Aromatic compounds contain a six-carbon ring that shares an electron (a benzene ring, **Figure 3-1**) and they are some of the most toxic compounds found in lingering oil. Concentrations of PAHs in the sediment will be used to assess attainment or impairment.

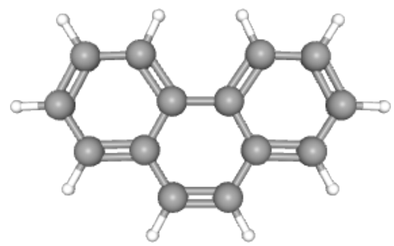

Figure 3-2: Typical Polycyclic Aromatic Chemical Structure (Phenanthrene, 3-ring)

The sediment PAH data are assessed in three ways:

- The concentration of high molecular weight (HMW) PAHs.
- The concentration of low molecular weight (LMW) PAHs.
- The concentration of benzo(a)pyrene (BaP) equivalents.

The reason PAH data are assessed three ways (HMW, LMW, and BaP equivalents) is because the first two measurements apply to wildlife receptors and the third applies to human receptors. To protect both human health and wildlife, different thresholds are needed.

Considering HMW versus LMW values for wildlife receptors is critical because these two groups of PAHs have very different toxicity. HMW PAHs are generally less toxic than LMW PAHs, and most toxicity values for wildlife refer to either HMW or LMW PAHs (not total PAHs). Sediment thresholds are for HMW and LMW PAHs because there are many wildlife toxicity values for LMW and HMW PAHs that have been in use since the 2000s, and there is very limited data for total PAHs.

3.1 Chemistry Analysis Requirements

Sediment should be, at a minimum, analyzed for the compounds in Table 2-3 of the LM. If more than two compounds were not measured, the data is inadequate for using sediment chemistry to assess attainment/impairment.

3.2 Protection of Human Health

For human health, the 2022 Agency for Toxic Substances and Disease Registry guidelines and the 2010 Canadian soil PAH guidelines (Agency for Toxic Substances and Disease Registry 2022; Canadian Council of Ministers of the Environment 2010) will be used to calculate BaP equivalents to protect humans against cancer risks of lingering oil.

To calculate BaP equivalents, multiply the concentration of each individual PAH in milligrams of PAHs per kilogram of sediment (mg/kg) on a dry weight basis by the potency factor (Table 2-3 of the LM), then sum those values. This gives a result of total BaP equivalents in mg/kg.

The Canadian Council of Ministers of the Environment guidance indicates a $1x10^{-5}$ excess lifetime cancer risk associated with a threshold value of 5.3 milligrams of BaP equivalents per kilogram of soil for all land uses. Given that human contact with marine sediment is generally less than human contact with soil, this value is likely to be conservatively protective.

3.3 Protection of Aquatic Life

For aquatic life, or organisms that inhabit the sediment on and near shorelines, the geometric mean of various thresholds from states and USEPA regions was used to evaluate protection of aquatic life from the worst adverse effects of lingering oil. A list of available sediment chemistry thresholds was downloaded from the Risk Assessment Information System at Oak Ridge National Laboratory. Threshold values for marine sediment were retained, as were generic nonspecific values that did not specify marine or freshwater sediment. Freshwater sediment values were not retained and were not used.

The thresholds for “effect” concentrations were retained. These values are defined as concentrations above which they are likely to have an adverse effect on aquatic life. The threshold values, and their sources, are detailed in Appendix B. To develop a specific numeric value for lingering oil, the geometric mean of the criteria in Appendix B was calculated because (1) it reduces the impact of very high and very low values or outliers; (2) it is a better representation of the central tendency of a dataset that is not-normally distributed (like these data); and (3) the geometric mean is frequently used by the USEPA when calculating screening levels and/or thresholds because it is robust and representative, leading to more reliable and defensible conclusions (USEPA 2024). The retained concentrations and the geometric mean for HMW PAHs and LMW PAHs are shown in **Figure 3-2** below.

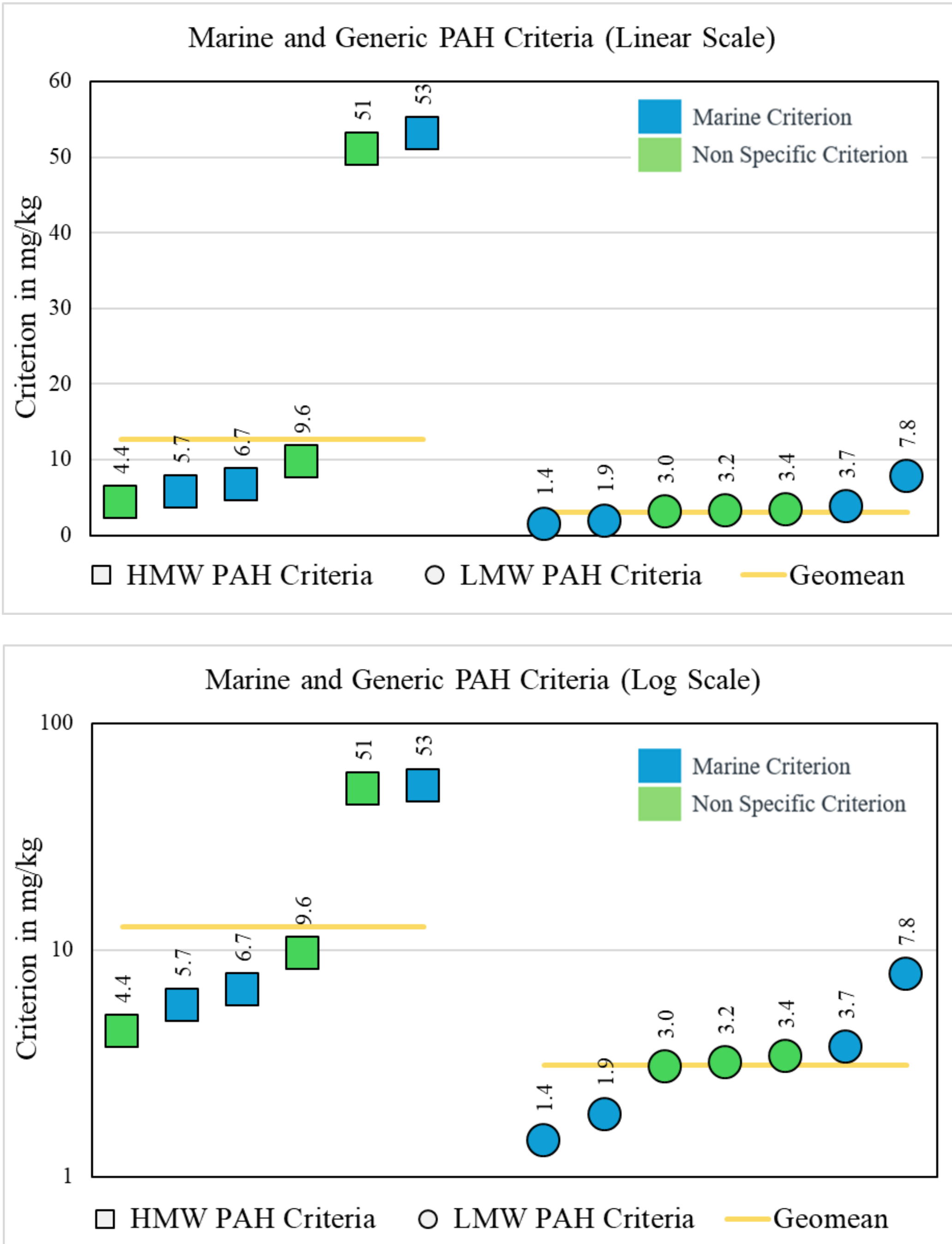

Figure 3-3: Aquatic Life Protection Thresholds for PAHs in Lingering Oil[4]

The geometric mean of marine and nonspecific (not specified if either marine or freshwater) criteria indicates an adverse effect is likely at concentrations higher than 12.7 mg/kg for HMW

[4] Orange lines indicate the corresponding PAH criteria geometric means on a mg/kg dry weight basis. The solid line between the squares on the left is the HMW PAH geometric mean, while the solid line between the circles on the right is the LMW PAH geometric mean. Nonspecific criterion is any that does not specify if it is freshwater or marine.

PAHs. The geometric mean of marine and nonspecific criteria indicates an adverse effect is likely at concentrations higher than 3.1 mg/kg for LMW PAHs.

3.4 Age

The current PWS EVOS data span from 1989 to 2014, with most data concentrated between 1989 and 1994. Many locations contain both alkane and PAH data, though not all. Additionally, some locations have a limited suite of PAH data and others have data for the complete list of PAHs. The prevalence of PAH data available in the EVOS database for PAHs by year is shown on **Figure 3-3**.

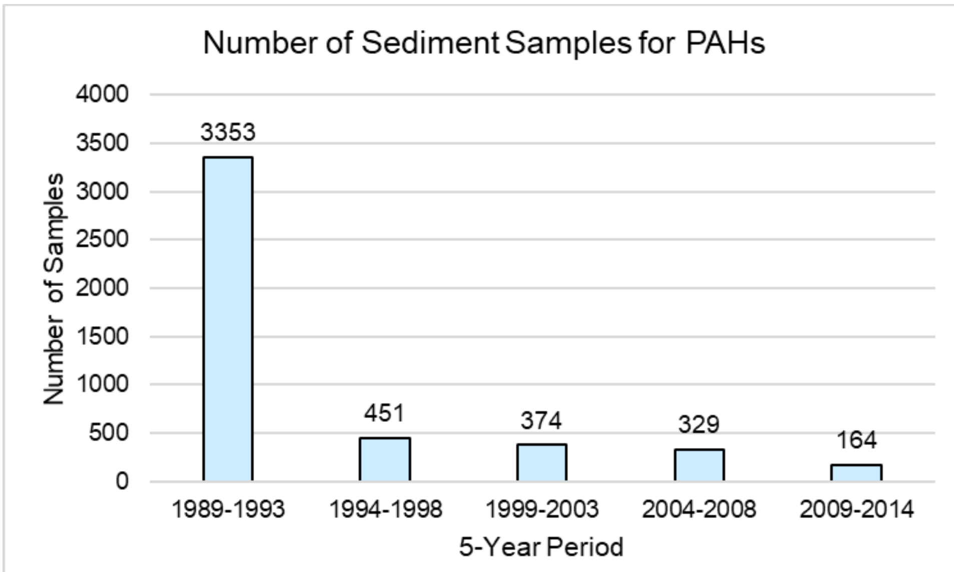

Figure 3-4: PAH Sediment Chemistry Data Available for EVOS by Year

Most data are more than 30 years old, and all are at least 10 years old. Given that lingering oil PAH concentrations are unlikely to change due to their sequestered state, data older than 10 years and even 30-year-old data could be appropriate for inclusion in an assessment procedure. Data 10 years old or less are preferred. Data older than 10 years are also acceptable but will undergo additional scrutiny. The 30-year-old and older data will be considered in Tier 5 data along with other lines of evidence; however, these values are likely to be conservative because the concentration of oil in the sediment has potentially diminished.

3.5 Data Requirements

Like Tier 1, the availability of sediment chemistry data for determining if a waterbody is attaining or impaired due to lingering oil is influenced by the established assessment unit length and the accessibility of the shoreline for sample collection, especially in the case of PWS. The decision was made to maintain a minimum number of 10 samples for an assessment unit, consistent with Tier 1. In DEC's LM for PAHs (DEC 2015), the threshold of at least 20 samples per beach segment over 2 different years within a 10-year period is presented. This guidance was determined to be unrealistic in the case of assessing beaches in PWS.

3.6 Sediment Chemistry Thresholds

Following review of the potential receptors and various literature establishing numeric endpoints for protecting both human health and aquatic life, the thresholds of 13 mg/kg dry weight for HMW PAHs, 3.1 mg/kg dry weight for LWM PAHs, and 5.3 mg/kg dry weight for BaP equivalents were selected for making attainment and impairment determinations for lingering oil (Table 2-4 of the LM). Both the HMW PAH value and the LMW PAH value are the geometric mean of marine and nonspecific (neither marine nor freshwater) values that indicate an adverse effect is likely at concentrations higher than this value. The BaP equivalents value is equivalent to a 10^{-5} excess lifetime cancer risk from PAHs.

4. TIER 3: BIOLOGICAL DATA

Biological data are valuable for determining if a waterbody is attaining or impaired due to lingering oil because they provide a direct line of evidence of impacts to the environment. Biological data include measurements of effects of oil on biota or measurements of individual, population, or community health. The types of data required need to be those that are possible to evaluate over a short period or that allow for a comparison of site results to reference site results. Multiple lines of evidence are recommended when it comes to biota because organism-related data tend to be highly variable. **Table 4-1** lists the lines of evidence that were considered.

Table 4-5: Biological Data Types for Attainment Determination of Lingering Oil

Lines of Evidence	Organism Type(s)	Reference
Tissue chemistry	Immobile invertebrates such as: clams; mussels; other intertidal species	Shingenaka et al. 2008 Boehm et al. 2004 Page et al. 2005 https://www.adfg.alaska.gov/index.cfm?adfg=animals.listinvertebrates
Sediment toxicity	Marine amphipods	Integral Consulting, Inc. (2006)
Populations and communities in the intertidal	Benthic infauna (e.g., worms) Benthic epifauna (e.g., mussels)	Coats et al. (1999) Jewett et al. (1999)
Food web contaminant uptake analysis	Sensitive invertivorous birds or mammals (e.g., shorebirds, sea otters, etc.)	USEPA (1997)

After the EVOS, biological data were collected to assess and evaluate the recovery of intertidal invertebrates, fish, and wildlife that forage in these areas. The types of biological data that have been collected since the spill, have been used in the analysis of recovery trends, and can be used for making attainment decisions for shorelines with possible lingering oil-related impacts include the following:

- Tissue chemistry to evaluate changes in PAHs and alkanes over time in species including mussels, clams, and fish (Barron et al. 2020; Michel et al. 2016; Shingenaka et al. 2008; Boehm et al. 2004, Page et al. 2005).
- Sediment toxicity (to invertebrates): Sediment toxicity tests have previously been used to evaluate toxicity of sediments at different intertidal elevations (Integral Consulting, Inc., 2006) using amphipods (*Rhepoxynius abronius* and *Ampelisca abdita*) and Pacific oyster larvae (*Crassostrea gigas*) in accordance with standardized test methods.
- Abundance and diversity of benthic infauna such as littleneck clams, polychaetes, and amphipods along with epifauna (e.g., marine algae [seaweed], sponges, sea anemones,

and sea stars) have previously been evaluated over time to assess recovery trends (Coats et al. 1999, Jewett et al. 1999).

- Food web contaminant uptake analysis, while not previously used, can also be used to assess effects on aquatic-dependent wildlife (USEPA 1993, 1997).

4.1 Age

Biological data beyond tissue chemistry from the EVOS database are sparse. The PWS EVOS tissue chemistry data spans from 1989 to 2014, with most data concentrated between 1989 and 1994. Many locations contain both alkane and PAH data, though not all. Additionally, some locations have a limited suite of PAH data, and others have data for the complete list of PAHs. Most data are more than 30 years old, and all are at least 10 years old. In this one case for EVOS, the 30-year-old data are potentially usable as Tier 5 data along with other lines of evidence, with the caveat that these values are likely to be conservative because the concentration of oil in the sediment has either not changed or diminished. In general, biological data less than 10 years old are preferred.

4.2 Data Requirements

Like for Tiers 1 and 2, the requirements for biological data for determining if a waterbody is attaining or impaired due to lingering oil were based on length and the number of samples per assessment unit. The number of samples required in an assessment unit in most instances is five or more depending on the type of biological data line of evidence. Fewer than five samples would be considered if they are spatially representative (e.g., results from three composite samples where samples are taken from a large area of the beach).

However, there are no specific guidelines for the number of samples. For biological lines of evidence, sufficient data are needed to conduct a comparison to a reference site that will provide a statistically significant difference for a biologically relevant effect size. The criteria are set at a 95% confidence level, which generally requires at least 10 sample points to obtain a 20% effect size (USEPA 2010).

Four lines of evidence are considered for biological data because they can be collected within a single sampling event, and they allow for a quantitative or semiquantitative evaluation of impacts relative to a reference site (or a reference toxicity value).

The number of data points for each line of evidence is variable and the following are considered the minimum number for each data type:

- Tissue Chemistry: Due to the challenge associated with the collection of organisms (depends on their presence), a minimum of five composite tissue samples should be collected from an assessment unit and compared to a minimum of five composite samples from a reference site. Composite samples from both target and reference sites ought to include similar species composition. Organisms should be collected in the middle to upper intertidal zone, closest to or on the shoreline at low tide.

- Sediment toxicity testing: Prior to testing, surface sediment (top 5 cm) from an assessment unit and a beach reference site should be collected; the beach sampling approach for sediment would be to use a systematic unaligned sampling design. A grid would be placed across the assessment unit and the sampleable portion of the beach. Five random grid cells would be selected across the assessment unit, and, within each grid cell, five random locations would be sampled and composited. Sediment testing using amphipods would then be performed in accordance with USEPA (1994) and/or ASTM International (ASTM) (2014) on the five composite samples from the assessment unit and the five composite samples from the reference beach.
- Community Diversity and Population: Use one or both methods:
    - Infauna Abundance/Taxonomy: The approach should follow Coats et al. (1999). Briefly, five replicate samples of infauna should be collected with a modified cylindrical clam corer at each of 12 low intertidal sites placed along a transect at both the assessment unit and the reference beach. A paired but separate sample should also be collected for grain size and total organic carbon. The tidal zone (upper, middle, and lower) is evaluated. Comparisons should be made for the same species, across as many taxa as possible. The total abundance of all organisms is evaluated.
    - Epifauna Abundance/Taxonomy: The sampling and analysis approach should follow Coats et al. (1999). Briefly, epifauna should be counted at multiple elevations as appropriate at the assessment unit and the reference beach. At each elevation (low, middle, upper), the elevation should be measured, epifauna counted, and the coverage of organisms estimated within five to ten 0.25 m quadrats established along a transect parallel to the shoreline. Comparisons should be made for the same species, across as many taxa as possible. The total abundance of all organisms is evaluated.

Food web contaminant uptake analysis: Tissue and sediment toxicity testing are used from the assessment unit and the reference beach as described in the first two lines of evidence. Exposure point concentrations (or the median and maximum) of sediment chemical and tissue chemical concentrations are calculated for the assessment unit and reference beach. A food web contaminant uptake analysis is developed for sensitive shorebirds and mammals using these data in accordance with USEPA (1997) and compared to USEPA (1993) or peer-reviewed toxicity reference values relevant to specific shoreline birds. Toxicity reference values are benchmarks used in risk assessments to evaluate the potential health risks posed by exposure to various substances. They are derived from scientific studies and data, and they help determine safe exposure levels for humans and the environment. The food web contaminant uptake analysis can be performed for the target species at the assessment unit to test if there are any risk levels with hazard quotients greater than 1, indicating a dietary uptake risk. An ecological risk assessment uses data from the reference beach as well for comparison.

4.3 Biological Data Thresholds

For the attainment determination, two or more of the types of biological data included in Table 2-6 in the LM are used as lines of evidence due to high variability of biological data. Biological data thresholds are different for each line of evidence.

For sediment toxicity, tissue chemistry, and community diversity and population, the thresholds are based on comparison between the site and a reference site. An effect size over 20% is substantial enough to indicate population level effect, at a 5% threshold for statistical significance ($\alpha= 0.05$), meaning 95% confidence that the test group is statistically significantly different from the control group (i.e., USEPA 2010). This effect size and significance level are standard for environmental toxicology (Suter 2000, USEPA 2010). Effect size is calculated by:

% effect size = [(mean at reference site – mean at oiled beach)/(mean at reference site)] X 100

For both infauna abundance/taxonomy and epifauna/taxonomy, comparisons should be made for the same species across as many taxa as possible, and the total abundance of all organisms can also be considered.

Like the approach for sediment (Section 3, Tier 2), tissue chemistry should be evaluated for PAHs and compared to a threshold that is protective of ecological receptors. The threshold was developed using tissue residue PAHs data from the United States Army Corps of Engineers Environmental Residue-Effects Database (2024). This is a comprehensive database of residue-effects data compiled from peer-reviewed literature and reports, primarily focusing on the impacts of chemical stressors on aquatic and terrestrial species. Developed by the U.S. Army Engineer Research and Development Center, the database includes about 15,000 test records from 990 studies for 340 species. The extracted dataset was further reduced to controlled studies in which lowest observable effects concentrations (LOECs) were determined for reproduction, growth, and/or mortality endpoints. In some cases, an effect less than 50% was retained if no LOEC was available. Fish PAH data were not included because they are not expected to be exposed to lingering oil and they are known to rapidly metabolize PAHs and thus do not readily bioaccumulate them. The refined dataset is shown in **Figure 4-1** and Appendix C.

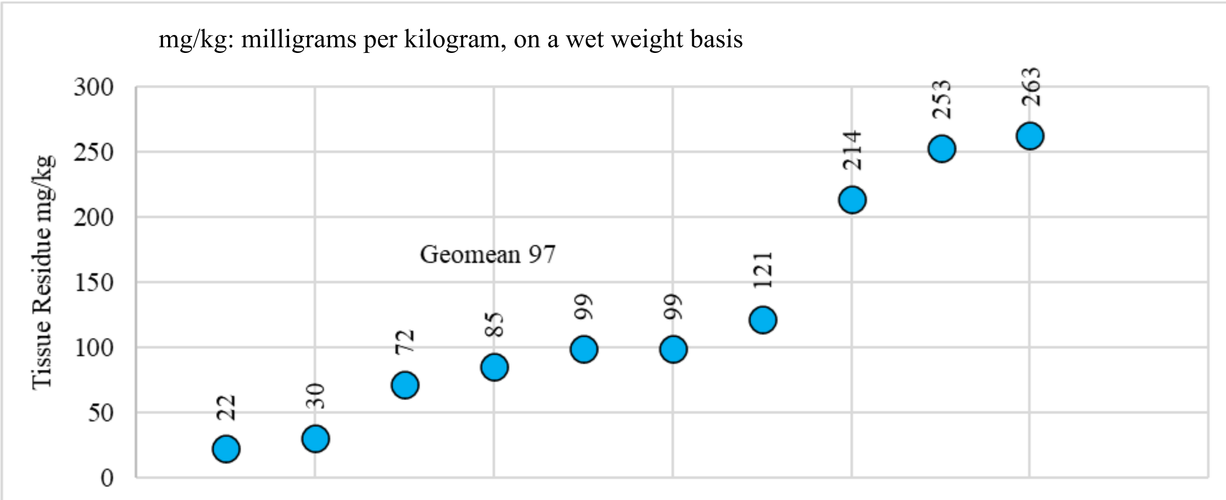

Figure 4-1: Invertebrate Tissue PAH LOECs for Growth, Reproduction, and Mortality

The geometric mean of the LOECs in the refined dataset was calculated as 97 mg/kg wet weight. It includes values for fluorene, fluoranthene, and phenanthrene because the controlled studies in the ERED for invertebrates are based on exposures to the individual PAHs. These individual PAHs can be considered representative chemicals for exposure to total PAHs. Most of the studies cited in Figure 4-1 are based on amphipods, which are one of the most sensitive groups of invertebrates when it comes to PAHs (Eisler 1987). The sum total of all PAHs from the tissue of organisms found within the sediment on beaches would be compared to the threshold value of 97 mg/kg ww.

Food web contaminant uptake analysis relevant to the assessment unit should be established in accordance with regulatory guidance (USEPA 1993, 1997). Exposure point concentrations for sediment chemicals and tissue chemicals (if available) should be established as the maximum and median concentrations on the assessment unit. Toxicity reference values should also be determined for selected receptors that are representative of invertivorous birds (i.e., that typically consume invertebrates found on shorelines) with a small home range. If there are any risk levels with hazard quotients greater than 1, additional scientifically justifiable refinements to the model can be made (i.e., adjusting the area use factor to a more realistic value). A model can be run using data from the reference beach as well. A lack of dietary uptake risk relative to the toxicity reference values is considered a line of evidence demonstrating attainment.

The attainment thresholds for biological lines of evidence are summarized in Table 2-6 in the LM.

5. TIER 4: MODELING

Environmental models (oil spill and transport, groundwater flow, subsurface seismic/geologic conditions, weather, etc.) use mathematical equations solved by computer programs to represent processes and conditions of a real environmental system. The modeled output typically consists of spatially and temporally defined quantified parameters (concentration of oil or contaminant, flow velocity, rock properties, temperature, etc.). The quantity of each parameter also has an inherent uncertainty due to a model's tendency to simplify the complexity of the physical phenomena that are being simulated. The usefulness of modeled data depends on the model's ability to accurately produce values that have reasonable uncertainties and closely represent values of observed/verified data.

For oil within an environment, modeled data can include SCAT data or level of oiling, toxicity, bioavailability, or other data types. In general, the model would produce a spatially continuous distribution of one or more of these parameters and could include a temporal component. The processes and conditions considered in the model would likely include distance from oil source, currents, shape of shoreline, slope of shoreline, sediment type, etc.

Multiple iterations of models have been published related to the probability of the existence of subsurface oiling at beaches in PWS (Michel et al. 2009, Michel et al. 2011, Nixon and Michel 2015), with the most recent being the Nixon and Michel 2015 model. This model uses field data and predictor variables as model input. The field data are test pit descriptions, and the predictor variables include historical oiling from original SCAT data; shoreline geomorphology; surface slope/rugosity; NOAA Environmental Sensitivity Index data, which provide a value describing a shoreline's relative sensitivity to oil; permeability based on field measurements; exposure to wave energy; overwater distance to stream mouths; and distance/angle of oil approaching the spill site. Importantly, the EVOS models do not predict whether oil will deplete over time.

Key components in a model are whether the quality of the model meets a standard to confirm that it has undergone third-party expert review; has thorough documentation on its methods, assumptions, and boundary conditions; and has been calibrated, validated, and can show repeatable results. These are basic minimum conditions set out in ASTM standards for modeling.

5.1 Age

The quality and timeframe of the data used for training and testing a model may significantly impact the model's results. While using the most recent high-quality data is ideal, achieving sufficient data density may require incorporating data that is more than 10 years old. When new data becomes available, it is important to assess whether the model's outputs change over time or remain static. If the model can be updated with the new data, it should be rerun to ensure the most accurate results.

The PWS model uses field data (test pit descriptions) from 2001, 2003, and 2007 as model input. Additionally, the historical oiling predictor variable in the model input parameters is derived from SCAT data from 1989, 1990, and 1991. The output data predict the following:

- The probability of encountering subsurface oil in a pit at a given alongshore location.
- The probability of encountering subsurface oil categorized as MOR or HOR in a pit at a given alongshore location.
- The probability of encountering subsurface any subsurface oil in a pit at a given alongshore location at a tidal elevation lower than 1.5 m above mean lower low water.

While there is no temporal prediction of oil depletion in the model output, if additional more recent data are added to the model, there could be opportunities for understanding a temporal component of lingering oil. Therefore, the age of the data used in a model for lingering oil was not a consideration for data age; however, the age of the most recent update to the model is an important factor for consideration. It is preferred that a model used for determining if a waterbody is attaining or impaired by lingering oil will have been updated within the last 10 years, but older models will be considered.

5.2 Data Requirements

Each model will likely include subsegments within a given length of shoreline that vary in length and vary by waterbody. At a minimum, the subsegments should provide coverage across the shoreline segment to be representative of conditions. Data density will be variable depending on model output and ought to be spatially representative of the assessment unit. In a model, representativeness is determined by calibration, validation, and showing repeatable results. Models with spatially continuous data coverage and fine resolutions (e.g., 1 to 100 m compared to field SCAT data over length 0.2 to 2 km) are far more informative and useful than coarse and discontinuous models. Neighboring fine-scale model outputs of like characteristics can be aggregated to simplify data processing and determine if a waterbody is attaining or impaired.

When applying modeled data to the LM, the scale of the individual model outputs and data coverage within an assessment unit needs to be considered. If the model does not have data coverage for portions of a shoreline within an assessment unit, it is important to consider the balance between excessive extrapolation and avoiding segmenting the shoreline into an unreasonable number of subsegments. To use modeled data to assess a shoreline as attaining or impaired with Tier 4 of the LM, at least 50% of the shoreline length being assessed must have modeled data coverage (shown in **Table 1-3** of the LM).

The PWS model output includes the probability of subsurface oiling and the probability of each oiling level (LOR, MOR, and HOR) of a given 7.3-m shoreline segment. Other studies that utilize this modeled data have combined the 7.3-m segments into larger discrete sites to create shoreline segments that have a more practical scale. The discrete sites were defined as an aggregation of shoreline segments with high probability of being oiled and are adjacent by less than 50 m (Boufadel et al. 2015). For MOR and HOR, this results in discrete sites ranging from 100 to 1,000 m.

5.3 Modeled Data Thresholds

The attainment threshold established is less than or equal to 10% of modeled subsegments indicate a greater-than-or-equal-to 15% probability of subsurface oiling. This is recommended because the model is calibrated and verified using test pit data (Tier 1), so it is appropriate for the attainment threshold to be consistent with Tier 1. The impaired threshold is the inverse to the attainment threshold—more than 10% of modeled subsegments have a greater-than-or-equal-to 15% probability of subsurface oiling. Table 2-7 in the LM presents a summary of the attainment and impaired thresholds.

6. TIER 5: OVERWHELMING EVIDENCE

If available data do not meet the minimum conditions outlined for Tiers 1 through 4 or are inconclusive, overwhelming evidence will be considered. Overwhelming evidence uses multiple lines of evidence to determine whether a particular narrative threshold is exceeded. This approach would be used in cases where sample sizes do not meet minimum tier requirements, or where sampling data is inconclusive in the previous tiers, and yet in combination taking all the information available, there is overwhelming evidence of an impairment or attainment. For example, under this tier an assessment unit may be attaining if it has test pit data at too low a resolution (< 10 test pits) but all indicate very light oiling, sediment chemistry data that are too old (> 10 years) but all have PAH data less than the threshold, and modeled data covering less than 50% of the assessment unit showing no subsegments predicted to have subsurface oil.

Best professional judgement will be exercised when selecting a line of evidence consisting of screening level data that might not meet the minimum tier threshold. Acceptable data can include those that meet quality objectives and use approved laboratory methods but do not meet the sample density required for the tier.

Lines of evidence used can include the following:

- Multiple types of screening level data
- SPAR cleanup status
- Uses (e.g., cultural, subsistence) along with visual observations (e.g., if lingering oil becomes unburied and exposed following a severe weather event)
- New science or new data types
- Public health advisories
- Other biologic indicators or habitat data

The multiple lines of evidence combine to offer overwhelming evidence that the assessment unit can be deemed attaining or impaired. For this tier, there are not clear guidelines on what could be acceptable; these decisions will require professional judgment. In general, data should be of known quality and from a credible source, preferably collected under a quality assurance project plan or similar data collection plan. Data less than 10 years old will be given preference; however, older data will be considered.

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APPENDIX A

Other Relevant Regulations Considered

Contaminated Sites Cleanup

There are four methods of calculating cleanup levels according to 18 AAC 75.340. Cleanup levels can be based on human health risk and protection of migration to surface water. Under Method 3 or Method 4, alternative cleanup levels are calculated to protect human health, safety, and welfare, and the environment.

Method 1 is a calculation based on depth to groundwater, mean annual precipitation, soil type, potential drinking water intakes, and the volume of contaminated soil. This process is scored differently in Arctic and non-Arctic zones.

Method 2 is a table of cleanup values based on human health (soil ingestion of petroleum hydrocarbons) and migration to groundwater. Table B1 Method 2: Soil Cleanup Levels Table has human health-based criteria for PAHs and other toxic chemicals, and Table B2 Method 2: Petroleum Hydrocarbon Soil Cleanup Levels has human health-based criteria for hydrocarbon fractions (18 AAC 75.340).

Method 3 involves calculating cleanup levels based on human health (inhalation and ingestion pathways) and migration to groundwater based on approved site-specific soil and groundwater data, as well as an approved fate and transport model protecting groundwater based on commercial or industrial exposure parameters.

Method 4 is based on a risk assessment that is protective of human health, safety, and welfare, and of the environment.

However, DEC can require a cleanup level that integrates (1) human health risk from vapor intrusion; (2) sediment contamination; (3) impacts to ecological receptors, (4) other site uses such as recreational, agricultural, or subsistence use, or (5) the presence of sensitive subpopulations (of human receptors) who respond biologically to lower levels of exposure to a hazardous substance.

Light Nonaqueous Phase Liquids Recovery Guidance

Alaska has specific guidance for the recovery of light nonaqueous phase liquids from groundwater that might also be pertinent to the EVOS (DEC 2023). This guidance also introduces the concept of cleaning to the maximum extent practicable (MEP). The goal of this guidance is as follows:

- Minimize the spread of contamination into an uncontaminated area by using containment, recovery, and disposal techniques appropriate to site conditions.
- Avoid additional discharge.
- Dispose of the recovered material in compliance with local, state, and federal requirements.

The concept of MEP means that the concentration left in the environment after cleanup could be greater than zero. For light nonaqueous phase liquids, this might be based on the rate at which it moves through soil (very slow movement could indicate that MEP has been reached). Once MEP has been reached, the guidance indicates that human and/or ecological exposure should be examined. This exposure is used to determine if there is a threat to or damage to human health, safety, or welfare, or to the environment.

Sediment

SPAR updated their *Sediment Quality Guidelines* in 2001 (SPAR 2001) and summarized them in 2013 (SPAR 2013).[5] The 2001 guidelines recommend the use of threshold effect level and probable effects level (PEL) sediment quality guidelines from NOAA's Screening Quick Reference Tables (SQuiRTs; Buchman 1999). The SQuiRTs were updated in 2008 (Buchman 2008), and the 2013 SPAR summary reflects this update.

The SQuiRTs are based on consensus sediment criteria (MacDonald et al. 1996; MacDonald et al. 2000). These benchmarks were derived by examining lab and field data and putting them into three categories: minimal effects, possible effects, and probable effects. Between 1996 and 2000, the criteria for hydrocarbons as threshold effect levels and PELs focused on PAHs as both individual chemicals and summed as LMW, HMW, and total PAHs. Other important (and potentially toxic) oil fractions were not considered, as the PAHs are some of the most toxic fractions of hydrocarbons.

In addition, the 2001 *Sediment Quality Guideline Options for the State of Alaska* (SPAR 2001) also gives the user options for calculating site-specific sediment quality guidelines using equilibrium partitioning, background, acid volatile sulfides, and porewater effect concentrations.

However, in 2024, NOAA removed the SQuiRTs from their website, stating, *"As of April 4, 2024, OR&R [the Office of Restoration and Response] has decided to remove the SQuiRT cards from this website because they are out of date. More recent literature should be considered in contaminant evaluation"* (NOAA 2024).

[5] 18 AAC 75 and 18 AAC 78.

APPENDIX B
PAH Criteria from the Risk Assessment Information System

Analyte	Group	Benchmark	Value mg/kg	Type
HMW	Sediment	USEPA ARCS PEC (1996)	4.35	PEC
HMW	Marine Sediment	USEPA Region 6 Sediment Saltwater Benthic PCL (August 2020)	5.65	PCL
HMW	Marine Sediment	FDEP Marine PEL (1994)	6.676	PEL
HMW	Sediment	NOAA Effects Range-Median (ERM) (1999), Washington Marine Sediment Cleanup Objective (2013), and USEPA Region 6 Sediment Saltwater Second Effects (August 2020)	9.6	ERM
HMW	Sediment	USEPA ARCS No Effect Concentration (NEC) (1996)	51	NEC
HMW	Marine Sediment	Washington Marine Sediment Cleanup Screening Level (2013)	53	Cleanup
LMW	Marine Sediment	FDEP Marine PEL (1994)	1.442	PEL
LMW	Marine Sediment	USEPA Region 6 Sediment Saltwater Benthic PCL (August 2020)	1.86	PCL
LMW	Sediment	USEPA ARCS No Effect Concentration (NEC) (1996)	3.04	NEC
LMW	Sediment	NOAA Effects Range-Median (ERM) (1999), USEPA Region 6 Sediment Saltwater Second Effects (August 2020)	3.16	ERM
LMW	Sediment	USEPA ARCS PEC (1996)	3.37	PEC
LMW	Marine Sediment	Washington Marine Sediment Cleanup Objective (2013)	3.7	Cleanup
LMW	Marine Sediment	Washington Marine Sediment Cleanup Screening Level (2013)	7.8	Screening

TOTAL PAHs (for information only, not used in developing LM thresholds, mg/kg)		
Sediment	USEPA ARCS PEC) (1996)	13.66
Marine Sediment	FDEP Marine PEL (1994)	16.77
Sediment	Consensus-Based PEC (2000), USEPA Region 6 Sediment Freshwater Second Effects (August 2020)	22.8
Marine Sediment	USEPA Region 6 Sediment Saltwater Benthic PCL (August 2020)	24.41
Sediment	NOAA Effects Range-Median (ERM) (1999), USEPA Region 6 Sediment Saltwater Second Effects (August 2020)	44.792

Marine Sediment	New York Department of Environmental Conservation Saltwater Sediment Class C and Class B High Range Value (2014)	45
Sediment	USEPA ARCS No Effect Concentration (NEC) (1996)	84.6
Sediment	Ontario Sediment Severe Effect Level (1993)	1000

ARCS: USEPA's Assessment and Remediation of Contaminated Sediments program
ERM: effects range median
FDEP: Florida Department of Environmental Protection
mg/kg: milligrams per kilogram
NEC: no effect concentration
NOAA: National Oceanographic and Atmospheric Administration
PAH: polycyclic aromatic hydrocarbon
PCL: protective concentration level
PEC: probable effects concentration
PEL: probable effects level
USEPA United States Environmental Protection Agency

<u>Sources (Per the Risk Assessment Information System):</u>

<u>USEPA ARCS</u>

In support of the United States's commitment to the Great Lakes Water Quality Agreement, Section 118 (c)(3) of the Clean Water Act authorized the USEPA Great Lakes National Program Office to carry out a 5-year study and demonstration project relating to the control and removal of toxic pollutants in sediments of the Great Lakes called the Assessment and Remediation of Contaminated Sediment (ARCS) project. The representative effect concentration selected from among the high no-effect-concentrations (NEC) for *Hyalella azteca* and *Chironomus riparius* is a concentration above which statistically significant adverse biological effects always occur; effects can occur below these levels. The PEC is the geometric mean of the 50th percentile in the effects dataset and the 85th percentile in the no effects dataset. It represents the lower limit of the range of concentrations usually associated with adverse effects. A concentration greater than the PEC is likely to result in adverse effects to these organisms. The threshold effect concentration is the geometric mean of the 15th percentile in the effects dataset and the 50th percentile in the no effects dataset. It is a concentration that represents the upper limit of the range dominated by no effects data. Concentrations above the threshold effect concentration can result in adverse effects to these organisms; concentrations below the threshold effect concentration are unlikely to result in adverse effects. The majority of the data are for freshwater sediments. These values are from Table 4 in *Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod* Hyalella Azteca *and the Midge* Chironomus Riparius, EPA 905-R96-008, September 1996 (Jones et al., 1997).

Note: The terminology used in the ARCS program is unique to that program and can be found here: The Risk Assessment Information System

<u>USEPA Region 6</u>

USEPA Region 6 recommends use of ecological benchmarks developed for the Texas Commission on Environmental Quality. The Texas Commission on Environmental Quality ecological risk assessment program provides guidance and resources for regulated entities that must evaluate ecological risk at a site in one of the Remediation Division programs. According to the Texas Risk Reduction Program rule, some form of an ecological risk assessment is required to be conducted at all remediation sites. These values are all available from Texas Commission on Environmental Quality (TCEQ, 2020).

<u>Florida: Florida Department of Environmental Protection (FDEP)</u>

Using the recommended approach, numerical sediment quality assessment guidelines were developed for assessing sediment quality in Florida coastal waters (FDEP, 1994). These guidelines were derived using information from numerous investigations of coastal sediment quality conducted in North America and are based on a weight of evidence that links contaminant concentrations with adverse biological effects. In this respect, the guidelines are a cost-effective response to a practical need for assessment tools. However, these guidelines should be revised or refined depending on the results of field validation and other related studies conducted in Florida and elsewhere in North America. These guidelines should be used in conjunction with other interpretive tools to conduct comprehensive and reliable assessments.

NOAA

The sediment quality guidelines were initially intended for use by NOAA scientists in ranking areas that warranted further detailed study on the actual occurrence of adverse effects such as toxicity. Also, they were intended for use in ranking chemicals that might be of potential concern. In many regional surveys of sediment toxicity performed throughout North America, NOAA has used the guidelines to compare the degree of contamination among subregions and to identify chemicals elevated in concentrations above the guidelines that were also associated with measures of adverse effects. The sediment quality guidelines were not promulgated as regulatory criteria or standards. They were not intended as cleanup or remediation targets, nor as discharge attainment targets. Nor were they intended as pass-fail criteria for dredged material disposal decisions or any other regulatory purpose. Rather, they were intended as informal (nonregulatory) guidelines for use in interpreting chemical data from analyses of sediments. Values are available from NOAA's National Status and Trends Program, Sediment Quality Guidelines (NOAA, 1999). The values for trace metals can be found in Table 1 and the values for organic compounds can be found in Table 2 (NOAA, 1999).

https://products.coastalscience.noaa.gov/publications/detail.aspx?resource=rRbGi26G/XOtqoZzBofxXxCb+IigtXT4iFyiHoP7M7o=

Washington Sediment Management Standards

The Washington State Sediment Management Standards Chapter 173-204 WAC were developed to reduce and ultimately eliminate adverse effects on biological resources and significant threats to human health from surface sediment contamination. Values are found in Table III (Marine) and VI (Freshwater) (Washington Department of Ecology, 2013)

APPENDIX C
Invertebrate Tissue PAH LOECs for Growth, Reproduction, and Mortality

Scientific name	Common name	Test species group	Chemical name	Tissue residue mg/kg	Tissue fraction	Test effects	Risk assessment parameter
Hyalella azteca	freshwater amphipod	crustaceans	Fluorene	22	whole body	reproduction	LOEC
Chironomus tentans	midge	aquatic insects	Fluorene	30	whole body	reproduction	LOEC
Diporeia sp.	amphipod	crustaceans	Fluoranthene	72	whole body	mortality	LOEC
Hyalella azteca	freshwater amphipod	crustaceans	Fluorene	85	whole body	growth	LOEC
Hyalella azteca	freshwater amphipod	crustaceans	Fluorene	99	whole body	mortality	LOEC
Hyalella azteca	freshwater amphipod	crustaceans	Fluorene	99	whole body	mortality	LOEC
Schizopera knabeni	copepod	crustaceans	Fluoranthene	121	whole body	reproduction	LOEC
Diporeia sp.	amphipod	crustaceans	Phenanthrene	214	whole body	mortality	LOEC
Diporeia sp.	amphipod	crustaceans	Fluoranthene	253	whole body	mortality	LOEC
Coullana sp.	copepod	crustaceans	Fluoranthene	263	whole body	mortality	LOEC

LOEC: lowest observable effects concentration
mg/kg: milligrams per kilogram
Table values from selected studies in: United States Army Engineer Research and Development Center. 2024. Environmental Residue Effects Database (ERED). https://ered.el.erdc.dren.mil/index.cfm.