A Department of Ecology Report

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Sediment Management Standards
Sediment Site Ranking
SEDRANK Guidance Document

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SEDIMENT MANAGEMENT STANDARDS
SEDIMENT SITE RANKING
SEDRANK GUIDANCE DOCUMENT

Prepared for

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LIST OF ACRONYMS

BCFs	bioconcentration factors
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
HRS	hazard ranking system
IRIS	Integrated Risk Information System
K_{ow}	octanol-water partition coefficient
SQS	Sediment Quality Standards
TOC	total organic carbon
WARM	Washington ranking method

1. INTRODUCTION

The purpose of this document is to provide specific instructions for the ranking of contaminated sediment sites, as required by the State of Washington Sediment Management Standards (Chapter 173-204 WAC). Contaminated sediment sites are ranked to allow the Washington Department of Ecology (Ecology) to establish priorities for site cleanup. Ecological and human health hazards are both to be considered during site ranking. Chapter 2 of this document provides background information on the sediment cleanup process and the role of site ranking. Ranking is conducted by applying the SEDRANK method (as described in WAC 173-204-540), using best professional judgment to take into consideration other site-specific information that is available. Chapters 3 and 4 of this document describe the information required to apply SEDRANK and the steps and calculations to be carried out to produce a site ranking score with SEDRANK.

Modification of the SEDRANK score based on best professional judgment is not described here, for, although an environmental health or human health expert may be able to tell *why* he or she recommends a different rank in a particular case, too little is known about *how* such a decision is arrived at to allow step-by-step directions to be given. Nevertheless, Chapter 5 of this document provides some guidelines for interpreting scores produced by the SEDRANK method. Because it does not completely codify professional judgment, this document provides directions for meeting some, but not all, of the requirements of WAC 173-204-540.

2. OVERVIEW OF THE CLEANUP PROCESS

Marine sediments in several areas of Puget Sound and Washington State are contaminated with toxic substances, such as petroleum-derived compounds, chlorinated organic compounds, and metals. Areas with sediment contamination have been associated with impacts to local fish and shellfish. In several areas, local health departments have advised residents to limit their consumption of seafood.

The Sediment Management Standards provide Ecology with a uniform set of procedures and requirements to manage contaminated sediments. Site ranking is one step in the sediment cleanup decision process defined by the Sediment Management Standards. This process includes the following steps:

- Identification of station clusters
- Characterization of station clusters as station clusters of potential concern or station clusters of low concern
- Collection of biological, chemical, and other data pertaining to site conditions (hazard assessment)
- Identification of the cluster as a site based on chemical and biological data (clusters that are not designated to be sites are returned to the data inventory, possibly to be reconsidered if other data become available)
- Site ranking
- Site listing, which establishes the site as a hazardous waste site that is designated for cleanup
- Determination of site-specific cleanup standards and a remedy
- Implementation of the remedy
- Monitoring and maintenance.

Different steps in this process may be carried out by different agencies or organizations, including Ecology, the U.S. Environmental Protection Agency (EPA), and potentially liable parties. Site ranking will be performed by Ecology's Sediment Management Unit.

Sediment Quality Standards (SQS) established by the rule are used for several steps in this process, including station cluster identification and screening, site identification, and site ranking. Whereas early steps in this process can be carried out using relatively limited data (e.g., clusters can be identified on the basis of sediment chemistry data alone), each subsequent step requires more data or data of higher quality. Existing data may be used for all steps through site ranking. Site ranking requires the most data of any technical step prior to the cleanup study, in which additional site-specific data are collected to support selection of cleanup standards and a remedy. Site ranking has the most stringent data requirements that must be met with existing information. The application of best professional judgment to interpret the effect of data limitations is therefore an important part of the site ranking step.

Descriptions of steps in the cleanup decision process other than site ranking can be found in the *Sediment Cleanup Standards Guidance Document* (PTI 1991c).

3. DESCRIPTION OF SEDRANK

SEDRANK is designed to assess the relative hazards of different contaminated sediment sites to ecological and human health. The intent of SEDRANK is to provide an objective numerical basis for assessing the relative degree of risk at different sites. It is similar to other hazardous site ranking systems [e.g., the Washington ranking method (WARM) and the federal Superfund hazard ranking system (HRS)]. SEDRANK, however, specifically includes impacts associated with marine sediment contamination that are not considered by other methods. This broader definition of contaminants used with SEDRANK includes debris and excess organic matter. Within the context of the Sediment Management Standards, the results of SEDRANK should be balanced with other information that is not quantitatively addressed by the method. Other information and effects that should be considered include the potential for migration of sediment and consequent offsite impacts. These factors are incorporated during site prioritization (described in Chapter 5).

The current formulation of SEDRANK is the result of several stages of development and review. The initial structure of the method was outlined in PTI (1988). The role of the proposed method in the sediment cleanup decision process was described in PTI (1989). A detailed description of the method, including a discussion of each of the scoring terms, was provided in *Sediment Ranking System* (PTI 1990). Further refinements have subsequently been made to the method, including finalization of scaling terms, compilation of reference tables, and case study testing. The description of SEDRANK presented in this document is based on PTI (1990), including subsequent modifications to the method (PTI 1991d).

SEDRANK produces two numerical scores by which sites can be ranked, one score for ecological hazard and one score for human health hazard. Although based on some of the same information, these scores are independent and should be used for separate estimates of relative site ranks. No method has been developed for numerical combination of the separately derived ecological and human health hazard scores.

The ecological and human health hazard scores are both computed from a number of individual scoring terms. The range of values for each term, and hence the range of values for the final scores, are constrained to certain limits. Both ecological and human health hazard scores can range up to 100. These scores do not represent any objectively interpretable quantity (such as the probability of a statistically significant impact of some type). These scores should be used only for comparison to scores of other sites produced by the same method. Because of simplifications made in the assignment of values to individual scoring terms, and the form of the equations for combining these values, the scale of the final scores is not necessarily linear. That is, a site with a score twice as high as that of another site is not necessarily twice as hazardous (by whatever other means hazard is assessed). Interpretation of the scores should therefore be limited to a qualitative evaluation of the relative magnitudes of the scores. Sites with higher scores should be interpreted as having greater potential for impacts to human health and the environment than sites with lower scores. SEDRANK ecological and human health hazard scores for different sites should not be compared directly; only the relative ranks of different sites produced by the two different types of scores should be compared.

Ecological and human health hazard assessments are structured similarly. Direct exposure of aquatic organisms to contaminated sediments (in the case of ecological hazard) and exposure of edible organisms (in the case of human health hazard) are considered the primary exposure pathways for the two hazard categories. Three categories of factors are used to evaluate these exposure pathways: waste characteristics, site characteristics, and affected resources. A value for each of these categories is produced by combining distinct scoring terms (e.g., water depth, chemical toxicity, or proximity of wetlands). Higher scores for site characteristics and affected resources are assigned to sites with greater ecological value or potential for human exposure. A higher score for waste characteristics is assigned to sites with a greater number of contaminants, higher contaminant concentrations, or contaminants that are more toxic. Waste characteristics and target resources are evaluated differently for ecological hazard and human health hazard scores. The values for each of the three categories (waste characteristics, site characteristics, and affected resources) are then combined to produce separate SEDRANK scores for ecological hazard and human health hazard.

3.1 Ecological Hazard

Direct exposure of infauna and epifauna is the most important pathway for assessing the overall ecological hazard posed by contaminated sediment because the sediment-water interface is an extremely sensitive environment. The ecological hazard score calculated by SEDRANK is directly related to both the characteristics of the waste and the ecological importance of the site. Ecological importance is assessed as a combination of site characteristics such as habitat quality and the actual resources present at a site.

3.1.1 Waste Characteristics

The key waste characteristics that define ecological hazard are toxicity, persistence, and areal extent. Sediment contamination falls into two general categories: contamination by specific toxic chemicals (i.e., metals and organic compounds) and contamination associated with other types of material (i.e., debris and excess organic matter). The toxicity of an individual chemical is expressed as the ratio of measured concentration to the SQS established by Chapter 173-204 WAC. The SQS are effects-based values, and exceedance of these values is regarded as indicative of conditions that would lead to adverse biological effects. Chemical concentrations are used in preference to biological test results because 1) individual contaminants can be characterized and evaluated, 2) contaminant diversity can be incorporated into the assessment, and 3) the relative magnitude of contaminant concentration can be evaluated. Furthermore, the use of chemical standards is consistent with the screening nature of the ranking system. The results of biological tests are incorporated into the site prioritization step.

Organic enrichment and debris such as wood chips or plastic waste are included in the characterization of sediment contamination because they can adversely affect aquatic life. Although organic matter is essential to the productivity of marine ecosystems, elevated concentrations of organic carbon can cause adverse effects by supporting increased bacterial activity that depletes the oxygen in sediments. This effect decreases the diversity of the benthic community and enhances the productivity of opportunistic organisms. Extremely high organic loading rates can result in complete depletion of oxygen in sediments and in some cases can even deplete the overlying water of oxygen, especially when water circulation is restricted. This process renders the sediments toxic to all higher life forms. Debris such as plastic wastes can also result in death by entanglement or ingestion.

The persistence of chemical contaminants is a function of their susceptibility to degradation or transformation by chemical or biological processes and their tendency to diffuse across the sediment-water interface. These processes influence the rate at which a site will recover naturally after sources of contamination have been controlled. However, very little data on biological degradation rates of chemical contaminants in sediments are available. Solubility of contaminants in water is the principal means available for estimating chemical persistence in sediments.

The extent of sediment contamination is defined by the area of sediments that exhibit sediment concentrations exceeding the SQS or that exhibit unacceptable concentrations of organic matter or debris. This simple representation of the magnitude of the affected environment is justified by the fact that biological effects are related to contamination at or near the sediment-water interface. Deeply buried waste is less ecologically relevant because the biologically active zone typically extends only 10–20 centimeters below the sediment surface.

3.1.2 Site Characteristics

The quality of a site as a potential habitat for aquatic life is the most important site characteristic for assessing ecological hazard. Although many factors can influence the habitat quality of sites in Puget Sound, two of the most important factors are depth and habitat complexity. Animal assemblages in shallow habitats are often more productive and diverse than assemblages in the deeper areas of the sound. Shallow habitats also provide spawning grounds and nursery areas for many species and are the habitats that are most accessible for human use. The shallowest habitats are intertidal areas, which support unique animal assemblages and are particularly vulnerable to human impacts. Animal assemblages in habitats characterized by spatial complexity are usually more productive and diverse than habitats that are relatively monotonous in character (e.g., flat, soft-bottom sediments). Spatial complexity in the form of macrophytes, rocks, and shell hash creates numerous microenvironments that are not found in typical soft-bottom habitats. Depth and habitat complexity are therefore used in the ranking scheme as the key characteristics for evaluating the potential habitat quality of a site.

Water depth is a readily available measurement that is well correlated with the potential of a site to support aquatic life. Sediments underlying deep water (i.e., 100 feet) do not generally support diverse communities or sensitive life stages. The extent to which sediments are covered with macrophytes is another important predictor of habitat quality. Aquatic macrophytes provide microenvironments for many species and breeding grounds for some others (e.g., eelgrass beds are used as breeding grounds for herring). Finally, sites with a high degree of spatial complexity can provide microenvironments for diverse aquatic species. Spatial complexity is represented in the SEDRANK method by an assessment of the presence or absence of vertical relief, such as underwater rocks or reefs.

The potential for a site to recover naturally is included in the evaluation of site characteristics. This potential is a function of chemical persistence (included under contaminant characteristics), the sediment accumulation rate (i.e., the rate at which clean sediments accumulate and bury contaminated sediments), and the rate and degree of mixing of surface sediments by the activity of benthic organisms. Recovery potential is essential to any assessment of sediment contamination because it may guide the timing and form of potential remedial action at the site. For example, if sites A and B are contaminated by historical sources and display similar degrees of sediment contamination, but site B is located in a depositional environment with a high sediment accumulation rate, site A should be ranked higher for remedial action because site B has the potential to recover naturally.

3.1.3 Affected Resources

Affected resources are defined as those organisms that occupy or are directly exposed to contaminated sediments at a site. Affected resources include demersal fish, benthic macroinvertebrates, benthic megainvertebrates, and macrophytes. Organisms associated with the types of habitat described in the previous section are assigned a similar status or degree of importance. The primary difference between affected resources and site characteristics is that the potential for a site to support a valuable or sensitive habitat type is assessed as a site characteristic, whereas the existing community is assessed as an affected resource. In effect, this scoring category gives greater weight to existing ecosystems that are exposed to sediment contamination than to ecosystems that would be present under ideal conditions.

3.2 Human Health Hazard

The SEDRANK method directly incorporates an assessment of onsite exposure impacts, based on evaluation of waste characteristics, site characteristics, and affected resources. The primary differences between human health hazard and ecological hazard assessments are derived from differences in the contaminants and resources of concern.

The fundamental assumption about the relationship between contaminated sediments and human health effects is that seafood consumption is the most sensitive indicator of human health hazard. The bioaccumulation of chemicals by edible organisms exposed to sediment contamination at a site is the primary exposure pathway for assessing the overall human health hazard posed by a contaminated sediment site. The exposure rate from other pathways is low relative to that resulting from seafood consumption (Becker et al. 1989).

3.2.1 Waste Characteristics

The key characteristics of contamination that determine the threat posed to human health are concentration, bioaccumulation potential, toxicity, persistence, and areal extent. Persistence is not included in the approach presented here. The assessment of waste characteristics for human health is less straightforward than ecological hazard assessment because SQS representative of human health hazard have not yet been established.

In the absence of SQS, net toxicity of a given chemical can be assessed by evaluating concentration, bioaccumulation potential, and toxicity. The concentration of a given chemical is assessed relative to reference conditions. For naturally occurring chemicals (e.g., metals and polycyclic aromatic hydrocarbons) or ubiquitous manmade chemicals (e.g., polychlorinated biphenyls), reference concentrations are often measurable by conventional analytical techniques. For other chemical contaminants (e.g., dioxins and chlorinated hydrocarbons) reference concentrations are often defined by analytical detection limits. In the latter case, elevation above reference concentrations is less meaningful because it does not provide an index of relative magnitude (or risk), but is instead an artifact of analytical limitations.

Bioaccumulation potential is the degree to which living organisms will take up and retain chemical contaminants from all exposure pathways, including intake of food and water and contact with sediments. Bioaccumulation potential is determined by environmental influences on bioavailability (e.g., dispersion, sedimentation, and degradation), physiologic mechanisms of uptake and elimination, and the chemical properties of the substance. Chemical properties are the most important of these three factors and influence the other two factors. The octanol-water partition coefficient (K_{ow}) is considered to be the best indicator of bioaccumulation potential for organic chemicals (Tetra Tech 1985) on the basis of the following:

- Empirical tests using K_{ow} produced an order of magnitude estimate of the bioconcentration of discharged substances in fish liver
- It is a reasonable model for partitioning between water and biological tissues
- It can be used to predict soil sorption coefficients and is thereby useful for predicting equilibrium partitioning among sediments, water, and biota.

Chemical indices, such as K_{ow}, have not been developed for metals, so another method must be used so that bioaccumulation potential can be evaluated uniformly at sites contaminated by both organic chemicals and metals. Bioconcentration factors (BCFs) can be used because they have been empirically determined for many metals and organic chemicals that are present as contaminants in sediments. Tetra Tech (1985) calculated BCFs as the ratio of the concentrations of organic contaminants in fish liver to the concentrations in sewage discharge effluent. BCFs are empirically derived and can vary widely, introducing uncertainty into the ranking. Consequently, they are not used in a strictly quantitative evaluation. However, BCFs are the best relative measure of bioaccumulation potential for chemicals for which K_{ow} are not available or relevant (e.g., chemicals that undergo biotransformations that influence their potential to bioaccumulate).

Relative toxicity is based on chronic oral reference doses and carcinogenic potency factors established by EPA. Chronic toxicity data are expected to be more representative of site risks (i.e., long-term exposures to low levels of contaminants in fish and shellfish) than acute toxicity data. Acute oral reference doses should be used only when no chronic toxicity or carcinogenicity data are available. Chronic toxicity and carcinogenicity data are available in the EPA Integrated Risk Information System (IRIS) (U.S. EPA, no date).

The areal extent of sediment contamination is defined by the area of sediments that exhibit elevations over reference area concentrations that exceed a factor of 5. This simple representation of the amount of material that poses a potential health risk is justified by the fact that biological effects, specifically uptake of contaminants by fish and shellfish, are related to contamination at or near the sediment-water interface.

3.2.2 Site Characteristics

The site characteristics used to evaluate human health hazards are identical to those used to evaluate ecological hazards.

3.2.3 Affected Resources

Resources that are relevant to the assessment of human health hazards include all edible species that are harvested commercially or recreationally. Resources must be present at or near the site to be considered affected. A site may affect nearby resources either by transport of contaminants off the site or as a consequence of the resource (specifically, fish) spending a portion of their life at the site. The size of the site will influence the extent to which fish populations may be affected. Fish may be expected to spend a smaller proportion of their life in the area of a smaller site, unless that site represents a special or sensitive habitat, such as a feeding or spawning ground. Non-motile resources, such as shellfish, should not be expected to be affected by the size of the site. Developed access points that encourage recreational fisherman to fish in particular locations are a special concern because they increase the potential for exposure to contaminants.

3.3 Data Used by SEDRANK

In this section, each environmental condition or item of reference information used to formulate the ecological or human health hazard scores will be described. These descriptions are organized by the scoring terms and supporting information used to compute the scores. The representation of each condition (e.g., as a coded value) is described.

Both ecological and human health hazard scores depend on site-specific information or variables. Each of the variables used to compute a SEDRANK score is assigned a numerical value that is used for the computation. Some of these variables are ordinarily represented by numerical values, and these same values are used for SEDRANK scoring (e.g., the actual concentrations of contaminants). Some variables are ordinarily represented by numerical values, but are re-coded for the purpose of SEDRANK scoring (e.g., scores of 1-4 corresponding to different depth ranges). Some variables are not ordinarily represented by numerical values, but are assigned scores for the purpose of SEDRANK scoring (e.g., the presence or absence of debris).

The most recent available site-specific data that meet the data quality guidelines described in the *Sediment Cleanup Standards Guidance Document* should be used in all cases. Site-specific chemical data and current reference information can be obtained from the database manager at Ecology's Sediment Management Unit. The source of all information used for a SEDRANK calculation should be recorded so that the need for a revised calculation can be determined if more recent data become available.

3.3.1 Sediment Quality Standards

The SQS for each contaminant present at a site must be obtained from Table 3-1 or an update. The SQS are used to calculate the ecological hazard score.

3.3.2 Site-Specific Chemical and Organic Carbon Concentrations

The concentrations of all chemicals that are detected in sediments at a site are required for calculation of the waste characteristics score for both ecological and human health hazard. Concentrations must be expressed on the same basis [dry weight or normalized to total organic

TABLE 3-1. MARINE SEDIMENT QUALITY STANDARDS AND CLEANUP SCREENING LEVELS FOR PUGET SOUND

Chemical Parameter	SQS[a]	CSL and MCUL[a]
Metals (mg/kg dry weight)		
Arsenic	57	93
Cadmium	5.1	6.7
Chromium	260	270
Copper	390	390
Lead	450	530
Mercury	0.41	0.59
Silver	6.1	6.1
Zinc	410	960
Nonionizable Organic Chemicals (mg/kg organic carbon)		
LPAH[b]	370	780
Naphthalene	99	170
Acenaphthalene	66	66
Acenaphthene	16	57
Fluorene	23	79
Phenanthrene	100	480
Anthracene	220	1,200
2-Methylnaphthalene	38	64
HPAH[c]	960	5,300
Fluoranthene	160	1,200
Pyrene	1,000	1,400
Benz(a)anthracene	110	270
Chrysene	110	460
Total benzofluoranthenes[d]	230	450
Benzo(a)pyrene	99	210
Indeno(1,2,3-c,d)pyrene	34	88
Dibenz(a,h)anthracene	12	33
Benzo(g,h,i)perylene	31	78
1,2-Dichlorobenzene	2.3	2.3
1,4-Dichlorobenzene	3.1	9
1,2,4-Trichlorobenzene	0.81	1.8
Hexachlorobenzene	0.38	2.3
Dimethyl phthalate	53	53
Diethyl phthalate	61	110

TABLE 3-1. (Continued)

Chemical Parameter	SQS[a]	CSL and MCUL[a]
Di-n-butyl phthalate	220	1,700
Butylbenzyl phthalate	4.9	64
Bis(2-ethylhexyl) phthalate	47	78
Di-n-octyl phthalate	58	4,500
Dibenzofuran	15	58
Hexachlorobutadiene	3.9	6.2
N-nitrosodiphenylamine	11	11
Total PCBs	12	65
Ionizable Organic Chemicals (mg/kg dry weight)		
Phenol	0.42	1.2
2-Methylphenol	0.063	0.063
4-Methylphenol	0.67	0.67
2,4-Dimethylphenol	0.029	0.029
Pentachlorophenol	0.36	0.69
Benzyl alcohol	0.057	0.073
Benzoic acid	0.65	0.65

[a] SQS - sediment quality standards
CSL - cleanup screening levels
MCUL - minimum cleanup levels

When laboratory analysis indicates a chemical is not detected in a sediment sample, the detection limit shall be reported and must be at or below the criteria value shown in this table. Where chemical criteria in this table represent the sum of individual compounds or isomers, and a chemical analysis identifies an undetected value for one or more individual compounds or isomers, the detection limit shall be used for calculating the sum of the respective compounds or isomers.

[b] The LPAH criterion represents the sum of the following low molecular weight polycyclic aromatic hydrocarbons (PAHs): naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. The LPAH criterion is not the sum of the values for the listed individual LPAH compounds.

[c] The HPAH criterion represents the sum of the following high molecular weight PAHs: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene. The HPAH criterion is not the sum of the values for the listed individual HPAH compounds.

[d] The total benzofluoranthenes criterion represents the sum of the concentrations of the b, j, and k isomers.

carbon (TOC)] and in the same units (mg/kg or μg/kg) as the SQS. Chemical concentrations are normalized to TOC by dividing the dry-weight chemical concentration by the TOC concentration expressed as a fraction of total sediment mass. Chemical concentrations at each station should be normalized using TOC measurements made at that station.

Contaminant concentrations have a large impact on the ecological and human health hazard scores (PTI 1991d). Chemistry data to be used for site ranking should therefore be as recent as possible and should conform to PSEP (1990) standards or equivalent standards approved by Ecology.

The TOC concentration is needed both to normalize contaminant concentrations and to provide an independent measurement of waste characteristics. When it is used as a measure of waste characteristics, TOC must be represented by a scaled value, as shown in Table 3-2.

3.3.3 Reference Area Chemical Concentrations

The concentrations of site contaminants at appropriate reference areas must be collected to compute the SEDRANK human health hazard score. This information must be collected for all contaminants that are detected at the site and for contaminants that are expected to be present at the site (based on site history, presence of parent or breakdown compounds, or other information), which may have been undetected because of high detection limits. The concentrations of contaminants in reference areas should be expressed on the same basis (dry weight or normalized to TOC) and in the same units (mg/kg or μg/kg) as the corresponding SQS.

Table 3-3 summarizes reference area concentrations for some of the chemicals for which SQS have been established. These concentrations are the reference area performance standards (upper 90th percentiles of the distribution of concentrations in reference areas). Ecology's Sediment Management Unit should be contacted to obtain values for chemicals that are not in Table 3-3.

3.3.4 Debris

Information on the presence or absence of debris at a site must be collected. Material that is considered debris includes wood waste, plastics, and other nonbiodegradable materials. No standards exist to define the amount of debris that should be considered ecologically

TABLE 3-2. SCORES FOR TOTAL ORGANIC CARBON

Total Organic Carbon Concentration Range (percent)	Total Organic Carbon Value
<3	1
3–5	2
>5	3

TABLE 3-3. REFERENCE AREA CONCENTRATIONS

Metal/Metalloid	mg/kg Dry Weight (ppm dry)
Antimony	5.9[a]
Arsenic	22[b]
Cadmium	1.5[b]
Chromium	85[b]
Copper	53[b]
Lead	20[b]
Mercury	0.15[b]
Nickel	42[b]
Silver	0.32[b]
Zinc	103[b]

Nonionic Organic Chemical	μg/kg Dry Weight (ppb dry)
LPAH[c]	200[b]
Naphthalene	94[a]
Acenaphthylene	130[d]
Acenaphthene	25[d]
Fluorene	170[a]
Phenanthrene	150[a]
Anthracene	36[a]
2-Methylnaphthalene	21[a]
HPAH[e]	330[b]
Fluoranthene	98[a]
Pyrene	93[a]
Benz(a)anthracene	100[a]
Chrysene	67[a]
Total benzofluoranthenes[f]	100[a]
Benzo(a)pyrene	70[a]
Indeno(1,2,3-c,d)pyrene	420[a]
Dibenzo(a,h)anthracene	30[d]
Benzo(g,h,i)perylene	420[a]
1,2-Dichlorobenzene	U10[g]
1,3-Dichlorobenzene	U10[g]
1,4-Dichlorobenzene	U10[g]
1,2,4-Trichlorobenzene	U10[g]
Hexachlorobenzene	U10[g]
Total phthalates	1,300[b]

TABLE 3-3. (Continued)

Nonionic Organic Chemical	μg/kg Dry Weight (ppb dry)
Dimethyl phthalate	U10[g]
Diethyl phthalate	U10[g]
Bis(2-ethylhexyl)phthalate	2,000[a]
Di-*n*-butyl phthalate	U10[g]
Butyl benzyl phthalate	U10[g]
Bis(2-ethylhexyl)phthalate	U10[g]
Di-*n*-octyl phthalate	U10[g]
Dibenzofuran	U10[g]
Hexachlorobutadiene	U10[g]
N-nitrosodiphenylamine	U10[g]
Tetrachloroethene	U2[g]
Ethylbenzene	U2[g]
Total xylene	U2[g]
Total PCBs	47[a]

Ionizable Organic Chemical	μg/kg Dry Weight (ppb dry)
Phenol	510[a]
2-Methylphenol	U10[g]
4-Methylphenol	1,400[a]
2,4-Dimethylphenol	U10[g]
Pentachlorophenol	U50[g]
Benzyl alcohol	U10[g]
Benzoic acid	U50[g]

[a] Source: *Pollutants of Concern in Puget Sound* (PTI 1991a). Values are the 90th percentile of concentrations observed in reference areas.

[b] Source: *Reference Area Performance Standards for Puget Sound* (PTI 1991b). Values are the 90th percentile of concentrations observed in reference areas.

[c] The low molecular weight polycyclic aromatic hydrocarbon (LPAH) criteria are applicable to the sum of the following LPAH compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.

[d] Values represent the mean value measured in selected reference areas in Puget Sound that are represented in the SEDQUAL database. Mean includes undetected values as detection limits.

[e] The high molecular weight polycyclic aromatic hydrocarbon (HPAH) criteria are applicable to the sum of the following HPAH compounds: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

[f] The total benzofluoranthenes criterion represents the sum of the b, j, and k isomers.

[g] Lower range of the limit of detection (PSEP 1990) for samples without significant interferences; U - undetected at concentration indicated.

harmful. Best professional judgment should be employed when evaluating the ecological significance of debris observed at a site.

Presence or absence of debris is scored as shown in Table 3-4. These values are used to compute the ecological hazard score.

3.3.5 Site Area

The total area of the site must be expressed in square yards. Area must be computed using a representation of the site boundary that has been approved by Ecology. Either manual methods (using a planimeter) or computerized tools (such as a geographic information system) may be used to calculate the area. Thiessen polygons constructed around each station at the site can be used as a basis for estimating site area (all the points in a Thiessen polygon are closer to the central station than to any other station).

3.3.6 Chemical Loss Factor

Chemical solubility is used to estimate the loss of contaminants from the sediment (loss factor). If adequate data become available in the future, the effect of biodegradation may be included as a component of the chemical loss factor. An order-of-magnitude estimate of solubility is required. Solubilities for most chemicals for which SQS have been established are listed in Table 3-5. Revisions to this information may be obtained from the Hazardous Substances Data Bank (HSDB 1989), other reference sources, or the database manager at Ecology's Sediment Management Unit.

Chemical loss factors are based on the logarithm of the solubility. Low, medium, and high loss factors are defined as shown in Table 3-6. Each loss factor has an associated value that is used to compute the SEDRANK score. If no solubility data are available for a contaminant, a loss factor value of 1.0 should be used.

3.3.7 Water Depth

Water depth is used to evaluate site characteristics for both the ecological and human health hazard scores. Depth information can be obtained from National Oceanic and Atmospheric Administration navigation charts or from recent surveys of the site. For use in the SEDRANK calculation, values are assigned to different depth ranges as shown in Table 3-7. If a site varies in depth, it should be assigned a value

TABLE 3-4. SCORES FOR DEBRIS

Observation	Debris Value
Absent	1
Present	2

TABLE 3-5. CHEMICAL TOXICITY

Contaminant	Solubility in Water (mg/L)	Log Solubility	Description	Loss Factor
Acenaphthene	Insoluble in water	--	Low	1.0
Acenaphthylene	3.93	0	Medium	0.9
Anthracene	0.6[a]	0	Medium	0.9
Benz(a)anthracene	0.01	−2	Low	1.0
Benzofluoranthenes (total)	0.0043	−3	Low	1.0
Benzoic acid	2,700[b]	3	High	0.8
Benzo(a)pyrene	0.005–0.010[a]	−2	Low	1.0
Benzo(g,h,i)perylene	0.00026	−4	Low	1.0
Benzyl alcohol	35,000[c]	4	High	0.8
Bis(2-ethylhexyl)phthalate	0.3	−1	Medium	0.9
Butyl benzyl phthalate	2.69	0	Medium	0.9
Chrysene	Insoluble in water	--	Low	1.0
Di-n-butyl phthalate	11.2	1	Medium	0.9
Di-n-octyl phthalate	0.285[d]	−1	Medium	0.9
Dibenz(a,h)anthracene	Insoluble in water	--	Low	1.0
Dibenzofuran	ND[e]	--	--	--
1,4-Dichlorobenzene	87	2	High	0.8
Dimethyl phthalate	4,000	3	High	0.8
Fluoranthene	0.120[a,d]	−1	Medium	0.9
Fluorene	0.6–1.0[a,f]	0	Medium	0.9
Hexachlorobenzene	0.0062	−2	Low	1.0
Hexachlorobutadiene	2.55[c]	0	Medium	0.9
Indeno(1,2,3-c,d)pyrene	0.00053	−3	Low	1.0
2-Methylnaphthalene	--	--	--	--
4-Methylphenol (p-Cresol)	22,600[g]	4	High	0.8

TABLE 3-5. (Continued)

Contaminant	Solubility in Water (mg/L)	Log Solubility	Description	Loss Factor
Naphthalene	31.7	1	Medium	0.9
p-Nitrosodiphenylamine	--	--	--	--
PCBs (Aroclor)	0.04–0.2	–1	Medium	0.9
Phenanthrene	0.5–0.7[a,f]	0	Medium	0.9
Phenol	87,000	5	High	0.8
Pyrene	0.032[d]	–2	Low	1.0
Arsenic	Insoluble in water	--	Low	1.0
Cadmium	Insoluble in water	--	Low	1.0
Copper	Insoluble in water	--	Low	1.0
Lead	Insoluble in water	--	Low	1.0
Mercury	0.056	–1	Medium	0.9
Silver	Insoluble in water	--	Low	1.0
Zinc	Insoluble in water	--	Low	1.0

[a] Solubility in saltwater.

[b] Measured at 18°C.

[c] Measured at 20°C.

[d] Measured at 24°C.

[e] ND - no data available.

[f] Measured at 22°C.

[g] Measured at 40°C.

TABLE 3-6. SCORES FOR CHEMICAL LOSS FACTOR

Loss Factor	$\log_{10}$ Solubility	Loss Factor Value
Low	Insoluble or < −1	1.0
Medium	−1 to 1	0.9
High	>1	0.8

TABLE 3-7. SCORES FOR DEPTH

Depth	Depth Value
>100 feet	1
50–100 feet	2
0–50 feet	3
Site includes intertidal areas	4

corresponding to the shallowest depth found at the site. Variations in depth may also affect the habitat complexity value.

3.3.8 Habitat Complexity

The potential of a site to support multiple or diverse communities is represented by the habitat complexity score. Higher values are assigned to sites with more relief (i.e., a greater range of depths available to infauna and epifauna, either as a consequence of variations in bottom elevation or the presence of large macrophytes), more or a greater variety of substrates (including rock, shell hash, and macrophytes), and a greater number of microhabitats (e.g., crevices, intertidal areas, and regions of varying current or wave energy). The three habitat complexity values that may be assigned to a site are summarized in Table 3-8.

3.3.9 Recovery Factor

The recovery factor is used to estimate the potential for natural recovery at a site in the absence of cleanup action. The principal effect determining the potential for natural recovery is the rate of net sediment accumulation. In the absence of an ongoing source of contamination, higher sediment accumulation rates will lead to more rapid recovery as a consequence of the burial of contaminated sediment. If contamination is still being introduced to the site from ongoing sources, the potential for natural recovery is limited, even at high sediment accumulation rates.

Values for the recovery factor range from 0.1 to 1.0, which express the fraction of the initial concentrations remaining after natural recovery. These values correspond to the effective reduction in contaminant levels that would result from accumulation of clean sediment over a 10-year period (Tetra Tech 1987), with 1.0 indicating no reduction. Higher recovery factors therefore are applied to sites with lower potential for natural recovery. Sedimentation rate data for much of Puget Sound is presented in Carpenter et al. (1985) and Lavelle et al. (1986). In the absence of any site-specific data regarding sediment accumulation rates or source control status, a recovery factor of 1.0 should be used.

Both the sedimentation rate and the presence of ongoing sources must be known so that an appropriate recovery factor can be selected. Table 3-9 presents the relationship between source status, sediment accumulation rate, and recovery factor.

TABLE 3-8. SCORES FOR HABITAT COMPLEXITY

Characteristics	Habitat Complexity Value
Little or no relief Areal extent of macrophytes, rocks, shell hash, or other habitat-enhancing material is less than 10 percent Few microhabitats are available other than those found in a typical soft-bottom environment	1
Moderate relief or spatial complexity Areal extent of habitat-enhancing material is between 10 and 50 percent A moderate number of microhabitats is available	2
High degree of relief or spatial complexity Areal extent of habitat-enhancing material is greater than 50 percent A relatively large number of microhabitats is available	3

TABLE 3-9. SCORES FOR RECOVERY FACTOR

Source Status	Sediment Accumulation Rate (cm/year)	Recovery Factor Value
Ongoing	<0.2	1.0
	0.2–2	0.9
	>2	0.8
Historical	0	1.0
	0–0.2	0.9
	0.2–0.4	0.8
	0.4–0.6	0.6
	0.6–0.8	0.5
	0.8–1.0	0.4
	1.0–1.4	0.3
	1.4–1.8	0.2
	>1.8	0.1

3.3.10 Presence of Special Marine Habitats

Special marine habitats are regarded as sensitive resources that may be affected by contamination at the site. Special marine habitats include:

- Macrophyte (e.g., eelgrass or kelp) beds
- Salt marshes and other wetlands
- Fish spawning, nursery, and feeding grounds
- Seabird nesting and feeding areas
- Marine mammal haul-out areas.

The locations of special marine habitats are shown in PSEP (1987), NOAA (1987), and PSWQA (1988). Other, more site-specific data sources should be used if available.

The presence of a special habitat is indicated by a score in the range of 1 to 3, as shown in Table 3-10. A value of 3 should be used if any special habitat is within the established site boundary. A value of 2 should be used if the special habitat abuts the contaminated site or if there is a likelihood of interaction between the site and the special habitat. Proximity values for special habitats that are not actually within the site should be based on best professional judgment, and may require the expertise of a trained biologist, ecologist, chemist, or oceanographer. Factors that should be considered when making such a judgment include:

- Passage through the site of fish or marine mammals using the special habitat
- Feeding on the site by waterfowl that use the special habitat (e.g., as a nesting area)
- Transportation of contaminated sediment from the site to the special habitat by currents or tidal action.

3.3.11 Presence of Wildlife Refuges or Sanctuaries

Established wildlife refuges and sanctuaries are regarded as a component of affected resources separate from special marine habitats. The presence or absence of refuges or sanctuaries should be represented by values as shown in Table 3-11.

TABLE 3-10. SCORES FOR SPECIAL MARINE HABITATS

Characteristics	Special Marine Habitat Value
No special marine habitat near or within site	1
Special marine habitat near site	2
Special marine habitat within site	3

TABLE 3-11. SCORES FOR WILDLIFE REFUGES AND SANCTUARIES

Characteristics	Wildlife Refuges and Sanctuaries Value
No refuge or sanctuary near site	1
Designated refuge or sanctuary near or within site	2

The locations of wildlife refuges and sanctuaries in Puget Sound are shown in PSEP (1987). The proximity value for either of these types of areas to a contaminated site should be assessed in the same manner as special marine habitats (Section 3.3.10).

3.3.12 Chemical Toxicity and Carcinogenicity

Chemical toxicity and carcinogenicity information is used to compute the SEDRANK score for human health risk. Current chronic oral toxicity values and carcinogenicity potency values for contaminants should be obtained at the time a site is scored. These values may be obtained from IRIS.

Toxicity is represented in SEDRANK by one of five values: very high, high, medium, low, and very low. Chronic oral toxicity and carcinogenicity for each chemical are each categorized and assigned one of these five values. The highest value assigned to either chronic toxicity or carcinogenicity is used as the SEDRANK toxicity score. These non-numeric values are used to select a waste characteristics score, as described in Section 4.3.5.

Ranges of chronic toxicity values are converted to values for SEDRANK use as shown in Table 3-12. If a chronic toxicity value is not available for any chemical, an acute toxicity value, if available, should be used instead. Chronic toxicity values, if available, should always be used in preference to acute toxicity values, as they are considered more representative of the effects of long-term sediment contamination. Table 3-13 illustrates the conversion of acute oral toxicity values expressed as LD_{50} or LD_{LO} to the SEDRANK toxicity value. Table 3-14 illustrates the correspondence between EPA carcinogenic potency factors and SEDRANK toxicity values.

3.3.13 Bioaccumulation Factors

The potential for bioaccumulation of each of the contaminants present at a site must be assessed to compute the SEDRANK human health hazard score. K_{ow} (for organic compounds) and BCF values are used as the basis for assigning bioaccumulation factors to specific chemicals. Table 3-15 lists bioaccumulation factors for selected chemicals.

TABLE 3-12. SCORES FOR CHRONIC TOXICITY

Guideline for Chronic Oral Toxicity (mg/kg-day)[1]	SEDRANK Toxicity Value
$\leq 10^{-3}$	Very high
$>10^{-3}$ to 10^{-2}	High
$>10^{-2}$ to 10^{-1}	Medium
$>10^{-1}$ to 10	Low
>10	Very low

TABLE 3-13. SCORES FOR ACUTE TOXICITY

Acute Oral LD_{50} or LD_{LO} (mg/kg-body weight)	SEDRANK Toxicity Value
≤ 50	Very high
>50 to ≤ 500	High
>500 to $\leq 5,000$	Medium
$>5,000$ to $\leq 15,000$	Low
$>15,000$	Very low

TABLE 3-14. SCORES FOR CARCINOGENICITY

Carcinogenic Potency Factor (mg/kg-day)[1]	SEDRANK Toxicity Value
$>10^2$	Very high
>10 to 10^2	High
>1 to 10	Medium
$>10^{-2}$ to 1	Low
$>10^{-2}$	Very low

TABLE 3-15. BIOACCUMULATION FACTORS

Metal/Metalloid	Bioaccumulation[a] Factor
Arsenic	High
Cadmium	High
Chromium	High
Copper	High
Lead	High
Mercury	High
Nickel	High
Silver	High
Zinc	High

Nonionic Organic Chemical	Bioaccumulation[b] Factor
LPAH[c]	High
Naphthalene	Medium
Acenaphthylene	High
Acenaphthene	Medium
Fluorene	High
Phenanthrene	High
Anthracene	High
2-Methylnaphthalene	Medium
HPAH[e]	High
Fluoranthene	High
Pyrene	High
Benz(a)anthracene	High
Chrysene	High
Total benzofluoranthenes[f]	High
Benzo(a)pyrene	High
Indeno(1,2,3-c,d)pyrene	High
Dibenzo(a,h)anthracene	High
Benzo(g,h,i)perylene	High
1,2-Dichlorobenzene	Medium
1,3-Dichlorobenzene	Medium
1,4-Dichlorobenzene	Medium
1,2,4-Trichlorobenzene	High
Hexachlorobenzene	High

TABLE 3-15. (Continued)

Nonionic Organic Chemical	Bioaccumulation[c] Factor
Dimethyl phthalate	--
Diethyl phthalate	Low
Bis(2-ethylhexyl)phthalate	High
Di-*n*-butyl phthalate	High
Butyl benzyl phthalate	High
Bis(2-ethylhexyl)phthalate	High
Di-*n*-octyl phthalate	High
Dibenzofuran	High
Hexachlorobutadiene	High
N-nitrosodiphenylamine	Low
Tetrachloroethene	Medium
Ethylbenzene	Medium
Total xylene	--
Total PCBs	High

Ionizable Organic Chemical	µg/kg Dry Weight (ppb dry)
Phenol	Low
2-Methylphenol	--
4-Methylphenol	--
2,4-Dimethylphenol	--
Pentachlorophenol	High
Benzyl alcohol	--
Benzoic acid	--

[a] All metals were assigned interim ratings for bioaccumulation potential and were designated "high." Metal bioaccumulation potential may vary depending on speciation.

[b] Organic chemicals were assigned interim ratings for bioaccumulation potential based on the rank order developed in Tetra Tech (1985), which was based on octanol-water partition coefficients (K_{ow}) and empirical bioconcentration factors. All chemicals with log K_{ow} >4.0 were designated "high," all chemicals with log K_{ow} <2.53 were designated "low," and chemicals with intermediate log K_{ow} values were designated "medium."

[c] The low molecular weight polycyclic aromatic hydrocarbon (LPAH) criteria are applicable to the sum of the following LPAH compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.

[d] The high molecular weight polycyclic aromatic hydrocarbon (HPAH) criteria are applicable to the sum of the following HPAH compounds: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

[e] The total benzofluoranthenes criterion represents the sum of the b, j, and k isomers.

3.3.14 Presence of Fisheries

Human health risk is presumed to be affected principally by the ingestion of edible resources (fish, shellfish, crustacea, and seaweeds) from the site. The existence of commercial or recreational fisheries at or near the site is evidence of exposure to these resources. Commercial and recreational fisheries are evaluated independently in SEDRANK. Individual exposure is expected to be highest if there is a tribal fishery within the site (for commercial fisheries) or if the site is easily accessible to recreational fishermen (e.g., by piers or adjacent boat launches). Tables 3-16 and 3-17 list the values to be used for different characteristics of commercial and recreational fisheries at the site.

TABLE 3-16. SCORES FOR COMMERCIAL FISHERIES

Characteristics	Commercial Fisheries Value
No fishery near or within site	1
Fishery near site	2
Fishery within site	3
Tribal fishery within site	4

TABLE 3-17. SCORES FOR RECREATIONAL FISHERIES

Characteristics	Recreational Fisheries Value
No fishery near or within site	1
Fishery near site	2
Fishery within site	3
Enhanced access	4

4. USE OF SEDRANK

This section provides step-by-step directions for collating the data and calculating individual scoring terms and overall site scores for both ecological and human health hazard.

4.1 Data Collection

Prior to ranking, a hazard assessment should be conducted at the site. Data to be collected during this hazard assessment include all of the information specified in WAC 173-204-530, the *Sediment Cleanup Standards Guidance Document* (PTI 1991c), and Section 3.3 of this document. Qualitative data regarding the site should be collected to assist interpretation (and possible modification) of SEDRANK scores.

Collection and analysis of new samples is not required to complete a hazard assessment. A hazard assessment may, however, be delayed to allow inclusion of data collected by parties concerned with the site. Data that have been subjected to the most rigorous quality assurance procedures are preferred. The Puget Sound Estuary Program standards specify a minimum level of quality assurance to which all data sets should adhere. More recent data are preferred over older data, unless there is substantial evidence that the recent data were collected during unusual conditions (e.g., following a 100-year flood that was accompanied by elevated upland erosion and deposition at the site).

Data needed for SEDRANK calculations should be transcribed onto the worksheets shown in Appendix A. These worksheets are designed to assist in the organization of scoring values and calculation of a final score. The scoring values to be used for each type of data are listed in the tables in Chapter 3 of this document. Individual worksheets are designed for the collation of data pertaining to waste characteristics, site characteristics, and affected resources for both ecological and human health hazard scores. The scoring of site characteristics is the same for both ecological and human health hazard scores and requires only a single worksheet. A total of seven types of worksheets must therefore be completed to calculate a site score. Note that because of the complexity of the waste characteristics scores, more than one page of the waste characteristics worksheet may be needed for a single site (for both ecological and human health hazard scores). In contrast, each worksheet for site characteristics and affected resources can be used to collate the data for several sites.

4.2 Scoring Equations

Although the scores for waste characteristics and affected resources are calculated differently for ecological hazard and human health hazard, the waste characteristics, site characteristics, and affected resources scores are combined in the same way for ecological and human health hazard ranking. The equation for computing both ecological and human health hazard scores is:

$$\text{Hazard Score} = \text{Waste Characteristics} \times [\text{Site Characteristics} + \text{Affected Resources}] \quad (1)$$

Site characteristics and affected resources are regarded as independent components of hazard at the site, so the final score is computed from the sum of these independent terms. The hazard score for site characteristics and affected resources depends directly on waste characteristics, hence the multiplicative relationship between waste characteristics and the other terms.

Maximum scores are assigned to each of the categories of waste characteristics, site characteristics, and affected resources. The total SEDRANK score therefore also has a fixed upper value. The maximum hazard score is 100. The maximum scores for waste characteristics, site characteristics, and affected resources are 10, 5, and 5, respectively.

4.2.1 Ecological Hazard Score

4.2.1.1 Waste Characteristics

The waste characteristics score is a function of area, chemical toxicity, organic content, and debris. Independent scores are calculated for chemical toxicity, organic content, and debris, as shown in Equations 2–4. Calculation of chemical toxicity is performed as shown in Equation 5. Sections 3.3.2 and 3.3.4 describe the data used to derive values for organic content and debris, respectively.

The highest result produced by any of Equations 2–4 is used as the waste characteristics score for a site. If the highest result is greater than 10, a value of 10 is used for the overall waste characteristics score. If the waste characteristics score is based on organic content or debris, the final ecological hazard score should be assigned a qualifier of C or D, respectively.

$$\text{Waste Characteristics} = \tfrac{1}{3} \times \text{Chemical Toxicity} \times \text{Areal Extent} \qquad (2)$$

$$\text{Waste Characteristics} = \tfrac{1}{3} \times \text{Organic Content} \times \text{Areal Extent} \qquad (3)$$

$$\text{Waste Characteristics} = \tfrac{1}{3} \times \text{Debris} \times \text{Areal Extent} \qquad (4)$$

$$\text{Chemical Toxicity} = 3 \times \log_{10} \sum_{j=1}^{N} \frac{L_j \times \left[\max_{k=1}^{S} C_{jk} \right]}{SQS_j} \qquad (5)$$

where:

- S = The number of stations at the site
- N = The number of chemicals exceeding SQS at the site
- C = Chemical concentration (see Section 3.3.2)
- L = Chemical loss factor (see Section 3.3.6).

4.2.1.2 Site Characteristics

The site characteristics score is determined from an assessment of the quality of habitat at the site and the potential for the site to recover naturally. The site characteristics score is calculated as shown in Equations 6 and 7.

$$\text{Site Characteristics} = \text{Habitat Quality} \times \text{Recovery Factor} \qquad (6)$$

$$\text{Habitat Quality} = \tfrac{5}{7} \times (\text{Depth Value} + \text{Habitat Complexity}) \qquad (7)$$

Values for water depth, habitat complexity, and recovery factor are selected as described in Sections 3.3.7, 3.3.8, and 3.3.9, respectively.

4.2.1.3 Affected Resources

The affected resources score is based on an assessment of the proximity of sensitive resources to the site. This score is calculated as shown in Equation 8.

$$\text{Affected Resources} = \text{Special Marine Habitat} + \text{Refuge or Sanctuary} \qquad (8)$$

Values for special habitat and refuge/sanctuary are selected as described in Sections 3.3.10 and 3.3.11, respectively.

4.2.2 Human Health Hazard Score

4.2.2.1 Waste Characteristics

The waste characteristics score is a function of area, chemical enrichment (observed chemical concentrations at the site divided by reference concentrations), bioaccumulation potential, and chemical toxicity. The waste characteristics score is calculated as shown in Equations 9 and 10.

$$\text{Waste Characteristics} = \frac{1}{3} \times \text{Overall Toxicity} \times \text{Areal Extent} \qquad (9)$$

$$\text{Overall Toxicity} = \frac{\sum_{j=1}^{N} (\text{Toxicity})_j}{15} \qquad (10)$$

where:

N = The number of chemicals exceeding SQS at the site.

The toxicity value shown in Equation 10 depends on the chemical toxicity/carcinogenicity, bioaccumulation potential, and enrichment ratio. Values for chemical toxicity/carcinogenicity are obtained as described in Section 3.3.12, values for bioaccumulation potential are obtained as described in Section 3.3.13, and the enrichment ratio is calculated by forming the ratio of the chemical concentration at the site (Section 3.3.2) to the reference area concentration (Section 3.3.3). These three values are used to select a toxicity value from Table 4-1.

If the waste characteristics score produced by using Equations 9 and 10 and Table 4-1 is greater than 10, a value of 10 should be used for the human health hazard calculation (Equation 1).

4.2.2.2 Site Characteristics

The site characteristics score for human health hazard is calculated identically to the corresponding score for ecological hazard (Section 4.2.1.2).

TABLE 4-1. HUMAN HEALTH HAZARD SCORE—OVERALL TOXICITY

High Enrichment Ratio[a]

Toxicity/Carcinogenicity	Bioaccumulation Potential: Low	Medium	High
Very high	8	9.5	10
High	7.5	8	9.5
Medium	6.5	7.5	8
Low	5.5	6.5	7.5
Very low	5	5.5	6.5

Medium Enrichment Ratio[b]

Toxicity/Carcinogenicity	Bioaccumulation Potential: Low	Medium	High
Very high	6	7	8
High	5	6	7
Medium	4	5	6
Low	3	4	5
Very low	3	3	4

Low Enrichment Ratio[c]

Toxicity/Carcinogenicity	Bioaccumulation Potential: Low	Medium	High
Very high	3	3.5	4
High	2.5	3	3.5
Medium	2	2.5	3
Low	1.5	2	2.5
Very low	1	1.5	2

[a] Concentrations in sediments 100–1,000 times greater than reference concentrations.

[b] Concentrations in sediments 10–100 times greater than reference concentrations.

[c] Concentrations in sediments 1–10 times greater than reference concentrations.

4.2.2.3 Affected Resources

The score for affected resources is based on an assessment of the proximity of edible resources to the site. This score is calculated as shown in Equation 11.

$$\text{Affected Resources} = \tfrac{5}{8} \times (\text{Commercial Fishery} + \text{Recreational Fishery}) \qquad (11)$$

Values for commercial and recreational fisheries are selected as described in Section 3.3.14.

4.3 Step-by-Step Calculation of Site Score

The ecological and human health hazard scores are computed independently and recorded on the *Ecological Hazard - Overall Score Worksheet* and the *Human Health Hazard - Overall Score Worksheet* (Appendix A). Enter the name(s) of all the site(s) to be ranked in the first column of these worksheets. Individual worksheets are used to calculate waste characteristics, site characteristics, and affected resources. All worksheets are presented in Appendix A.

4.3.1 Ecological Hazard Score

Waste Characteristics

1. Identify all sources of site-specific data, including chemical concentrations, TOC concentrations, and presence of debris. Prioritize these by data quality and recency to determine the most appropriate source to use for each contaminant type (i.e., chemical, TOC, or debris).

2. Record the name of each chemical observed at the site in Column 1 of the *Ecological Hazard - Chemical Toxicity Worksheet.*

3. In Column 2 of the worksheet record the highest concentration of each chemical observed among all stations within the boundary of the site. The highest concentrations of different chemicals may occur at different stations. All concentrations should be expressed on the same basis and in the same units (dry weight or TOC-normalized; mg/kg or µg/kg) as the SQS for the corresponding contaminant. If multiple measurements of equivalent quality and age are available (e.g., from different studies), use the average of the highest concentrations.

4. In Column 3 of the worksheet, enter the chemical SQS from Table 3-1. Note the source of these values at the bottom of the worksheet.

5. In Column 4 of the worksheet, compute the exceedance factor by dividing the value in Column 2 by the value in Column 3. If the value is ≤1, leave that row of Column 3 blank (chemicals that do not exceed the SQS do not contribute to the site score).

6. Identify an appropriate loss factor for each chemical by referring to Table 3-5. Enter these values in Column 5 of the worksheet.

7. Multiply the values in Columns 4 and 5 of the worksheet to generate values for Column 6. Remember, do not carry values for chemicals with exceedance factors ≤1 over to Column 6.

8. Add all of the values in Column 6 and enter the sum in Box A at the bottom of the column.

9. Compute the base-10 logarithm of the sum computed in Step 8 and multiply it by 3. Enter this value in Box B. (The result of Steps 1 through 9 corresponds to Equation 5.)

10. The chemical toxicity value for ecological hazard must not be >10. If the value computed in Step 9 is <10, enter it in Box C of the worksheet. If the value is ≥10, enter 10 in Box C. Copy the value from Box C to Column 3 of the *Ecological Hazard - Overall Score Worksheet.*

11. Determine the highest concentration of TOC at any station at the site and use Table 3-2 to determine the organic content score for the site. Record this value in Column 4 of the *Ecological Hazard - Overall Score Worksheet.*

12. Evaluate the abundance of debris and use Table 3-4 to determine the debris score for the site. Record this value in Column 5 of the *Ecological Hazard - Overall Score Worksheet.*

13. Determine the area of the site in square yards. This determination must be based on the site boundary as determined or approved by Ecology. Divide the area by 1,000,000 to determine the score for areal extent; if the score is >3, use a value of 3. Enter the areal extent in Column 2 of the *Ecological Hazard - Overall Score Worksheet.*

14. Multiply the highest values in Columns 3, 4, and 5 by the areal extent in Column 2 and divide by 3. This value is the ecological hazard waste characteristics score. This value should be ≤10. Enter this value, or 10 if the value is >10, in Column 6. If the waste characteristics score is based on organic carbon or debris, append a *C* or *D* qualifier, respectively, to the value in Column 6.

Site Characteristics

15. Enter the name of the site(s) to be ranked in Column 1 of the *Site Characteristics Worksheet*. Determine the shallowest water depth present at the site and convert this measurement into a depth score using Table 3-7. Enter the depth score in Column 2.

16. Evaluate the habitat complexity (as described in Section 3.3.8) and assign it a value using Table 3-8. Enter this value in Column 3 of the worksheet.

17. Add the values in Columns 2 and 3 and record the result in Column 4.

18. Multiply the value in Column 4 by 5/7 and record the result in Column 5 to get the habitat quality score.

19. If site-specific information on source control status and sedimentation rate is available, use this information to select a recovery factor as shown in Table 3-9. If no site-specific information is available, use a value of 1.0 for the recovery factor. Enter the recovery factor in Column 6 of the worksheet.

20. Multiply the values in Columns 5 and 6 of the worksheet to obtain the site characteristics score. Enter this score in Column 7 of the worksheet.

21. Copy this score to Column 7 of the *Ecological Hazard - Overall Score Worksheet*.

Affected Resources

22. Enter the name of the site(s) to be ranked in Column 1 of the *Ecological Hazard - Affected Resources Worksheet*. Determine whether there are any special marine habitats within or near the site (see Section 3.3.10) and assign the site a score according to Table 3-10. Record this score in Column 2 of the worksheet.

23. Determine whether there are wildlife refuges or sanctuaries near or within the site and select the corresponding score from Table 3-11. Record the score in Column 3 of the worksheet.

24. Add the values in Columns 2 and 3 of the worksheet and record the sum in Column 4. This is the affected resources score.

25. Copy this score to Column 8 of the *Ecological Hazard - Overall Score Worksheet*.

Overall Ecological Hazard Score

The overall ecological hazard score is calculated using Equation 1.

26. Add the values in Columns 7 and 8 of the *Ecological Hazard - Overall Score Worksheet* and multiply the sum by the waste characteristics score (Column 6). Enter the result in Column 9 of the worksheet. If the waste characteristics score is qualified with a *C* or *D*, append this same qualifier to the result. This number is the overall ecological hazard score.

4.3.2 Human Health Hazard Score

Waste Characteristics

1. Using the *Human Health Hazard - Chemical Toxicity Worksheet*, fill in Column 1 with the names of all of the contaminants found at the site that are known to have toxic or carcinogenic effects (see Section 3.3.12).

2. Determine the chronic oral toxicity of each chemical and assign the chemical a value according to Table 3-12. If chronic oral toxicity is unknown, but acute oral toxicity data are available, use Table 3-13 to select a value. Enter this value in Column 2 of the worksheet.

3. Determine the carcinogenic potency of each chemical and enter it in Column 3 of the worksheet (Section 3.3.12).

4. Take the highest value appearing in Columns 2 or 3 and record this value in Column 4.

5. Use available data in conjunction with Table 3-15 or other data sources to determine a value for the bioaccumulation potential. Enter this value in Column 5 of the worksheet.

6. Identify the characteristic reference area concentration for each chemical, using Table 3-3 or other data sources (see Section 3.3.3). Find the highest concentration of each chemical at any station at the site and divide this concentration by the reference area concentration for that chemical. Enter the result (the enrichment ratio) in Column 6 of the worksheet. If the enrichment ratio is <5, leave the column blank.

7. Use the values for toxicity/carcinogenicity, bioaccumulation potential, and enrichment ratio in Columns 4, 5, and 6 of the worksheet in conjunction with Table 4-1 to obtain an overall toxicity score for each chemical. Enter this value in Column 7 of the worksheet.

8. Add all of the values in Column 7 of the worksheet and enter the sum in Box A at the bottom of Column 7.

9. Divide the sum of the toxicity values in Box A by 15 and enter the result in Box B.

10. The human health hazard toxicity score must not be >10. If the value computed in Step 9 is <10, record it in Box C of the worksheet, otherwise enter 10 in this box. Multiply the value in Box C by the areal extent recorded in Column 2 of the *Ecological Hazard - Overall Score Worksheet* and divide the result by 3. Enter this value in Box D.

Site Characteristics

The site characteristics score recorded on the *Site Characteristics Worksheet* is used to calculate the human health hazard score.

Affected Resources

11. Enter the name(s) of the site(s) to be ranked in Column 1 of the *Human Health Hazard - Affected Resources Worksheet*. Assess the proximity of commercial or tribal fisheries to each site and assign a commercial fisheries score according to Table 3-16. Enter this value in Column 2 of the worksheet.

12. Evaluate the presence of recreational fisheries within or near the site, including the opportunities for enhanced access. Assign a recreational fisheries score to the site according to Table 3-17 and enter this value in Column 3 of the worksheet.

13. Add the values in Columns 2 and 3 of the worksheet, multiply by 5/8, and enter the result in Column 4. This value is the affected resources score for human health hazard ranking.

Overall Human Health Hazard Score

The overall human health hazard score is calculated using Equation 1.

14. Copy the waste characteristics, site characteristics, and affected resources values from the appropriate worksheets into Columns 2, 3, and 4, respectively, of the *Human Health Hazard - Overall Score Worksheet.*

15. Add the values in Columns 3 and 4 and multiply this sum by the value in Column 2. Enter the result in Column 5 of the worksheet. This value is the overall human health hazard score.

5. INTERPRETATION OF SEDRANK RESULTS

5.1 Balancing Ecological and Human Health Scores

SEDRANK scores for ecological and human health hazard are computed independently, and the relative magnitudes of the two scores do not imply relative severity of the hazard to the environment or human health. The ranks rather than the absolute magnitudes of the ecological and human health hazard scores for a site should be used to assess the relative hazard to the environment and human health.

For example, a site may have ecological and human health scores of 80 and 60, respectively. The apparent implication is that there is a greater hazard to the environment than to human health. When considered in the context of other sites that have been ranked by the same method, the ecological score might be found to be in the 60th percentile and the human health score in the 90th percentile.

Ecology will maintain a record of the scores assigned to each site by the SEDRANK method, as well as any modifications to these scores that have been made on the basis of best professional judgment. This information should be used to evaluate the scores assigned to each newly ranked site. Whenever SEDRANK scores are calculated for a new site, ranks must be recalculated for all sites. Scores of all sites can be obtained from Ecology's Sediment Management Unit.

5.2 Prioritizing Ranked Sites

Cleanup priorities will be established by Ecology using the SEDRANK results and other information collected during the hazard assessment. Aspects of the SEDRANK results to be considered are:

- The ranks of the ecological and human health hazard scores relative to other sites
- The presence of a *C* or *D* qualifier on the ecological hazard score
- The age, completeness, and quality of the data used to compute the site rank.

The maximum rank of either the ecological or human health score should be the primary determinant of priority for site cleanup. If the highest ranks for two sites are equal, the site with the greater average rank should be assigned the highest priority.

Use of organic carbon or debris to establish the ecological hazard score, as indicated by a *C* or *D* qualifier, provides a rationale for lowering the priority of a site relative to another site that has an equivalently ranked ecological hazard score that has been based on chemical toxicity. The reason for establishing this ordering of site priorities is that the relationship between contaminant concentrations and biological effects is more firmly established than that between organic content or debris and biological effects.

Site scores (and ranks) that have been calculated based on older data, or data that have been subjected to a less rigorous quality assurance review, may be discounted relative to ranks that are based on newer data or data of more certain quality. The impact of missing or incomplete data varies. SEDRANK is designed to produce conservative (i.e., higher) scores if some information, such as chemical loss factors, is missing. In such circumstances, the site score is possibly biased high. If, however, two sites of equivalent size are characterized by very different amounts of chemistry data, the rank of the station that has fewer measurements is possibly biased low (more data can only increase the site score).

Data that are less than 10 years old are preferable for site ranking. Older data may not be indicative of current conditions at the site; either human activities or natural recovery may have significantly altered conditions within this length of time. Older data may be used at the discretion of

Ecology. A sensitivity analysis of SEDRANK (PTI 1991d) indicates that sediment contaminant concentrations and site area are the most important determinants of both ecological and human health hazard scores. Use of the most current, high-quality chemistry data available is essential to establish accurate priorities among sites.

Factors other than the site rankings produced by SEDRANK may affect the priority of cleanup actions. These factors include other data such as the results of bioassay and bioaccumulation studies. For example, bioassay data may indicate the absence of biological effects at the site. Information such as this may be used to interpret the SEDRANK scores even if they are incomplete (e.g., bioassay results may not be available at all of the contaminated stations within the site).

The relationship of site ranking to other cleanup activities is described in the *Sediment Cleanup Standards Guidance Document* (PTI 1991c).

Priority classes may be established by Ecology as a means of recognizing the applicability of information other than that used by SEDRANK. Cleanup priorities could be established by a three-step process:

1. Assign each site to a priority class based on the ranks of the SEDRANK scores relative to other sites.

2. Evaluate the effects of data quality and completeness and use this information to establish cleanup priorities among sites within a site class. This information may also be used to move a site into the next higher or lower priority class.

3. Evaluate other factors and their impact on cleanup priorities. This information may be used to refine the priorities among sites within a site class or to move a site into the next higher or lower priority class.

The boundaries of priority classes should be flexible, as the ranks of the highest-priority sites to be cleaned up will presumably decrease as the highest-priority sites are cleaned up. That is, sites that are initially of secondary priority will eventually become the highest priority sites as the sites that were initially of highest priority are cleaned up.

5.4 Relationship to WARM

—RESERVED—

[NOTE—This section is currently reserved and will be addressed in a future draft of the *SEDRANK Guidance Document*.]

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APPENDIX A

Site Scoring Worksheets

ECOLOGICAL HAZARD - CHEMICAL TOXICITY WORKSHEET

Site Name ____________________

1. Chemical Name	2. Highest Concentration *(C)*	3. Sediment Quality Standard *(SQS)**	4. Exceedance Factor *(C/SQS)*	5. Loss Factor *(L)*	6. Exceedance *(C/SQS)* × Loss Factor *(L)*	
				Sum of *Column 6*		Box A
				3 × $\log_{10}$ of *Box A*		Box B
				Lesser value of 10 or *Box B*		Box C

* Source of SQS: ______________________________

SITE CHARACTERISTICS WORKSHEET

1. Site Name	2. Depth (*D*)	3. Habitat Complexity (*HC*)	4. *D* + *HC*	5. Habitat Quality [5/7 × (*D* + *HC*)]	6. Recovery Factor	7. Site Characteristics Score (*Column 5* × *Column 6*)

ECOLOGICAL HAZARD - AFFECTED RESOURCES WORKSHEET

1. Site Name	2. Special Marine Habitats (*MH*)	3. Wildlife Refuges and Sanctuaries (*RS*)	4. Affected Resources Score (*MH + RS*)

ECOLOGICAL HAZARD - OVERALL SCORE WORKSHEET

1. Site Name	2. Areal Extent	3. Chemical Toxicity	4. TOC	5. Debris	6. Waste Characteristics	7. Site Characteristics	8. Affected Resources	9. Ecological Hazard Score

HUMAN HEALTH HAZARD - CHEMICAL TOXICITY WORKSHEET

Site Name ____________________

1. Chemical Name	2. Chemical Toxicity *(T)*	3. Carcinogenicity *(C)*	4. Maximum of *T* and *C*	5. Bioaccumulation Potential	6. Enrichment Ratio	7. Chemical Hazard Score (from Table 4-1)

Sum of *Column 7*		Box A
Box A ÷ 15		Box B
Lesser value of 10 or *Box B*		Box C
(Areal extent × *Box C*) ÷ 3		Box D