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Lower Columbia River Restoration Prioritization Framework

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Prepared for the
Lower Columbia River Estuary Partnership

Battelle, Pacific Northwest Division
of Battelle Memorial Institute

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Overview

The Restoration Prioritization Framework was designed as a decision-making tool for the Lower Columbia River Estuary Partnership, to help identify the highest priority sites for restoration. The Framework is composed of three parts, which are intended for use together: 1) an overview of the concepts and description of Framework tools (this document), 2) a Microsoft Excel™ workbook containing detailed data, formulas, and workflow for the actual site prioritization, and 3) a Geographic Information System (GIS) database containing source and processed geospatial datasets.

The underlying concepts for this Framework were developed previously in the *Bainbridge Island Nearshore Habitat Assessment, Management Strategy Prioritization, and Monitoring Recommendations* (Williams et al. 2004) and *An Ecosystem-Based Restoration Plan with Emphasis on Salmonid Habitats in the Columbia River Estuary* (Johnson et al., 2003). The Prioritization Framework uses the conceptual model-based approach outlined in these documents to assign priority scores to sites. The conceptual model states that the physical controlling factors in a location drive the habitats that can form, and ultimately, the ecological functions that develop. The Framework uses this model to evaluate impacts to these controlling factors, using a variety of human impact "stressor" datasets, such as diking, agriculture, over-water structures, and flow restrictions.

This assessment is fundamentally a GIS-based analysis. Impact data is compiled from georeferenced sources, and linked to specific geographic sites. Data processing and calculations are done in Excel to derive priority scores, which are then re-linked to the geographic sites in the GIS. In this manner, all of the data and tools employed can be analyzed and queried in a geospatial context.

In addition to the core impact assessment, the Framework includes tools to incorporate information on hydrologic connectivity and existing function into the priority screening. Methods are also described for evaluating specific projects or proposals, using information on cost, expected functional change, site size, and predicted probability of success. This provides a tiered approach through which the Estuary Partnership can screen for impacted areas, prioritize areas based on desired ecological criteria, and evaluate selected projects.

Contents

Appendices (separate):

Background

The theoretical background as well as analysis of the major alterations and restoration needs in the Columbia River Estuary was covered in *An Ecosystem-Based Restoration Plan with Emphasis on Salmonid Habitats in the Columbia River Estuary* (Johnson et al. 2003). We will not elaborate on the previous findings and guidance but summarize here the following concepts that drive the present approach.

The fundamental concepts used in this prioritization are as follows:

1. In order to restore a site one needs to know the level of disturbance and types of disturbances to the site.
2. Disturbances are generally assumed to occur at the level of the factors that control the development and maintenance of habitats (i.e., the controlling factors). A conceptual model is used to extrapolate disturbances in the controlling factors to effects on ecosystem structure, processes and functions (Thom et al. 2004).
3. The development and maintenance of habitats at a site is dependent not only on disturbances at the site scale, but also at the landscape scale within which the site resides. If there are high disturbances in the landscape, that will affect the quality of the processes that form and maintain habitats.
4. The relative degree of disturbance of the landscape and the site dictate the most appropriate restoration strategies (i.e., restoration to historical conditions, enhancement of selected attributes, creation of a new habitat, conservation, protection) that have the highest probability of achieving the restoration goals.
5. Case studies provide an empirical basis for understanding the specific restoration actions (e.g., dike breaches, tide gate improvements, invasive species control) that have been most successful in estuaries in the Pacific Northwest and elsewhere.
6. There are uncertainties with regard to virtually all parts of this analysis including
    a. levels and types of disturbance on the site and landscape scales,
    b. relationships between disturbances of controlling factors and responses of the habitats and their functions,
    c. strategies that work best in a given situation,
    d. ability of a project to reach its expected goal, and,
    e. timeframe and trajectory of development of restoration projects.

    Thus, semi-quantitative ranks (e.g., low, medium, high) are employed for the assessment.

Approach

Conceptual Model

The prioritization assessment approach relies on the use of a conceptual model to measure potential impacts to ecosystem function. This model is based on work developed by Williams and Thom (2001), used in the Bainbridge Island Nearshore Assessment (Williams et al. 2004), and adapted to the Lower Columbia River Estuary by Johnson et al. (2003) and Thom et al. (2004). The conceptual model states that habitat structure, habitat processes, and ecosystem function are driven by the physical controlling factors that make up a landscape (Figure 1). Alterations to these physical factors can have effects that propagate to the functional level for ecosystems. On this basis, the Prioritization Framework uses stressors to the controlling factors as a proxy for ecosystem degradation. This provides a low cost and reliable method for assessing ecosystem impacts, using existing data where possible.

Figure 1. Simplified conceptual model from Williams and Thom (2001).

The LCR conceptual model used for this approach (Thom et al. 2004) was modified slightly to create a more concise list of controlling factors. The controlling factors used in the Framework are listed below, and described in detail later:

- Hydrology – River Scale
- Hydrology – Watershed Scale
- Hydrology – Site Scale
- Sediment Quality
- Water Quality
- Light
- Sediment Dynamics
- Physical Disturbance
- Depth/Slope
- Exotic Species

Spatial Scale

The Framework uses two spatial scales to assess the interaction between local and landscape level disturbance: "Management Area" and "site". With these two spatial scales, local site conditions can be compared to other sites which share a common landscape feature such as watershed hydrology. The relationship between local and landscape level impacts also defines the appropriate restoration strategies available to a site. For example, if ecosystem function is largely intact at the landscape level, local site conditions may be more easily improved and maintained. Conversely, overall landscape degradation may make local improvements more difficult to attain (see Appendix B for more information on landscape ecology and restoration strategies).

A multiple-scale approach also provides a more appropriate context for inter-site comparison than the entire lower estuary, normalizing for regional variation (i.e., comparing sites within distinct Management Areas along the river gradient).

Study Area

This Framework is designed for use within the historic floodplain of the Lower Columbia River Estuary (from the mouth to Bonneville Dam at river kilometer [rkm] 235) (Figure 2). This area represents the region of interest for restoration activities defined by the Lower Columbia River Estuary Partnership. However, the concepts and prioritization workflow could easily be adapted to other regions through the use of a locally-defined conceptual model of the ecosystem, and locally available geospatial datasets.

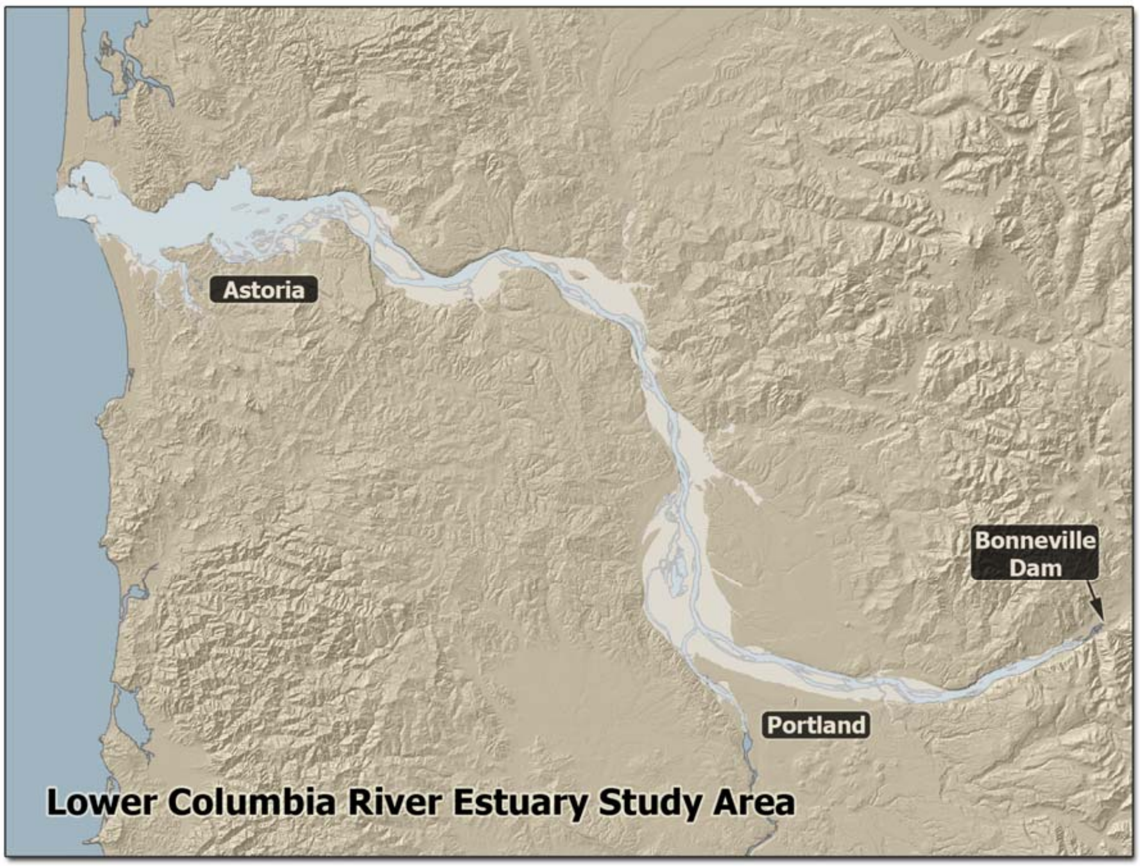

Figure 2. Lower Columbia River Estuary region of interest. Draft historic floodplain overlay is shown in light beige (courtesy of J. Burke, University of Washington).

Management Area Scale

In this Framework, the landscape level is termed "Management Area" (MA), and represents a grouping of sites that share similar landscape qualities within a defined spatial area. This grouping of sites must also meet the management needs of the Estuary Partnership, so a spatial scale was sought that would contain a manageable set of sites. USGS 6th-Field Hydrologic Unit Code (HUC) boundaries were chosen to define the MA boundaries. HUCs represent major watershed delineations (i.e., large tributaries), establishing a consistent hydrologic baseline for the sites contained within. For island sites that fall within the river mainstem (where no HUC boundary is available), the "hydrogeomorphic reaches" defined by Simenstad et al. (2004) are used for MA boundaries. There are 60 MAs, ranging in size from 2989 to 73,696 acres, with a mean of 23,797 acres. The number of sites per MA ranges from 1 to 155, with a mean of 35 (Figure 3).

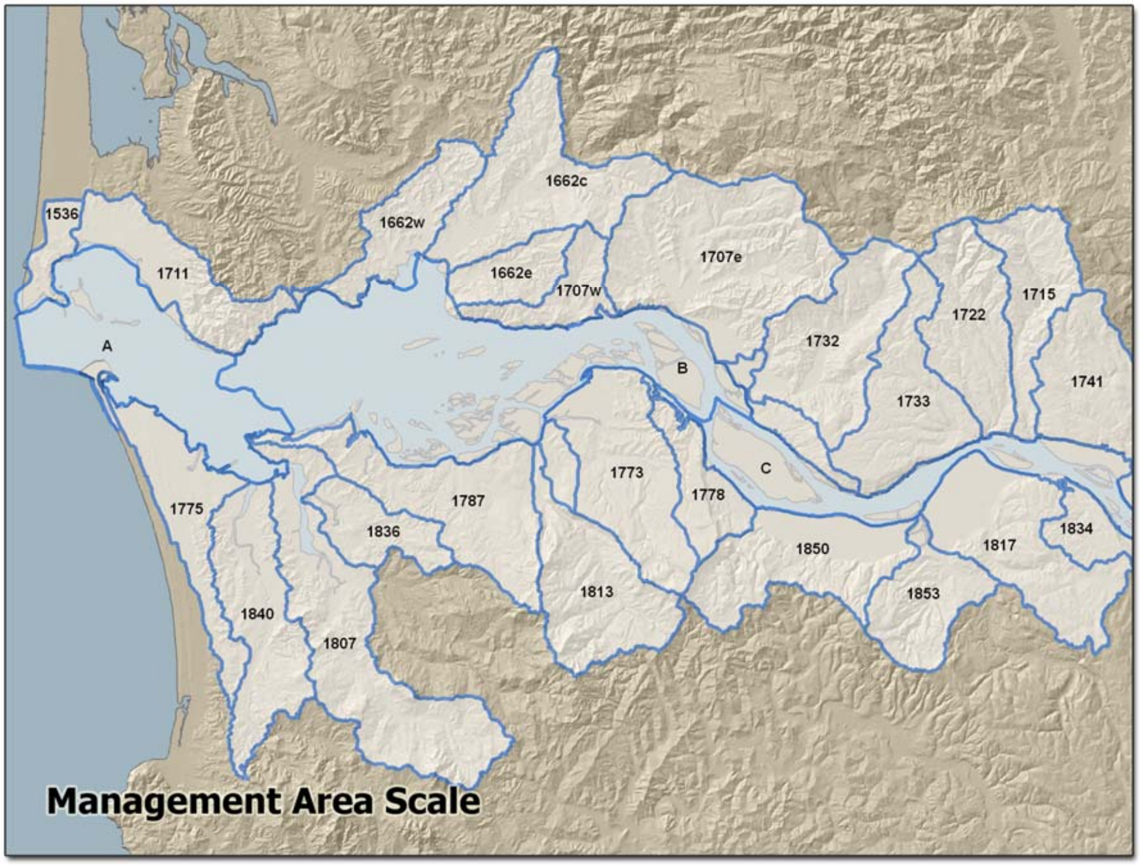

Figure 3. Example of Management Area delineation in the lower portion of the estuary. Management Areas are symbolized in light beige, with bold blue boundaries. The HUC ID or reach letter is indicated for each.

Site Scale

The local level scale for the Framework is termed "site", and represents an area defined by similar small-scale hydrologic characteristics or boundaries. The site scale allows for analysis of conditions at a fine geographic scale, within which actual restoration projects may occur. Sites were delineated using a combination of topography, hydrologic features, and anthropogenic factors (i.e., subwatershed boundaries, major roads, etc.). There are 2072 sites, ranging in size from 16 to 2154 acres. The majority of sites fall in the range 25 to 400 acres, with a mean of 166 acres (Figure 4).

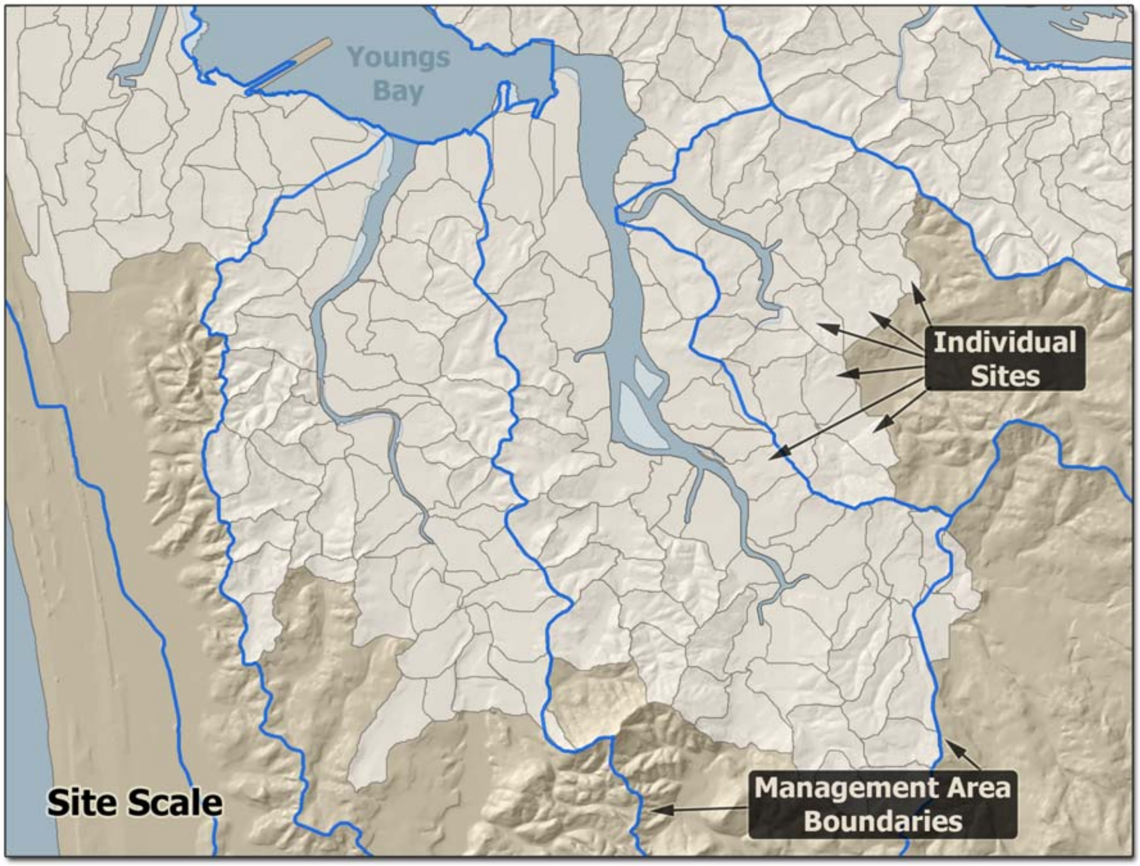

Figure 4. Example of site delineation in the Youngs Bay area. Sites are symbolized in light beige, with gray boundaries. Bold blue lines are Management Area boundaries.

Hydrologic Context

Understanding the hydrologic context for each site is important for determining how stressors impact controlling factors under varying hydrologic influence, so that scores can be applied to the sites appropriately. In other words, hydrologic context can be thought of as a "modifier" for the controlling factors assessment of a site. While data is not available at this time to provide a detailed hydrologic classification of each site, two general attributes are used to provide a useful hydrologic context for each site: Riverfront Shoreline and Slope Class.

Riverfront Shoreline

This attribute denotes whether a site has direct access to Columbia river currents with all or a portion of its boundary (including major tributaries). Sites with a direct river-connecting boundary greater than 50 meters (164 feet) are considered "Riverfront", while those that are not subject to direct river connection are denoted "Non-Riverfront". The 50 meter requirement simply provides a consistent method for screening out sites with negligible shoreline length (generally small tributary mouths). Sites with the "Riverfront" attribute are scored for impacts to sediment dynamics and light, which are less applicable to sites with no shoreline/nearshore processes occurring ("Non-Riverfront").

Slope Class

This attribute describes whether sites have either direct/indirect access to river hydrology via tidal and flood interactions, or whether their primary hydrology is dictated by upland sources (i.e., subwatersheds at the floodplain fringes). For simplicity, sites are coded "Flat" or "Steep" to denote predominant slope and hydrologic access. For example, only "Flat" sites are scored for impacts to hydrology via diking, which is not applicable to sites with a predominantly upland water source.

These two attributes result in four possible hydrologic classifications that modify how stressor information is applied to the controlling factors: Riverfront Flat, Riverfront Steep, Non-Riverfront Flat, and Non-Riverfront Steep (Figure 5). The overall impact for each site is then normalized to other sites with the same hydrologic classification in order to facilitate appropriate inter-site comparisons. Normalizing is accomplished by dividing each site score by the maximum score for sites with the same hydrologic context, thereby ranking each site relative to its "peers".

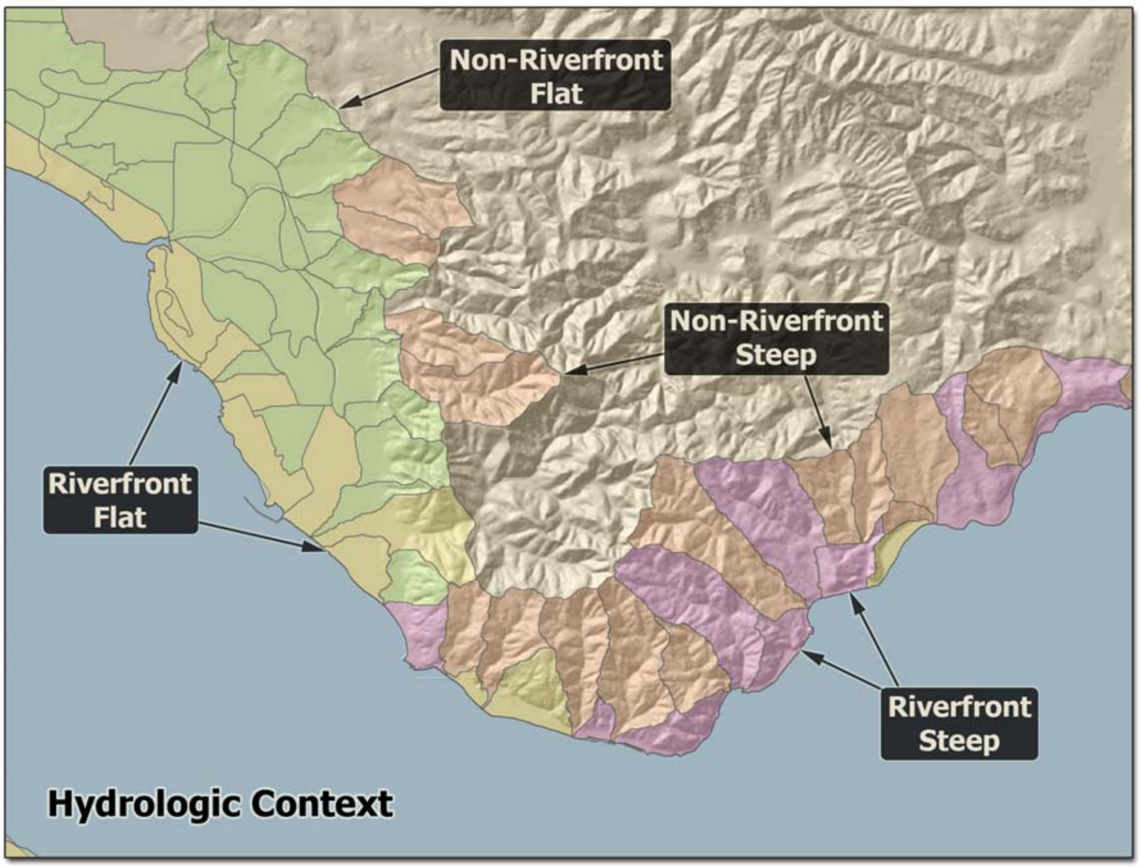

Figure 5. Examples of hydrologic context applied to sites.

Historical Context

Historical change within a site is an important measure for determining overall impact and restoration potential. Historical T-Sheets are currently being digitized, and will be available in a future iteration of the Framework. This will provide a means of assessing general river morphology changes.

Application

In order to apply the concepts described previously, a two-tiered approach was designed that allows for varying levels of data analysis: 1) a system-wide screening tier to identify priority sites or regions for potential restoration actions, and 2) a project evaluation tier containing specific metrics to rank individual projects or proposals. Tier I is a GIS-based screen using comprehensive data for the LCR, while Tier II defines project-specific metrics such as cost and potential change, and is not GIS based.

These tiers are illustrated in Figure 6, which gives a general overview of the Framework.

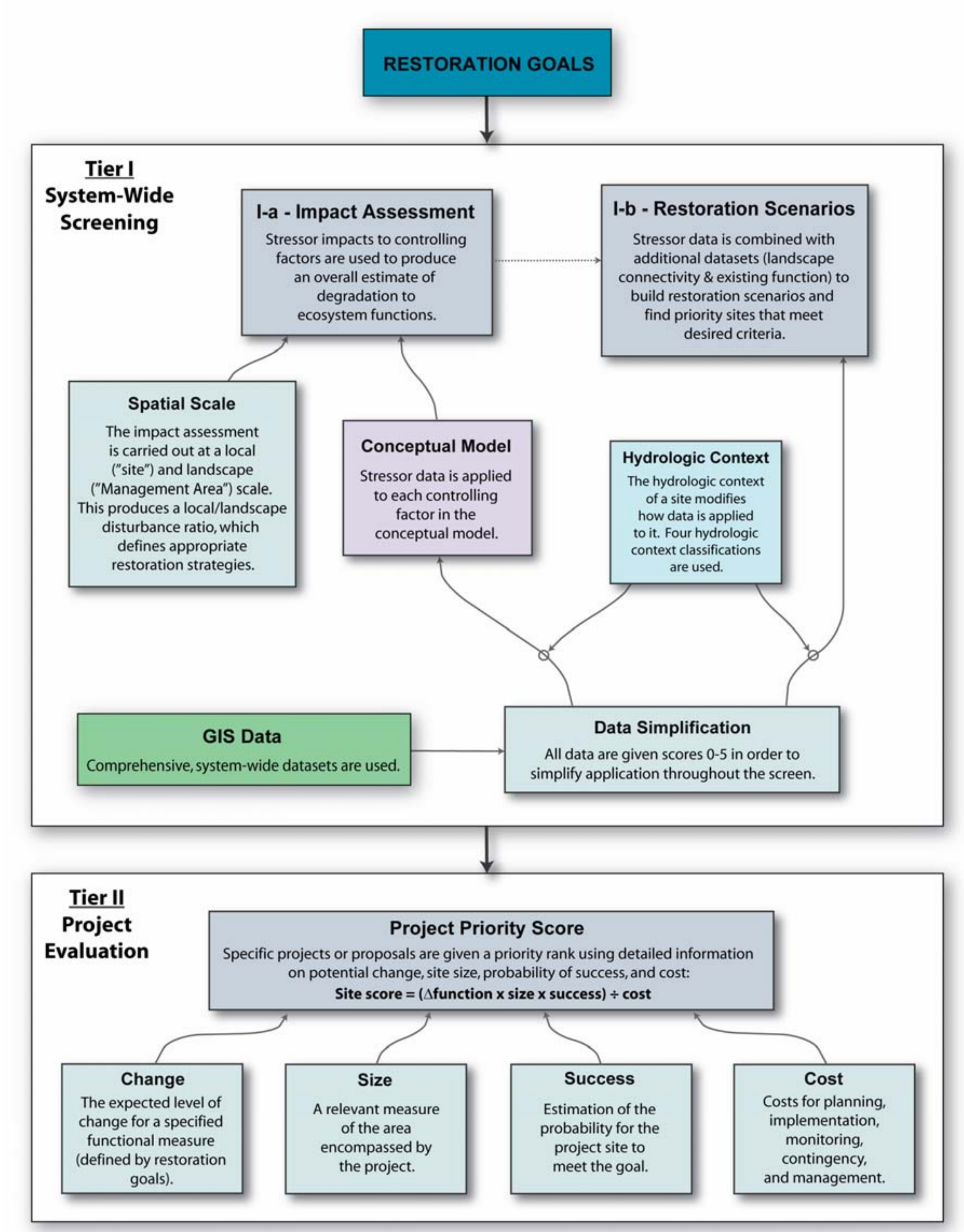

Figure 6. Overview of the Prioritization Framework.

Tier I – System-Wide Screen

The system-wide screen consists of two primary parts, which can be used independently or together to identify priority areas. The first part is a general impact assessment, using information on system stressors to estimate overall degradation of controlling factors within a site. The second part takes a directed prioritization approach, allowing the user to create restoration scenarios using the compiled data, thereby ranking sites according to specified criteria.

All of the data inputs for Tier I are compiled into an Excel workbook, which can be explored and modified to produce site prioritization rankings. The data are linked to a GIS-ready worksheet that can be easily exported and viewed geospatially. A detailed description and workflow model of the workbook is contained within the workbook itself, and is therefore not explained further in this document.

Tier I-a – Impact Assessment

The impact assessment methods build upon the foundational principles described above: conceptual model, spatial scale, and hydrologic context. The implementation of these concepts uses a score-based approach, wherein impacts to each controlling factor are calculated and accumulated for every site, resulting in an overall "impact score".

LCR Controlling Factors

A brief description of the controlling factors used in this assessment follows (with corresponding controlling factor from Thom et al. 2004 model in parentheses if different):

<u>Hydrology – Columbia River Flow Regime (Hydrodynamics)</u>

The general hydrology of the lower Columbia River is determined in varying degrees by two different sources: the amount of freshwater from upstream sources and tidal inundation from the ocean. While tidal forces are cyclical and somewhat predictable, freshwater flow was historically seasonal and highly variable in the absence of hydroelectric flow regulation (Kukulka and Jay 2003a). Numerous dams and water use programs located throughout the length of the river have changed the fluvial output, and presently much of the freshwater flow to the LCR is controlled by the Bonneville Dam at rkm 235. While there are still seasonal fluctuations in freshwater flow from local rain events and seasonal runoff, regulation by the dam has largely prevented most of the extreme freshets that once inundated the entire floodplain. However, the relative influence of Bonneville Dam decreases moving downriver due to increasing tidal flux at the mouth, which makes up a larger part of daily water movement in lower reaches (Kukulka and Jay 2003a). Since the flow on the Columbia River mainstem is a primary driver in this system and defines this project, it is important to characterize the different sections when considering impacts and restoration. Therefore, the overall lower river hydrology is evaluated as a controlling factor, with the extent of the study area broken into three sections: 0 - 50 rkm, 50 – 140 rkm, and 140 – 235 rkm. The lower section is primarily tidally driven and is bound by the approximate upstream limit for saline intrusion, while the fluvial flow is more important in determining hydrography above rkm 50 (Jay et al. 1990). Kukulka and Jay (2003a) determined that the river section above rkm 140 is also influenced by hydroelectric power peaking, so this last section is separated out from Jay et al.'s "tidal-fluvial reach" of rkm 50+ (Jay et al. 1990, cited in Kukulka and Jay 2003a).

Hydrology – Watershed/Management Area (Hydrodynamics)

At the watershed scale, changes in hydrology can drive ecosystem functions for all sites that share a common watershed and are especially significant for sites bordering a waterbody or conveyance. Watershed hydrology is heavily influenced by land use activities within the watershed boundaries, such as agriculture, forestry, and development. Due to the delineation of Management Areas using HUC-6 watershed boundaries, impacts to this controlling factor are assessed at the MA scale.

Hydrology – Site (Hydrodynamics)

There are many factors that can modify river hydrodynamics at a particular site, and the LCR is subject to a number of localized modifications that prevent historical water inundation to the entire floodplain extent or alter rates and durations of flow. This can fundamentally change the ecosystem both in front of and behind the barrier (Hood 2004) and remove shallow water habitat important to many aquatic species like salmon (Groot and Margolis 1991, Kukulka and Jay 2003b). In this section, changes in the site hydrography refer specifically to smaller site-scale alterations, such as blocked or restricted access (dikes, tide gates, culverts). These alterations can affect relatively small areas (e.g. small reach of a side channel) as well as large tracts of land (e.g. dike to protect agricultural fields).

Sediment Quality

Sediment quality refers to such attributes as organic matter and contaminant levels in the sediment or soil. Many of the activities undertaken in the lower Columbia River produce toxins that can be found in the soil/sediments. These can be materials such as heavy metals, petroleum products, pesticides and herbicides, and a suite of artificial compounds. Once in the environment, these pollutants may be taken up by a variety of plants and animals. The exact effects depend on the specific compounds found, but they can affect developmental and reproductive processes, immunity, and neurological systems. This is especially true of compounds that bioaccumulate up the food chain such that higher order predators have large concentrations of these toxins in their systems.

Water Quality (Nutrients, Salinity, Temperature, Turbidity)

Water quality encompasses several properties of the water itself. As with sediment quality, water quality also is affected by human activity. Many of the same toxic chemicals that accumulate in sediments can be found dissolved in the water and can have similar deleterious effects on local biota. This pollution is often more severe in areas where surfaces adjacent to the water are modified and impervious, due to increased runoff (May and Peterson 2003). Additionally, other conditions can compromise local water quality and ecosystem health. Eutrophication resulting from agricultural runoff or effluent from outfalls can upset the energy budgets of the system and restructure biological communities, as well as lead to harmful bacterial and algal blooms. Hot water discharges or loss of natural shade can elevate water temperatures enough to decrease local populations that are adapted to less extreme conditions, and may invite non-native competitors. Changes in salinity regime can adversely affect local populations in a similar manner. Finally, increased turbidity can reduce light penetration into the water column and reduce local primary productivity.

Light

Light is an important factor for primary productivity and animal behavior, yet the light regime in an area is often altered by various human activities. Shading from overwater structures like piers, marinas, and log rafts can be detrimental to submerged aquatic vegetation communities. In addition, artificial lighting around industrial piers can influence fish migration and feeding behavior (Duffy-Anderson and Able 1999, Able et al. 1998). For this analysis, impacts to light are only calculated for riverfront sites.

Sediment Dynamics (Currents)

Sediment dynamics involve the erosion and deposition of sediments within a system, which is primarily driven by water currents. Structures and activities that alter these currents can change rates of erosion and sedimentation, possibly altering benthic morphology in these areas. Jetties, dredging and dredge disposal, pile dikes, and shoreline armoring can all modify water currents and movement of sediment through the system. For this analysis, impacts to sediment dynamics are only calculated for riverfront sites.

Physical Disturbance (N/A)

Physical disturbance refers to the general physical impacts of structures or human activities. One measure of this disturbance is the amount of industrial activity (e.g., shipping, manufacturing) occurring along waterfront areas. Higher population densities also present an increased potential for disturbance through human interaction with the environment (e.g., trampling, litter, vandalism).

Depth/Slope (Elevation/Depth/Bathymetry)

Changes in the natural slope, elevation, or depth of the land can result from a number of activities including dredging (sediment removal or dredge spoil disposal), shoreline modification/armoring, and filling. These changes can affect submerged aquatic vegetation distribution, wetland formation, and tidal channel configuration.

Exotic Species (N/A)

Exotic species are not a "controlling factor" in the physical sense, but may have impacts at any level within the conceptual model, and are included here to provide a means of measuring this impact in the overall site ranking. Some introduced species can completely restructure communities and even affect the physical environment (e.g., through increased sedimentation). This is especially true for many plant species. Successful introduced species are often difficult to remove and could compromise potential recovery programs. The exotic species data available for the LCR appears to be incomplete at this time and is therefore not included in this analysis. However, given the potential importance of invasive species when considering any management plan, it is included in the model so it can easily be incorporated once comprehensive data are available for the LCR study area.

Stressor Datasets - Overview

The stressor data currently used in the Framework are listed below, and represent the most comprehensive public data available at this time. Additional datasets can easily be added as new information becomes available, by simply extracting a consistent, system-wide metric, and applying impact weighting for the stressor to each controlling factor.

Scoring

All data are reduced to a score of 0 through 5, in order to simplify analysis. Unless otherwise noted below, scoring is based on percentile breaks within the data. With this method, stressors are grouped by rank order of the existing data. Sites with the highest stressor levels are considered most highly impacted, and those with the lowest, least. In this manner, all of the sites are compared to one another, such that a relative ranking is achieved. While this method has some limitations, it is the most reasonable way to group data in the absence of published scientific justification for specific impact thresholds. The scores are typically broken into 6 groups for scores of 0 to 5. Group "0" has no impact, and corresponds to no presence of the stressor of interest. Groups 1 through 5 are broken into five percentile groups (i.e., 20th, 40th, 60th, 80th, 100th), with the higher scores indicating a higher measured quantity of the stressor of interest, be it point density, percentage of area, or other measurement derived from the data. Specific data values corresponding to the score breakpoints are defined explicitly in the accompanying Excel workbook.

Controlling Factor Impacts

In order to produce an impact score for each controlling factor, the relative impact of each available stressor dataset must be defined. This produces a weighted average of the stressor data scores for each controlling factor. The individual controlling factor scores are then averaged to obtain an overall site impact score. Again, this may introduce some uncertainty in the absence of documented impact thresholds. However, the controlling factor impact weights are defined explicitly in the accompanying Excel workbook, and can easily be modified as new information becomes available.

Site vs. Management Area Scores

Impacts to controlling factors are scored at the two scales of interest for this analysis – site and Management Area. Overall site impacts are calculated as a mean of the individual controlling factor impacts within the site. Management Area impacts are calculated using two parts: 1) an analysis of watershed hydrology impacts, and 2) the median site score for the MA. These two parts are combined equally to obtain an overall MA score. Using these two parts provides for a site-independent assessment (impacts to the watershed hydrology controlling factor), as well as a site-dependant assessment (median site score). In this manner, landscape-level effects that aren't likely to be corrected by individual site improvements will remain in the analysis. However, individual site improvements (measured by median score) can still affect the overall MA score, giving an indication of overall landscape improvement over time.

Site vs. Adjacent Site Scores

In addition to the local vs. landscape analysis provided by comparing site scores to MA scores, the Framework provides another metric to evaluate site priority: adjacent site scores. Once overall impact scores are calculated for each site, each site score is compared to the mean score of its directly adjacent neighbors. This provides a means of identifying pockets of highly impacted sites among local clusters – a potentially useful metric for determining the most strategic location of a restoration action among similar sites.

Site Scale Stressors

Bonneville Flow Alteration

As described above, the overall hydrography of the Columbia River is summarized in this metric. All sites are scored for river-scale hydrology, based on approximate river kilometer (using mainstem navigational channel). Scores of 1, 3, or 5 are given, based on zones described in Kukulka and Jay (2003a). No sites are scored 0, due to complete study area impact from Bonneville Dam. Sites in the range 0 to 50 rkm are given a 1, sites 50 to 140 rkm a 3, and sites 140+ rkm are given a 5.

Flow Restrictions

This dataset contains points of known restrictions/alterations to local water flow. This includes non-natural barriers and water impeding or diverting structures (culverts, dams, etc.), as well as tide gates. Flow restrictions are scored using point density within a site.

Diking

Diking is a widespread stressor in the LCR and represents thousands of acres of habitat potentially blocked from river hydrology. Only sites with hydrologic classification "Riverfront Flat" or "Non-Riverfront Flat" are given a score for dike impact, measured as percentage of the floodplain area within the site that is blocked from hydrology due to an existing dike structure.

SEDQUAL/Tetra Tech Contaminants Data

All sites were scored using sediment contaminant data points. The SEDQUAL and Tetra Tech LCR contaminants databases are used to determine the maximum Hazard Quotient (HQ) encountered within a site (Hazard Quotient refers to the chemical concentration relative to regulatory/effects criteria for that chemical, see Appendix C for more information). The chemical with the highest HQ is used in this analysis, so direct comparisons of HQ between sites may not be appropriate. Sites with no sampled or detected contaminants are given a score of 0. Sites that have any detected contaminant are given a score of 1. Sites with a detected maximum greater than the Threshold Effects Level (TEL), but less than the Probable Effects Level (PEL) are given a score of 2. Sites with a detected maximum greater than the PEL, but less than two times the PEL are given a score of 3. Those with a maximum greater than two times the PEL, but less than five times the PEL are given a score of 4. Finally, those sites with a detected contaminant maximum greater than five times the PEL are given a score of 5.

Industrial Development

All sites are scored for industrial land use as an estimate of potential impact from upland industrial activities (using percentage of site area dedicated to industrial activity).

303(d) Listed Waterways

All sites were evaluated for inclusion of waterways listed on the 303(d) list of contaminated waterbodies as required by the Clean Water Act. Both Washington and Oregon lists were used to cover the entire LCR study area. Sites are given a score of 5 if a 303(d)-listed waterbody is present within its boundary (regardless of contaminant). If no 303(d)-listed waterbody is present, a score of 0 is given.

Facilities of Interest

Point locations of all WADOE/ORDEQ facilities of regulatory interest (i.e., permitting) are used to measure potential impacts to sediment and water quality. The facilities dataset is split into "Water Type" and "Land Type" to indicate primary impact of a given facility for scoring purposes – water (i.e., NPDES permits), or soil/sediment (hazardous waste generators, landfills, etc.). Facilities are scored using point density within a site.

Agriculture

Agricultural land use is used to score sites as an estimate of potential impact from agricultural activities, such as nutrient runoff and grazing (using percentage of site area dedicated to agricultural uses).

Marinas

Sites with hydrologic context "Riverfront Flat" or "Riverfront Steep" are scored for marina presence as an estimate of potential impact from high-density boat mooring activity (nutrients, oils, shading, etc.). These riverfront datasets are summarized using a 200-meter riverfront shoreline (foreshore) buffer for each site, in order to ensure that floating structures are captured appropriately. Marinas are scored using the percentage of foreshore buffer area covered.

Protected Marinas

Marinas protected by an artificial breakwater or berm can impact local hydrodynamics and sediment dynamics and are therefore separated from regular marinas. Only sites with hydrologic context "Riverfront Flat" or "Riverfront Steep" are evaluated for this stressor. Sites with a protected marina are given a score of 5. Sites with no protected marinas are given a score of 0. Due to potential overlap with the above-mentioned marina dataset, a given controlling factor should only be scored for one of these datasets, depending upon impact of interest (i.e., use this dataset to score impacts to hydrology and currents, and normal marinas for impacts to light and nutrients).

Minor Overwater Structures

Sites with hydrologic context "Riverfront Flat" or "Riverfront Steep" are evaluated for "minor" overwater structures (OWS). These include docks as well as log rafts and other stationary objects (e.g. derelict barges). While these latter objects are potentially temporary, their impact area is larger and the sites are likely to be reused. Point density of minor overwater structures is used for scoring, expressed as a function of the site's riverfront shoreline length.

Major Overwater Structures

Sites with hydrologic context "Riverfront Flat" or "Riverfront Steep" are also evaluated for "major" overwater structures (industrial piers). Given the larger potential impact from these structures, they are weighted separately in the site analysis. Point density of major overwater structures is used for scoring, expressed as a function of the site's riverfront shoreline (foreshore) length.

Pile Dikes

Pile dikes are designed to constrain alongshore sediment transport, impacting sediment dynamics within a site. Sites with hydrologic context "Riverfront Flat" or "Riverfront Steep" are scored for pile dike presence. Those with one or more pile dikes present are given a score of 5, while those with no pile dikes are given a score of 0.

Dredge Material Disposal Sites (DMDS)

Dredge material is disposed of in numerous sites along the river, either along the river's edge or within the mainstem channel itself. Dredge material disposal represents a direct impact to the elevation and sediment dynamics of the location where it is placed. Sites with hydrologic context "Riverfront Flat" or "Riverfront Steep" are scored for DMDS using percentage of site area covered by dredged materials (including foreshore buffer area).

Population

Human population is used as an indication of potential disturbance to a site due to activities such as recreation and its associated impacts (e.g., physical disturbance, littering, etc.). Overall site population is calculated using US Census data, and sites are then scored using population density.

Industrial Shoreline

Industrial shoreline serves as an indicator of ongoing foreshore effects such as physical disturbance. While this metric has some overlap with "major overwater structures" it does take into account industrialized riverfront that may be lacking piers or other in-water structures. Sites with hydrologic context "Riverfront Flat" or "Riverfront Steep" are scored for length of industrial shoreline (as a percentage of the site's riverfront shoreline length).

Dredging (Navigational Channel)

Removal of sediment from a location results in direct modification to the depth and slope, as well as changes in sediment dynamics and other associated processes. In the Lower Columbia River, dredging occurs primarily in the navigational channel to ensure safe passage for large shipping vessels; however, enclosed marinas (e.g., Ilwaco) are often dredged as well. Detailed data indicating dredging activity is not available at this time, so the navigational channel is used as a proxy for potential dredging. This provides a reasonable estimate of the river area subject to dredging, but may be somewhat overestimated in places (e.g., not all locations within the navigational channel need dredging, due to natural bathymetry). Sites within close proximity to the channel (i.e., navigational channel intersects site and/or foreshore buffer) are given a score of 5. Sites with no dredging in the immediate vicinity are given a score of 0.

Shoreline Change

Current analysis is underway to estimate changes in shoreline morphology from historical conditions, using T-Sheets. These data will provide information on areas of fill and removal along the riverfront. While these data are not currently available, this metric is left in the model as a placeholder for future incorporation. Shoreline change will be scored using percentage change within a site.

Shoreline Armoring

Shoreline armoring has a variety of effects to nearshore environments, such as geomorphological change, alterations to reflective energy, and blockage of hydrologic and geomorphic interactions with the riverfront area. Detailed data on shoreline armoring is not currently available but is expected to be completed in the near future. This stressor will be scored using percentage and type of armoring along the riverfront shoreline.

Invasive Species

Comprehensive invasive species data are not currently available for the LCR, but will be incorporated when available for use in scoring the Exotic Species controlling factor.

Management Area Scale Stressors

Several datasets are used to estimate impacts to watershed hydrology within each Management Area. The stressors at this scale are applied only to the Hydrology – Watershed controlling factor, and were chosen as representative measures for a variety of common watershed health indices. Only MAs derived from USGS HUC boundaries are scored for watershed hydrology. In-river MAs (Reaches A through H) are not scored in this manner.

Road Length

Overall length of roads within the watershed is used as an estimate of transportation impacts such as runoff. Road density (length per MA area) is used for scoring.

Hydro-Road Intersections

The intersection of hydro lines (i.e., stream reaches) and road lines is used as an indication of hydrologic and habitat fragmentation within the watershed. Each intersection is documented as a point, and the overall point density within a Management Area is used for scoring.

Flow Restrictions

As with the site scale, flow-restricting structures at the MA level are incorporated as a measure of hydrologic regime change and fragmentation within the watershed. This dataset contains points of known restrictions/alterations to local water flow. This includes non-natural barriers and water impeding or diverting structures (culverts, dams, etc.), as well as tide gates. Flow restrictions are scored using point density within a Management Area.

Agriculture

Agricultural land use is used to estimate watershed-level impacts due to nutrients and runoff from agricultural processes. Agriculture is scored as a percentage of MA area.

Development

Developed land uses (residential, industrial) are used to estimate watershed-level impacts due to human activities, such as contaminants, impervious surfaces, and habitat loss. Development is scored as a percentage of MA area.

Forested

Overall forested area within the watershed is used to estimate impacts to hydrologic processes such as flood attenuation. Forested area is scored inversely as a percentage of MA area (i.e., lower forest area equals higher score).

Riparian Forested

Forested area is also scored in the immediate area surrounding hydro line features. This is done by using a buffer around all waterways, and estimating the percentage of forest within the buffer. This serves as an estimate of direct impacts to waterways due to removal of riparian forest, such as increased turbidity and water temperatures. Riparian forest area is scored inversely as a percentage of existing riparian area (using a 50 meter buffer).

Tier I-b – Restoration Scenarios

In addition to the impact assessment described above, the Framework includes a capacity for building "restoration scenarios" that address specific needs or questions from the user. All of the data available throughout the Framework can be ranked for utility in this overall scheme, producing a priority metric for every site. In addition to the stressor data described above, Tier I-b includes two additional data types: landscape connectivity metrics and existing functions. The accompanying Excel workbook contains the necessary infrastructure to build these scenarios with the available data.

Landscape Connectivity Metrics

Landscape connectivity metrics are used to estimate the hydrologic and physical connection of each site to other sites. This information can be useful when determining restoration priorities among sites with similar features. Those with higher connectivity may be desirable when considering restoration in a landscape processes context. The following metrics have been derived from the data for use in this manner. As with the stressor datasets, the connectivity metrics are broken into 0-5 scores based on percentile distribution, in order to simplify the data inputs.

Site Adjacency

For each site, the number of other sites it shares a border with is calculated. This provides an estimate of direct physical connection to nearby sites that may be affected by restoration actions. The list of adjacent sites is filtered to include only those that are within the same primary watershed (MA). If two sites are adjacent but in different MAs, they may be considered adjacent only if average site slope is less than ten degrees, indicating potential hydrologic interaction across the MA boundary.

In addition to the direct site count produced for this metric, the list of adjacent sites is used elsewhere in the Framework, in order to calculate the ratio of each site's score to its neighbors (described earlier).

Diked Area Blockage

Potential hydrologic restoration is calculated using the diked area dataset (for "Riverfront Flat" or "Non-Riverfront Flat" sites only). For each diked area polygon, the number of sites impacted is calculated. These totals are then summed for all of the diked areas impacting each site. This produces a metric that indicates the areas where dike removal may restore hydrology to the greatest number of sites.

Hydrologic Reach Connections

Direct hydrologic connection among sites is calculated using a hydro line dataset. The number of sites that each hydro line contacts is summed, and these totals are then summed for all of the unique hydro lines running through each site. Thus a rough metric of total site-to-site connectivity via waterways is formed. Note this metric is calculated using only first-order reach connections – multi-level network relationships and directional analysis were not performed.

Site Area

Site area is used as a landscape metric, in order to prioritize sites of a desired size within the landscape. As with the other datasets, the range of site area values is broken into percentile scores.

Existing Function

While information on existing ecosystem function is not widely available throughout the LCR, two comprehensive datasets have been compiled here for use in prioritizing restoration actions.

Fish Use

Anadromous fish use data is available for stream reaches within the LCR, and is used to derive a species/use diversity metric. The total number of unique species and use combinations present within a site is compiled as an indicator of existing site support for salmonid species. As with the stressor data, the range of unique fish use data values is binned using percentile classes for scoring.

Wetlands

National Wetlands Inventory data is available system-wide, and is used to estimate existing wetlands area within each site. Sites are scored for percentage wetland area, broken into percentile classes. Wetland type is not currently factored into the scoring, but could be used to refine the scoring if desired.

Tier II – Project Evaluation

Tier I provides guidance on where restoration would be beneficial and feasible, and indicates through analysis of known stressors where successful restoration could occur. Typically, opportunities arise when a viable site becomes available, and a lead entity and funding are identified. Generally, a variety of site opportunities are identified for a particular funding cycle (e.g., BPA). Therefore, Tier II is designed to help sort out the best and most viable projects from the mix of potential restoration projects. A set of methods that provide prioritization rankings within any suite of specific project opportunities is described in the following sections.

Developing Project Rankings

General Ranking Formula

As a unifying concept, the following equation summarizes the factors that may be included or considered in this ranking. Project-specific prioritization is based on the following general formula:

Site score = (Δ**function** x **size** x **success**) ÷ **cost**

Where,

Δ**function** = change in site ecological functions,
size = relevant measure of the area encompassed by the project,
success = an estimate of the probability for the site to meet the goal,
cost = planning, implementation, monitoring, contingency, management costs.

Each of the factors in the formula are defined below. Furthermore, each factor has inherent uncertainties. For example the change (Δ***function***) term could be defined as the amount of change from the existing condition, or the predicted similarity of the site to a reference site (e.g., plant species cover) or a particular performance criterion, following restoration. Other metrics include change in integrity, species diversity, connectance, opportunity for fish access, and capacity to support fish and wildlife.

Factor 1: Predict Ecological Change

Use the functions and processes lists from the conceptual model to make up this table. Add more or modify metrics as needed/justified.

Example:
Following restoration we expect that there will be a change in functions and processes (taken from the Thom et al. 2004 LCR Conceptual Model) (Table 1).

1 - Check the appropriate box next to each function or process.

Table 1. Matrix of functions and expected change for project.

Function/Process	Greater	Lesser	No change	Unsure	Not applicable
Primary production	X				

Function/Process	Greater	Lesser	No change	Unsure	Not applicable
Organic matter flux	X				
Sediment trapping	X				
Nutrient processing	X				
Flood attenuation	X				
Food web support		X			
Opportunity		X			
Capacity	X				
Natural complexity	X				
Natural biodiversity			X		
Total	7	2	1	0	0

2 - Tally the scores.
3 - Calculate a ratio = greater/(lesser + no change + unsure) = 7/3 = 2.3, with higher scores indicating greater enhancement of functions.

Factor 2: Size

Although size appears less uncertain, variation can occur if, for example, inundation of the site is not as extensive as expected. We recommend using the expected area of the project site as the initial estimator of size for the project. If area of inundation is the most important factor for the project, then use that area. It is also recommended to consider other factors such as the amount of buffer area that will either be created by the project or be adjacent to the project and would result in improved conditions on the project site.

Factor 3: Probability of Success

No project is 100% certain to reach its goals. What is known is that certain types of projects (e.g., dike breaches) often result in the most predictable and successful restoration of wetlands. However, the actual development to match reference site conditions is always less than perfect. In contrast, highly engineered projects (e.g., mechanically controlled tide gates), or those where a multitude of factors can affect the outcome of a project, such as in highly urbanized and disturbed estuaries, are less certain. Finally, the strategies vary in potential success. Semi-quantitative probabilities, based on empirical information from past relevant projects in the region, can be grouped as low, moderate and high.

Example:
It is proposed that the main method for restoring the site is to breach the levees in order to provide full tidal inundation to the formerly diked tidal wetland.

For each factor, check the box that indicates the relative level or quality of the factor relative to the proposed site and restoration method (Table 2). In the following example, case studies indicate that dike breaching often works well - especially if most of the dike is removed and natural hydrology is allowed to return to the site. The restoration strategy is one of the five indicated above (e.g., restoration to historical conditions), and the rank is based on the management area and site disturbance scores. Because hydrology is a key controlling factor, allowing natural habitat forming processes to affect the site is ranked high. The moderate scores for landscape features and self maintenance indicate that the landscape is moderately disturbed so that, although the site dike will be fully removed, the natural processes may inhibit the rate of recovery or long-term maintenance of the site. Viable natural habitats adjacent to and directly connected to a site to be restored can enhance the rate of development for the restored site as well as the probability of long-term viability. The Tier 1 screening also provides a mean score for all of the sites adjacent to a given site. The ratio of the site score to its adjacent neighbors' mean score provides a semi-quantitative measure of this factor that can be used to grade a site in Table 2. Time frame can be ranked as high, moderate, or low based on how long it is predicted for a site to reach its functional level, as indicated in the functional scoring analysis above.

1 – Check the appropriate boxes.

Table 2. Predicted success of project.

Factor	High	Moderate	Low	Unsure
Case studies data indicate success of…	X			
Restoration strategy is…	X			
Habitat forming processes will be…	X			
Landscape features are…		X		
The site condition is…			X	
Adjacent habitats are…	X			
Self-maintenance		X		
Resilience		X		
Time frame				X
Total	4	3	1	1

2 – Tally the scores
3 – Calculate a ratio = high/(moderate + low + unsure) = 0.8, with higher scores indicating a higher probability of success in the long term.

Factor 4: Cost

Cost can be very uncertain, but data from past projects can be useful in reducing uncertainties (Noble et al. 2000). Costs are not included here, but there is a growing body of information on costs of types of projects both in the Pacific Northwest and elsewhere. General items included in cost are labor, materials, travel, equipment, insurance, and overhead. Each of these items must be evaluated for every component in a restoration project, including planning, implementation, monitoring and dissemination of information. Often, costs are provided with a request for funding for a project. If this is the case then these costs can be used in the above formula.

Time

Time frame for development to meet the goal is another important factor to consider. Projects that will take decades to become functional may be less desirable to implement than those that can obtain most of their functionality within a shorter time frame, depending on the restoration goals. We suggest that the time factor be explicitly listed and considered in the evaluation of priorities, though there are currently few data from long term monitoring of restored systems upon which to quantify the time frame.

Sample Calculation

A sample calculation based on the data from the above tables is as follows:

Δfunction = 2.3
Size = 50 ha
Success = 0.8
Site score = (2.3 x 50 x 0.8) = 92.0

Using a cost estimate, one can complete the calculation to determine the score per unit cost.

Because site size can have a major influence on scores, it would be wise to compare site scores within defined size categories. For example, only compare sites greater than 100 acres in area, or 50-100 acres in area. In addition, it might be best to eliminate sites with a success rating of less than a certain value (e.g., 1.0), and those with a Δfunction of greater than a certain value (e.g., 2.0).

Note on the Hydrogeomorphic Approach for Functional Assessment

The hydrogeomorphic assessment methodology (HGM) developed by the Corps of Engineers and applied to some tidal systems (Oregon outer coast tidal wetlands, Adamus [2005]), can provide useful and simple models for rapid assessment to wetland functions. These models can then be used to compare the result from present with the predicted future conditions for these functions. The functions included in the Oregon HGM are shown in Table 3. The drawback at this time is that the models have not been developed specifically for the tidal portion of the Columbia River, and therefore may not be directly applicable.

Table 3. Potential tidal wetland functions taken directly from Adamus (2005).

Function	Potentially Associated Values
Produce aboveground organic matter	Forage for livestock; supporting biodiversity
Export aboveground plant & animal production	Supporting commercial fisheries & biodiversity
Maintain element cycling rates and pollutant processing; stabilize sediment	Minimizing costs for dredging & shore stabilization, purifying water, supporting commercial fisheries & biodiversity
Maintain habitat for native invertebrates	Supporting commercial fisheries & biodiversity
Maintain habitat for anadromous fish	Supporting commercial fisheries & biodiversity
Maintain habitat for visiting marine fish	Supporting commercial fisheries & biodiversity
Maintain habitat for other visiting and resident fish	Supporting commercial fisheries & biodiversity
Maintain habitat for nekton-feeding wildlife	Supporting biodiversity & ecotourism
Maintain habitat for ducks and geese	Supporting biodiversity & ecotourism
Maintain habitat for shorebirds	Supporting biodiversity & ecotourism
Maintain habitat for native landbirds, small mammals, & their predators	Supporting biodiversity & ecotourism
Maintain natural botanical conditions	Supporting biodiversity & ecotourism

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Lower Columbia River Restoration Prioritization Framework Appendices

Appendix A: Data Processing Notes

Unless otherwise noted, map units are meters. Therefore, all length calculations are in meters, and areas calculations are meters squared.

The “final” version of each dataset is stored in a “FINAL_DATA” folder. The name given to each dataset for this version is indicated. The FINAL_DATA folder is described with the GIS organization documentation.

Site Datasets and Delineation

Site Delineation

Site delineation was based on general hydrologic homogeneity. This was accomplished by first delineating draft site boundaries from the DEM using ArcHydro. Next, these boundaries were extensively edited using a combination of DOQ, hillshade, and land cover overlays. The following steps were taken to delineate sites:

1. It was decided that hydrology should be the driving factor for site delineation, so an initial "base layer" was created using ArcHydro (detailed below). For this layer, ArcHydro was optimized to produce sites under 100 acres when possible, though this size parameter is limited by the topography.
2. The hydro-produced base layer was used as a starting point for delineating the sites. Wherever possible, the boundaries created by this layer were kept. Certain areas needed extensive reworking, due to the failure of the topography-based algorithm (i.e., very flat areas, urban areas, highly modified agriculture).
3. For boundaries that needed reworking, the following guidelines were used:
    a) hydrology is the focus. If a "watershed" was apparent around a slough or other flatland feature, it was delineated. This would allow the entire land area around the slough to be assessed together (typical in Youngs Bay area).
    b) in many places, the "watershed" was so heavily modified, that it was no longer apparent. In these cases, water was the first priority to segment regions. For example, large tracts of ag land with a slough running through them were parceled out using the slough as the dividing line. This was typical on Sauvie Island.
    c) in order to further reduce the site size to a manageable area, we continued subdividing using other major hydro features, road lines, or cover type. Roads are a particularly useful boundary in many cases, as they clearly partitioned some areas into permanent, cohesive sites (i.e., the restoration project near Rooster Rock). In highly urbanized areas (Longview), they served to easily break down large areas with no other apparent boundary. In urban areas with lots of topography (Portland), the hydro-generated bounds were left in if possible. If we needed to get still smaller (some of the ag tracts are pretty large), we cut using the major cover type (i.e., crop changes). This shows up when the Landsat is overlayed (see Sauvie Island, for example).
    d) in some areas, it was prudent to cut flat areas from their associated foothills, by tracing along the hill base. This separated the lower floodplain areas from the hills. A good example of this is Grays Bay. In larger steep areas this was

"automatic", but in the smaller foothills the algorithm sometimes kept in portions of the flat areas in order to keep the site acreage up.

Processing (ArcHydro):

1. Subset the DEM Merge layer to the Management Area boundary layer using the Spatial Analyst raster calculator by setting Management Area as the Analysis Extent
2. Terrain Processing – FILL SINKS
3. Terrain Processing – FLOW DIRECTION
4. Terrain Processing – FLOW ACCUMULATION
5. Terrain Processing – STREAM DEFINITION – 4,046 pixels (10m x 10m) was input to account for the need to calculate 100 acre subwatershed segments as an final output – intuitively this number should be smaller because it determines the stream area needed for a stream initiation point but choosing a smaller number results in a tremendous amount of watersheds being 30-40 acres in size
6. Terrain Processing – STREAM SEGMENTATION
7. Terrain Processing – CATCHMENT GRID DELINATION
8. Terrain Processing – CATCHMENT POLYGON PROCESSING

In addition, it should be noted that there are currently more sites in the database than will ultimately exist. The initial hydro-based site delineation was based on the entire study area, and any sites that touched the draft floodplain were exported to a baseline sites file for editing. Due to the draft nature of the floodplain, it is estimated that additional areas outside of the current draft floodplain extent may be included when the dataset is finalized. In order to minimize unnecessary work later, more sites were included in this analysis than needed, so they could be removed in the future (easier than adding them back in). To accomplish this, a .5 mile buffer was placed around the current floodplain draft before selecting sites, as a means to select more than enough sites. Sites that are outside the current floodplain file are denoted as such, and are not used in the actual workbook analysis. Changing this denotation will automatically include them for future use.

Copied to FINAL_DATA as “sites”.

Site Buffers

Foreshore polygon buffers were created for all sites that were denoted “riverfront”. This buffer is intended to capture stressors occurring in the river area directly in front of a site, such as overwater structures, dredge material disposal, marinas, pile dikes, etc. A 200-meter buffer distance was used, which appeared to capture foreshore activity appropriately.

Processing:

1. BUFFER all site polygons , using “ALL” dissolve option.
2. UNION buffer polygon layer with sites. This results in a “cut” polygon buffer using site bounds. All non-riverfront sites are removed from the dataset at this point. Riverfront sites are temporarily removed, in order to leave only a buffer “ring” around the perimeter of the site area (i.e., all site-to-site buffering is removed, leaving only buffers around the outer edge of the set of sites). The outer perimeter of the buffer is cut and removed from this layer, resulting in a buffer polygon that only exists along the inner site perimeter (i.e., the river mainstem and major tribs).
3. EXPLODE to separate islands.

4. CUT buffer polygon at each site edge, so that individual buffer pieces are obtained (may be EXPLODED repeatedly to keep the dataset single-part).
5. CONVERT buffers to centroid points for joining with nearest site polygons
6. JOIN centroids to actual sites, so that all points receive a Site ID
7. EDIT – some centroids are assigned to incorrect sites (due to site or buffer morphology). These are fixed manually.
8. JOIN points back to buffer polygons, so each buffer piece has a Site ID.
9. Copied to FINAL_DATA as "site_buffers". This layer contains only the buffer polygons for each riverfront site.

In addition, the site buffers were merged with actual sites to obtain a site + buffer polygon for each site.

Processing:
1. MERGE sites and buffers
2. DISSOLVE using Site ID
3. CLEAN to ensure correctness
4. Copied to FINAL_DATA as "sites_buffered".

Site Shoreline

The length of riverfront shoreline was calculated for all "riverfront" sites. This shoreline was created by extracting the river-only portion of each site's perimeter.

Processing:
1. CONVERT site polygons to polylines (i.e., perimeter)
2. INTERSECT site polylines with buffer polygons to remove all but the river-fronting perimeter portions
3. DISSOLVE site lines to create continuous "shoreline"
4. INTERSECT with buffers to extract only riverfront site perimeter portions
5. DISSOLVE using Site ID, to get total shoreline feature for each site
6. ADD FIELD: "length"
7. Copied to FINAL_DATA as "site_shorelines"

Site Hydrologic Context

Two attributes were used to denote hydrologic context for each site: presence of riverfront shoreline, and predominant hydro access (indicated by slope).

<u>Riverfront Shoreline</u>

Presence of a non-negligible portion of the site's perimeter along direct riverfront shoreline resulting in a site receiving the attribute "riverfront". This was determined in the following manner:

Processing:
INTERSECT sites with WA Department of Ecology marine shoreline. This resulted in stretches of shoreline identified as having connection to each. However, the DOE shoreline is coarse scale, so manual post-editing was needed to verify these results.

EDIT – sites were examined visually along with a DOQ to determine if shoreline perimeter was in fact present, and the "riverfront" attribute edited as necessary. In addition, sites with a negligible portion of their perimeter touching the shoreline were denoted "non-riverfront". This generally occurred when the portion of site perimeter intersecting the river shoreline was simply a small tributary outlet, or subwatershed drainage point. For consistency, a minimum distance of 50 meters was established as the threshold for annotating a site as "riverfront".

Slope Class

Sites were given an attribute denoting predominant slope, which is an indicator of hydrologic access (i.e., flat sites receive hydrology via the river, while steep "subwatershed" site receive hydrology via upland sources). The average slope for each site was derived from the slope calculations for the LCR, described later. This served as an initial screen for finding "flat" sites, by denoting all sites with an average slope of < 9 degrees as "flat". This attribute was then manually edited in order to account for flat sites that aren't actually within "regular" access to the river – such as flat sites atop bluffs. The driving factor for attributing a site as "flat" was whether a non-negligible portion of its area could be affected by diking.

Combined

The riverfront and slope class attributes for each site were copied into a new shapefile containing the site polygons. This new layer contains information on these two attributes, as well as the MA ID for each site, and whether it intersects the current edition of the draft historic floodplain.

Copied to FINAL_DATA as "site_hydrologic".

Management Area Delineation

The process for delineating MAs is described here in detail. The process is designed to be as automated and rule-based as possible, in order to facilitate easy re-delineation if the input datasets change (e.g., the "complexes", which are currently draft), and to establish a well-documented, objective methodology. GIS tools are listed in all caps.

Input datasets

- HUC-6 polygons for the Pacific Northwest, created by USGS REO. Current version is h122302.e00, dated 12/23/2002.
- Historic floodplain boundary, created by Jen Burke. Current version is Prelim_floodplain_NODISTRIBUTE.mdb/prelim_fldplain_utm27, dated 8/25/2005
- Ecosystem complexes, created by Jen Burke. Current version is Complexes.mdb/complexes_A through /complexes_H.
- Hydrogeomorphic reaches, created by Jen Burke. Current version is hydrogeo_III_edit.shp, dated 5/24/2005.
- DEM Hillshade, created from USGS 10m DEM by Lee Miller. Current version is lcr_hs.img, dated 3/4/2005, from DEMs dated 7/31/1998 (distributed by OR BLM).

Relative paths are preceded with …\

Data preparation

Some data needs to be prepared for editing by converting to shapefiles and matching to a common projection.

HUC-6 polygons: Converted to coverage = …\USGS\HUC\huc6
Data is in NAD27 UTM10

Complexes extracted from Complexes.mdb. File:…\Jen\shp\complexes_A.shp, etc.
Complexes UNION to one shapefile. File:…\Jen\shp\complexes_union.shp
Complexes PROJECT into NAD27 UTM10. File:…\MA\complexes_union_project.shp

Hydrogeo PROJECT into NAD27 UTM10. File:…\MA\hydrogeo_III_edit_project.shp

Processing

<u>HUC-based MAs</u>

1. Roughly clip huc6 coverage into a smaller area around the LCR.
    - Method: Rectangle selection, export selected features
    - Input File: …\USGS\HUC\huc6
    - Output File:…\MA\huc6_rough_clip.shp

2. Split agreed upon HUCs into smaller regions for management purposes, as requested by Scott McEwen. Cut specified HUCs by tracing along the DEM ridgeline.
    - Method: Cut Polygon Features
    - Input File: …\MA\huc6_rough_clip.shp
    - Output File:…\MA\huc6_edit1.shp
    - Edits:
        - HUC 1536 to remove Long Beach Peninsula
        - HUC 1662 into 3 (Sisson Creek/Deep River, Grays River, Crooked Creek) West/Central/East
        - HUC 1707 into 2 (Jim Crow Creek, Skamokowah and tribs) West/East
        - HUC 2087 into 2 (Lewis River/Salmon Creek, Burnt Bridge Creek/Vancouver Lake) North/South

3. Clip edited HUCs with floodplain to remove any that do not have some portion of the floodplain boundary within them.
    - Method: Select by Location, using *prelim_fldplain_utm27* as intersection, export selected data.
    - Input File: …MA\huc6_edit1.shp
    - Output File: …\MA\huc6_edit2.shp

4. Remove unwanted HUCs that remain (outside of study area)
    - Method: Select/Delete
    - Input File:…\MA\huc6_edit2.shp
    - Output File:…MA\huc6_edit3.shp (export edit2 as edit3, then do edits)
    - Removed:
        - HUC 1770 (Clatsop – mostly OR coast)

- Edits: Assign a new field to the remaining HUCs for later use dissolving the complex unioned dataset. Field: Disslv_ID, based on FID

5. Union HUCs with complexes in order to re-define riverside boundaries and make it easy to separate island complexes from the HUCs
   - Method: UNION
   - Input Files: …\MA\complexes_union_project.shp + …\MA\huc6_edit3.shp
   - Output File:…\MA\huc6_edit4.shp

6. Delete any polygons from the unioned data which are either complexes with no HUC ID (i.e., they are already "in-river"), or are of the following types: Floodplain Island, Mainstem Channel, Mainstem Island, Shallows (i.e., these types should be "in-river", so HUCs will be trimmed if a portion of the polygon overlaps with one of these complex types).
   - Method: Select/Delete
   - Input File:…\MA\huc6_edit4.shp
   - Output File:…\MA\huc6_edit5.shp (export edit4 as edit5, then delete features)

7. Dissolve the remaining polygons back into HUCs, so the dataset only contains the same HUC as before, but with trimmed borders along the river.
   - Method: DISSOLVE, field: Disslv_ID
   - Input File:…\MA\huc6_edit5.shp
   - Output File:…MA\huc6_edit6.shp

<u>In-River MAs</u>

1. Create new shapefile to hold base polygon
   - Method: Create feature, draw polygon around all existing HUCs
   - Output File: …MA\river_base.shp

2. Erase river MA polygon to remove the existing HUCs
   - Method: ERASE (ArcInfo)
   - Input Files:…\MA\huc6_edit6shp + …MA\river_base.shp
   - Output File:…\MA\river_edit1.shp

3. Cut/trim river erase polygon to remove "outer" material (outside HUCs), so the only polygon feature that remains is in-river. The lower bound (MCR) is traced from the floodplain boundary, and the upper bound (Bonneville Dam) is traced from the complex boundary.
   - Method: Cut Polygon Features/Delete
   - Input File:…\MA\river_edit1.shp
   - Output File:…MA\river_edit2.shp

4. Cut clipped river polygon into reaches, using hydrogeo layer
   - Method: Cut Polygon Features/Annotate (manually label features A-H)
   - Input File…\MA\river_edit2.shp + overlay …MA\hydrogeo_III_edit_project.shp
   - Output File:…\MA\river_edit3.shp

<u>Combined</u>

1. Union the in-river polygons with the HUCs to create a seamless master dataset
   - Method: UNION
   - Input Files:…\MA\river_edit3.shp + …\MA\huc6_edit6.shp

- Output File:…\MA\ma_union.shp

2. Merge desired HUCs for management purposes
   - Method: Select/Merge
   - Input File:…\MA\ma_union.shp
   - Output File:…\MA\ma_merge
   - Merges (by HUC_ID):
     - 1741 into 1809
     - 1763 into 1734
     - 1852 into 1817
     - 1881 into 1807
     - 2011/2063 into 2074
   - Edits: Assign a new field to the merged MAs for later use dissolving the HUC unioned dataset. Field: Disslv_ID2 = FID+1

3. Union the merged MA layer to the original HUC layer, in order to retrieve the nearest HUC6_ID identifier field.
   - Method: UNION
   - Input Files:…\MA\ma_merge.shp + …\MA\huc6_edit1.shp
   - Output File:…\MA\ma-huc_union.shp

4. Dissolve the unioned dataset back into the "merge" configuration, retaining the HUC6_ID and Reach letter.
   - Method: DISSOLVE
   - Input File:…\MA\ma-huc_union.shp
   - Output File:…\MA\ma_09282005.shp
   - Parameters:
     - Dissolve Field: Disslv_ID2
     - Statistics: HUC6_ID (use MIN statistic), Reach (use FIRST statistic)
   - Edits:
     - Remove polygon with Disslv_ID2 = 0, which is all of the HUCs outside the floodplain clipping bounds.
     - Add Field "MA_ID" to combine Reach and HUC6_ID, as well as to allow addition of "w", "c", "e", "n", or "s" to MAs created from split HUCs 1662, 1707, and 2087 (west, central, east, north, south).
     - Add Fields "Area" and "Perimeter" to calculate descriptive statistics for each polygon.
   - Split HUCs near Bonneville Dam, which cross the river.
     - Method: EXPLODE, so that river-crossing HUCs become individual polygons on the north and south ends.
     - Edit MA ID to include "n" or "s". Affected HUCs are 2172, 2203, 2253, 2270
     - Update area and perimeter fields

The resulting file has the MA polygons created in (2), with the HUC6_IDs from the original HUC6 file. The HUC6_ID applies to all non-river MAs. The in-river MAs retain the Reach designation (A-H). It is possible that multiple HUCs were combined into one MA, which is why the MIN statistic was used – this simply takes the smallest HUC number, and assigns it to the output feature.

Copied to FINAL_DATA as “mas”

General & Stressor Datasets

DEM Slope and Hillshade

A hillshade layer was used extensively during site digitizing, to provide guidance on topographic changes. In addition, the average slope for each site was calculated as a first-cut screen to find “flat” sites for the Slope Class hydrologic context designation.

DEM data was acquired in quadrangles from Oregon BLM.

Processing:

1. MOSAIC TO NEW RASTER in ArcToolbox to create master DEM from quads (lcr_dems.ige)
2. REPROJECT merged dataset to UTM10-NAD27
3. SURFACE ANALYSIS – HILLSHADE to calculate hillshade using Spatial Analyst –at a 315 degree sun azimuth and 45 degree sun elevation (lcr_hs.img)
4. Slope grid created from DEM, using 3D Analyst (lcr_slope.img)
5. Slope information was summarized for MAs and sites, using Spatial Analyst ZONAL STATISTICS (ma_slope, sites_slope)
6. Copied to FINAL_DATA as “ma_slope” and “site_slope”

Floodplain

Draft historic floodplain was acquired from Jen Burke, UW. This floodplain was processed slightly in order to provide a consistent polygon layer for use in analysis.

Processing:

1. CLEAN GAPS – (equivalent to ArcINFO ELIMINATE) was performed to fill small gaps in the polygon resulting from DEM algorithms. Large gaps that were identified were deleted from the resulting file (i.e., large islands that were valid gaps).
2. ADD FIELD: “Area” in order to help identify very small gap polygons that should be filled.
3. DISSOLVE – remaining gap polygons were dissolved into the floodplain layer, resulting in a clean internal polygon set.
4. EDIT- remaining small polygons around the perimeter of the floodplain (i.e., as small tribs move upland, leaving DEM depressions) were removed.
5. PROJECT to UTM10-NAD27

Copied to FINAL_DATA as “floodplain”

Hydro

100k hydro line dataset was acquired from StreamNet for the Pacific Northwest. Data is distributed as regional shapefiles.

Processing:

1. MERGE regional shapefiles into master layer
2. PROJECT to UTM10-NAD27, update "length" field
3. CLIP to study area using MA layer, update "length" field
4. DELETE FEATURES – Columbia River centerline deleted (has no bearing on our use of the line feature dataset)
5. Copied to FINAL_DATA as "hydro"

Roads

TIGER road data acquired in regional shapefiles.

Processing:
1. MERGE regional shapefiles into master layer
2. PROJECT to UTM10-NAD27, update "length" field
3. CLIP to study area using MA layer, update "length" field
4. Copied to FINAL_DATA as "roads"

Hydro-Road Intersections

Hydro dataset and roads dataset were overlayed to find points of intersection.

Processing:
1. POINT INTERSECTION (ET GeoWizards) performed to find intersections. Output is a new point shapefile.
2. Copied to FINAL_DATA as "hydro-road-intersect"

Hydro Buffer

A hydro line buffer dataset was created for use with MA-level stressor calculations. This buffer was used to clip lulc data, for summarizing riparian cover.

Processing:
1. BUFFER hydro lines using 50 meter distance.
2. INTERSECT with MA layer to divide hydro buffers into MAs.
3. Copied to FINAL_DATA as "hydro_buffer".

Shoreline

A 100k marine shoreline was acquired from WA Department of Ecology. This shoreline extends to Bonneville Dam, and was used for various processing and display purposes in line and polygon form.

Processing:
1. PROJECT to UTM10-27
2. Copied to FINAL_DATA as "shore_line" and "shore_poly".

Rkm Zones

The navigation channel centerline was used to demarcate rkm points along the river. The relative location of each site along the river was then assigned a "zone" based on Kukulka and Jay's work.

Processing:

1. Navigational channel digitized from NOAA ENC lines (centerline extracted, then slightly digitized upstream of Portland)
2. PROJECT to OR Lambert for measuring
3. EXPLODE lines to break multipart features
4. ROUTE lines to flip directions so all features are end-to-end
5. Points generated every 1km along line, starting at mouth, using DIVIDE to create a new point file.
6. Script used to create perpendicular lines to the centerline at each rkm. The perpendicular lines were then edited to remove overlaps.
7. CLIP perpendicular lines to original floodplain.
8. JOIN perpendicular lines and rkm points, so every perpendicular line has an rkm value. This provides a "measuring stick" across the river for estimating the rkm of each site.
9. New polygon layer created to encompass all sites
10. CUT POLYGON AREA on new polygon layer, using rkm distances noted in Kukulka and Jay. This end result is a layer that encompasses all sites, and demarcates major tidal/fluvial transitions along the lower river.
11. PROJECT to UTM10-NAD27
12. Copied to FINAL_DATA as "rkm_zones".

Diking

Draft dike line and polygon layers were acquired from Jen Burke & Si Simenstad, UW. These layers were edited to create a master polygon layer representing diked areas in the LCR. Additional diking data not present in the UW layer was added from ACOE diking file. All lines were converted to polygons that represent the estimated area blocked from river hydrology behind the dike. This was estimated using floodplain boundaries and DOQs. The master diking file was then post-processed to create a clean and consistent dataset.

Processing:

1. EXPLODE multipart features
2. DISSOLVE to remove overlaps and merge adjacent polygons
3. CLEAN to ensure correct topology and overlap removal
4. ADD FIELD: "Dike_ID" (FID+1), "Area"
5. DELETE FIELD: all other fields.
6. PROJECT to UTM10-NAD27, updated area field
7. Copied to FINAL_DATA as "diking". Note that this dataset represents areas of estimated hydrologic blockage, not individual dike polygons.

Additional Processing:

1. CLIP diking polygon using draft floodplain
2. Copied to FINAL_DATA as "diking_clip". This dataset represents diked area polygons that have been clipped to the floodplain, so that percentage of blocked floodplain can be calculated.

Flow Restrictions

Three datasets were used to create a combined flow restrictions layer. This dataset represents points of potential flow alteration due to tide gates, dams, culverts, or other non-natural structures. The datasets incorporated are ACOE Tidegate Inventory (digitized by Matt Burlin, Estuary Partnership), WDFW "fishpass" system barrier data, and ODFW "bar_pts2" barrier data.

ACOE Tidegate Inventory

Processing:
1. PROJECT to UTM10-NAD27
2. Copied to barriers folder for later merging
3. ADD FIELD: "Orig_ID", "Source", "Type"
4. DELETE FIELD: all other fields

WDFW Barriers

Processing:
1. "fishpass" data extracted from online barrier database for LCR region
2. ADD FIELD: "Orig_ID", "Source", "Type"
3. DELETE FIELD: all other fields
4. DELETE FEATURES: natural barriers "Gradient" and "Waterfall" (contained in file "wdfw_nn")
5. "barrierrep" data also used, to find points where culverts had been repaired for fish passage, but were still in place. All *culvert* points from this dataset (as opposed to bridges) were exported to a new file.
6. SPATIAL JOIN fishpass and barrierrep files to find duplicates. Barrierrep points <1m from an original fishpass points were deleted.
7. MERGE edited files into a new WDFW barrier file.
8. PROJECT to UTM10-NAD27
9. CLIP to study area using MA layer.
10. Converted dataset from "multipoint" to "singlepoint" feature type for later merge compatibility.

ODFW Barriers

Processing:
1. PROJECT to UTM10-NAD27
2. CLIP to study area using MA layer
3. ADD FIELD: "Orig_ID", "Source", "Type"
4. DELETE FIELD: all other fields

Combined

Processing:
1. MERGE WDFW and ODFW into master barriers file
2. MERGE barriers with tidegates to create final flow restrictions file
3. Copied to FINAL_DATA as "flow_restrictions"

Contaminants

SEDQUAL and Tetra Tech databases were merged to form a combined contaminants database. The databases were scored separately for TEL/PEL, and Score (see J Ward writeup, Appendix C).

After processing, Tetra Tech points within 150 meters of any SEDQUAL point were selected for removal, except for chemicals that had no corresponding SEDQUAL sample to risk duplication with (BnzaAnth, BnzaPyren, Heptacle). The points greater than 150m from any SEDQUAL point were exported. The SEDQUAL data and TT data were both projected to UTM10-NAD27 separately, then merged. Copied to FINAL_DATA as "contaminants"

Facilities of Interest

"Facilities of Interest" are those facilities that WA Department of Ecology or OR Department of Environmental Quality has a legal interest in, such as for permitting or other regulation. Each state has a unique database of these facilities. The two state datasets were merged into one dataset for assessment purposes, using common generalized attributes.

<u>Oregon</u>

The OR facilities database was acquired from OR DEQ using the web-based Facility Profiler tool. This tool allows users to query the database for facilities in a region of interest. All Oregon facilities were extracted for Columbia, Clatsop, and Multnomah counties, and saved as a comma-delimited file.

Processing:

1. ADD XY – csv file imported to ArcGIS as point layer, using "OGIC_X" and "OGIC_Y" fields.
2. EXPORT points to new shapefile.
3. PROJECT dataset to UTM10-NAD27.
4. CLIP dataset to study area using MA layer.
5. ADD FIELD: "ID" = FID + 1, for tracing data back to pre-edited shapefile.
6. EXPORT a new copy for editing.
7. DELETE FEATURES – the following feature types were removed from the dataset:
    a. Air permitted facilities (ACSIS program)
    b. ECSI program facilities with non-null "No Further Action" (NFA) date. This was done to ensure that facilities were only scored that DEQ has a current interest in.
    c. LUST – removed items with non-null NFA date.
8. ADD FIELD "SOURCE" = ORDEQ.
9. ADD FIELD "TYPE" = Land or Water. This distinction was made based on the program responsible for the facility. The intention is to note some facilities as impacts to land/sediment, and others as impacts to water quality.
    a. Land: SWIFT, ECSI, HWMS, LUST, and UST programs
    b. Water: SIS program
10. Several comment fields were added in order to keep attribute fields of interest, yet create a new field name for common use between states:
    a. "Comment1" = Program_ID
    b. "Comment2" = InterestTy
    c. "Comment3" = InterestSu
    d. "Comment4" = Comments
    e. "Comment5" = Status
11. DELETE FIELD – all other fields removed from the attribute table.

<u>Washington</u>

The WA facilities database was acquired from WADOE as a shapefile of point features. Notable attributes included "ECO_INT_CD", which is a letter code indicating Ecology's interest reason, and "INT_DS", which is a text description of the interest code.

Processing:

1. PROJECT dataset to UTM10-NAD27.
2. CLIP dataset to study area using MA layer.
3. ADD FIELD: "ID" = FID + 1, for tracing data back to pre-edited shapefile.
4. EXPORT a new copy for editing.
5. DELETE FEATURES – the following feature types were removed from the dataset:
    a. Air permitted facilities (ECO_INT_CD = AQSYNMNR, AQLA, AQOPS)
    b. Dams (redundant with flow restrictions dataset)
    c. All facilities with "STATUS_CD" = "I" (inactive).
    d. Facilities with ECO_INT_CD: VOLCLNST
6. ADD FIELD "SOURCE" = WADOE.
7. ADD FIELD "TYPE" = Land or Water.
    a. Land: ECO_INT_CD = ENFORFNL, FCS, HWG, HWOTHER, HWP, HWTRNSFR, INDPNDNT, INDUSTRL, IRAP, LANDFILL, LUST, NONENFNL,ORA, SCS, TIER2, TRI, UST
    b. Water: ECO_INT_CD = 401PROJ, all other codes beginning with "WQ".
8. Several comment fields were added in order to keep attribute fields of interest, yet create a new field name for common use between states:
    a. "Comment2" = ECO_INT_CD
    b. "Comment3" = INT_DS
    c. "Comment5" = STATUS_CD
9. DELETE FIELD – all other fields removed from the attribute table.

<u>Combined</u>

Each edited state dataset was then merged into a new combined facilities dataset:

1. MERGE datasets into new point shapefile with common attribute fields.
2. Copied to FINAL_DATA as "facilities".

LULC

Two land use/land cover datasets were processed: The Estuary Partnership's (LCREP) Landsat-based classification from Garano et al., and the National Land Cover Dataset from USGS. Due to pending re-classification and limited spatial extent of the LCREP edition, the dataset was ultimately not used in the analysis. It is available in the GIS database if needed.

<u>LCREP</u>

Latest unmasked ("lc_pretide") dataset was acquired.
Processing:

1. CONVERT grid to polygon features
2. CLEAN polygon features to ensure correctness
3. PROJECT to UTM10-NAD27
4. Copied to FINAL_DATA as "lulc_lcrep"

<u>NLCD</u>

Latest data acquired from USGS online data repository for the LCR region.
Processing:

1. CONVERT grid to polygon features
2. CLEAN polygon features to ensure correctness
3. PROJECT to UTM10-NAD27
4. CLIP to study area using MA layer
5. Copied to FINAL_DATA as “lulc_nlcd”

NLCD note: This dataset was used for estimating % Agriculture, Industrial, Forested, etc. within sites and MAs. The following LULC classes (defined in the metadata) were aggregated to estimate each type:
Agriculture: 71,81,82,83,84
Developed: 21,22,23,85
Forested: 41,42,43,51
Industrial: 23

303(d) listed waterbodies

Oregon and Washington are both required by the Clean Water Act section 303(d) to maintain a list of waterbodies considered “impaired”. These datasets were acquired for each state and merged. For ease of processing and site linking, all data was eventually compiled into a single polygon dataset.

<u>Oregon</u>

Oregon 303(d) data was acquired from Oregon Geospatial Data Clearinghouse. The data is distributed as two shapefiles, one for polygon-type waterbodies, and another for line-type waterbodies (or_303d_lakes, and or_303d_streams).

Processing:

1. BUFFER – line dataset was converted to polygons by applying a 1-meter buffer to all features.
2. MERGE line and polygon datasets into a master dataset for OR.
3. PROJECT dataset to UTM10-NAD27.
4. CLIP dataset to study area using MA layer.
5. ADD FIELD – several fields were added to create common attributes between states:
   a. “Param” = Parameter
   b. “Source” = ORDEQ-OGDC
   c. “Year” = 2002
   d. “Source_ID” = PKMATRIVID
   e. “ID” = FID + 1
6. DELETE FIELD – all other fields removed.

<u>Washington</u>

Washington 303(d) data was acquired from Washington Department of Ecology. The data is distributed as a single polygon shapefile.

Processing:

1. PROJECT dataset to UTM10-NAD27
2. CLIP dataset to study area using MA layer
3. ADD FIELD – several fields were added to create common attributes between states:

    a. "Param" = Parameter
    b. "Source" = ORDEQ-OGDC
    c. "Year" = 2002
    d. "Source_ID" = PKMATRIVID
    e. "ID" = FID + 1
4. DELETE FIELD – all other fields removed.

<u>Combined</u>

Each edited state dataset was then merged into a new combined 303(d) dataset:

3. MERGE datasets into new polygon shapefile with common attribute fields.
4. Copied to FINAL_DATA as "303d".

Invasive Species

Dataset acquired from Jill Leary at the Estuary Partnership. This data was extracted from LCRANS database by Jill, and saved as a point shapefile, representing locations of observed nuisance species.

Processing:

1. PROJECT dataset to UTM10-NAD27.
2. Copied to FINAL_DATA as "invasives".

Over-water Structures (OWS)

Over-water structures were digitized using 1-meter DOQs. The entire study area was panned, and structures apparent on the DOQ were added as point or polygon features to new shapefiles. The following over-water structure types were digitized:

- Points – docks, unknown structures, industrial piers, log rafts, and other stationary objects (i.e., groups of barges tied together, indicating a location used for temporary storage of these vessels).
- Polygons – marinas, protected marinas (i.e., marinas containing a protective structure such as a breakwater), and industrial piers

Processing:

1. For all layers, ADD FIELD: "ID" = FID + 1, "TYPE" indicating structure type.
2. For polygon layers, ADD FIELD: "Area" to store polygon area calculation.
3. MERGE point layers into a single shapefile.
4. MERGE polygon layers into a single shapefile.
5. PROJECT both payers to UTM10-NAD27.
6. Copied to FINAL_DATA as "ows_points" and "ows_polys".

Note: protected marina polygons may overlap with regular marinas. Marinas are defined by EPA as any pier with capacity for ten or more vessels. The vessel occupation are was digitized in these case, in order to estimate potential area of light impact. Protected marinas were digitized around the entire protecting structure, in order to estimate area of potential sediment dynamics disruption.

Piledikes

This dataset consists of two parts. The original part was acquired from Gregg Bertram, U.S. Army Corps of Engineers as a CAD file, and converted to a shapefile. The second part was digitized in ArcGIS. The original piledike dataset was overlayed on 1-meter DOQs. The entire study area was panned, and missing piledikes that were apparent on the DOQ were digitized to a new shapefile.

Processing:
1. Both datasets were given a new field: "Source" containing either "ACOE" or "DOQ" as appropriate.
2. MERGE datasets into a single shapefile.
3. PROJECT dataset to UTM10-NAD27.
4. Copied to FINAL_DATA as "piledikes".

Dredge Material Disposal Sites (DMDS)

Dataset acquired from Gregg Bertram, U.S. Army Corps of Engineers as a CAD file and converted to shapefiles. This dataset contains lines and polygons representing areas of known historic dredge material disposal. The only other attributes present in the dataset are disposal site name.

Processing:
1. Line features converted to polygons.
2. CLEAN – polygon dataset cleaned to ensure correct topology.
3. DISSOLVE – cleaned dataset dissolved to merge adjacent polygons and ensure no overlap present.
4. ADD FIELD "ID" = FID + 1.
5. DELETE FIELD - all other fields.
6. Recalculated polygon areas to reflect cleaned/dissolved polygons.
7. PROJECT dataset to UTM10-NAD27.
8. Updated areas to reflect new map units.
9. Copied to FINAL_DATA as "dmds".

Population density

Data acquired from ESRI USA data. Original data source U.S. Census data, pre-processed by ESRI for distribution with ArcGIS. Dataset used is census block group polygons, which represent U.S. Census-defined "block groups" for survey data (ESRI\usa\census\blkgrp.sdc).

Initial data prep:
1. SELECT (by location) all census block groups within 1km of the overall MA area. This is to ensure that all needed data is present in the regional subset used.
2. PROJECT dataset to UTM10-NAD27.
3. ADD FIELD "Area" to get block group area in map units; "Pop_m2" to store calculation of population density in map units. Original data stored population density in "POP04_SQMI" field, so these fields were used to convert the units to map units.
4. ADD FIELD "Area_km2" and "Pop_km2" to check decimal precision of population density using small map units of meters.

5. ADD FIELD: “ID” = FID + 1, for tracing.
6. DELETE FIELD - extra census data fields (i.e., race, gender, etc.). “ObjectID” field retained so processed data can be traced back to features in original dataset.
7. Copied to FINAL_DATA as “census_block_groups”.

Population calculations for sites:
1. INTERSECT block groups with sites.
2. DELETE FIELD (site area, length, acres, FID).
3. ADD FIELD “New_Area” = Area of intersected block group/site polygon; “New_Pop” = “Pop_m2” * “New_Area”. This “New_Pop” field now has total census population for the intersected block group polygons within each site.
4. Opened intersected attribute table (dbf) and saved as “pop_calcs.xls”. Within pop_calcs, all data columns were deleted except “ID”, “Site_ID”, “New_Area”, and “New_Pop”. Data was sorted by Site_ID, and total population for all block groups polygons within each site was summed. Total population was also divided by total site area, to achieve a comprehensive population density value for each site.
5. Pop_cals.xls exported to text for ArcGIS import as a table.
6. JOIN imported table to sites using Site_ID.
7. EXPORT joined dataset to FINAL_DATA\joined\sites as “census_block_groups_Intersect”.

Industrial Shoreline

Industrial shoreline areas were initially identified from the LCREP land cover classification and then digitized as line features based on the 1-meter DOQs.Only areas immediately adjacent to the shoreline were considered. The following shorelines were considered industrial:

- Non-recreational sized docks and associated structures
- Oil refineries
- Gravel and material sifting operations

Processing:
1. Create line shapefile, perform digitizing
2. ADD FIELD: “ID” and “Length”
3. Copied to FINAL_DATA as “industrial_shore”

Navigational Channel

Polygon of navigational channel was acquired from Gregg Bertram, US. Army Corps of Engineers.

Processing:
1. CLEAN to ensure correctness
2. PROJECT to UTM10-NAD27
3. CLIP to study area using MA (original included southern coast channels)
4. Copied to FINAL_DATA as “navchan”.

Connectivity Datasets

Hydro Connectivity

A “hydrologic connectivity” metric was derived using the hydro dataset. For each hydro line in the dataset, the number of sites it runs through was counted. Then, for each hydro line running through each site, the hydro line site counts were summed. This produces a coarse look at inter-site connectivity (i.e., which sites are connected to the most other sites via stream reaches).

Processing:

1. DISSOLVE hydro line dataset using LLID, with “no multipart” option.
2. ADD FIELD: “ID”, to differentiate unique hydro features (this was required because not all features have an LLID due to incompleteness of the dataset’s attributes).
3. INTERSECT dissolved hydro lines with site polygons.
4. Attribute table loaded in Excel and summarized so that the total number of hydro lines running through (intersecting) each site was counted, and their site counts summed.
5. Summary table JOINED back to site polygons (sites_hydro.shp).

Diked Area Blockage

This metric is used to estimate how many sites are blocked by any given diked area polygon. It can be used to find areas where the highest number of sites are blocked in a contiguous area – potentially restoring hydrology to the greatest number if sites if a dike breach were to occur. As with the hydro metric, the number of sites blocked (intersected) by each dike polygon was counted, and summed for all of the diked area polygons intersecting each site.

Processing:

1. INTERSECT diked area layer with sites.
2. Attribute table loaded in Excel and summarized so that the total number of diked area polygons running through (intersecting) each site was counted, and their site counts summed.
3. Summary table JOINED back to site polygons (sites_diking.shp).

Site Adjacency

This metric is used to count the total number of sites that border (share perimeter lines) with each site. In the prioritization workbook, the list of sites is filtered to meet certain criteria (must be within floodplain, same MA, and if not must be < 10 degrees average slope).

Processing:
GET ADJACENT POLYGONS tool (ET GeoWizards) used to retrieve list of sites with coincident borders (sites_adjacent.shp)
Attribute table loaded in Excel and summarized: adjacent polygon list sorted and counted for each site.

Combined

All three of the connectivity metrics described above were joined back to the site polygons file as a master "connectivity layer" containing the values for each site. Copied to FINAL_DATA as "site_connectivity".

Existing Function Datasets

Fish Use

Anadromous fish use data was compiled for each site, in order to derive a species/use diversity metric (total count of unique species/use combinations). Data acquired from StreamNet. Original data source Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, and Montana Fish, Wildlife, and Parks. Polyline data represents stream reaches with fish species and use attributes (http://www.streamnet.org/online-data/GISData.html).

Initial data prep:

8. SELECT (by location) all stream reaches within 1km of the overall MA area. This is to ensure that all needed data is present in the regional subset used.
9. PROJECT dataset to UTM10-NAD27.
10. DELETE FIELD - extra data fields (i.e., run ID, collector, etc.). Species ID, Use ID, and Stream ID retained.
11. Copied to FINAL_DATA as "fish_use_anad".

Fish calculations for sites:

8. INTERSECT polylines with sites.
9. BUFFER sites where polylines did not intersect with site (i.e., wide tributaries and side channels)
10. SELECT (manually) sites that were too far from stream reach to use a buffer on either the site or the reach (e.g., Sturgeon Lake, mainstem Columbia River, etc.).
11. COPIED site data into intersected data file.
12. CALCULATED values for fish use based on the reach data
13. DISSOLVED all records by Site ID, Species ID, Use ID, and Stream Name
14. EXPORT joined dataset to FINAL_DATA\joined\sites as "fish_use_anad_Dissolve".

Wetlands

Existing wetland area is also used as a measure of existing function.
Data acquired from USFWS, National Wetlands Inventory. Polygon data represents wetland area (http://wetlandsfws.er.usgs.gov/).

Initial data prep:

1. SELECT (by location) all stream reaches within 1km of the overall MA area. This is to ensure that all needed data is present in the regional subset used.
2. PROJECT dataset to UTM10-NAD27.
3. Copy all data into single dataset
4. CLEAN to remove duplicate polygons

5. DELETE FIELD - extra data fields (i.e., acres, HGM code, etc.). Attribute, Wetland Type, and Area retained.
6. Copied to FINAL_DATA as “NWI”.

Fish calculations for sites:

1. INTERSECT polylines with sites and MAs.
2. DISSOLVED all records by Site ID, Attribute, and Wetland Type
3. EXPORT joined datasets to FINAL_DATA\joined\sites as "NWI_Intersect" and “NWI_Intersect_Dissolve”. EXPORT joined datasets to FINAL_DATA\joined\MA as "NWI_Intersect" and “NWI_Intersect_Dissolve”

Associating Data with Sites or MAs

In order to associate final datasets with individual site polygons or MAs, a set of joining methods was used. The specific join method depends on the type of input dataset. The basic join procedures and decision rules are described here. Joining of data to sites and MAs must be done before the data can be used in the analysis. All joined data is stored in a “joined” database, and is named using the layer name and a keyword indicating the join type. In addition, the site foreshore buffer was used for joining of certain datasets (e.g., overwater structures, dredge material disposal). In this case, the letter “B” was appended to the layer name to indicate the join was performed on a buffered site. The letters “BO” are appended to indicate the join was performed on the buffers only.

Spatial Join

If points need to receive a site or MA ID for the polygon within which they reside, a spatial join is used. The output joined points can then be summarized in a worksheet (i.e., counted). The text “_Join” is appended to the data name for this join method.

Intersect

Intersect is used to cut lines or polygons into the site/MA that they fall within. This creates new boundaries for each data feature, and the new area/perimeter of the feature is recalculated. For instance, intersecting the diking polygon with sites produces a new set of diking features that are divided into each site – allowing us to estimate the area within each site that is diked. Intersected datasets are appended with the text “_Intersect”

Select

For some datasets, a spatial or attribute selection is used to “subset” the data. This occurred with “protected marinas”. All sites that contained a protected marina were selected and exported to a new file. The text “_Select” is appended.

Dissolve

To summarize large datasets, features may be dissolved using the site ID and other attributes. For example, the lulc data was dissolved using site ID and grid code (classification number). The output dataset then contains no more than one feature of each code type for each site. The area of this feature can be calculated, and represents the total area within the site for that cover type. Dissolve is performed subsequent to an Intersect, and the text "_Dissolve" is appended to the layer name.

Appendix B: Restoration Strategies and Landscape Disturbance (adapted from Bainbridge Island Nearshore Assessment)

Nearshore Management Strategies

Five fundamental strategies for improving ecosystem functions of nearshore systems (listed in no particular order) are included in the process and form the basis for management decisions:

- Creation – Creation involves bringing into being a new ecosystem that previously did not exist on the site (NRC 1992). In contrast to restoration, creation involves the conversion of one habitat type or ecosystem into another.
- Enhancement – Enhancement means any improvement of a structural or functional attribute (NRC 1992). As noted by Lewis (1990), enhancement and restoration are often confused. Enhancement is the intentional alteration of an existing habitat to provide conditions that previously did not exist and which by consensus increase one or more attributes. Shreffler and Thom (1993) found that, for estuarine systems, enhancement often meant *enhancement of selected attributes* of the ecosystem, such as improving the quality or size of a tidal marsh or eelgrass meadow.
- Restoration – As defined in the scientific literature, restoration means the return of an ecosystem to a close approximation of its previously existing condition (e.g., Lewis 1990, NRC 1992). We use the term restoration to refer to any form of human intervention with the intent of improving upon the existing condition of the ecosystem or habitat. Restoration involves doing *something* to increase the rate of recovery over the rate of natural recovery occurring without human intervention.
- Conservation – Conservation, as defined by Meffe et al. (1994), refers to the maintenance of biodiversity. Conservation Biology is a synthetic field that applies the principles of ecology, biogeography, population genetics, economics, sociology, anthropology, philosophy and other theoretically based disciplines to the maintenance of biological diversity. Conservation can allow development to occur as long as biodiversity and the structure and processes to maintain it are not affected.
- Preservation – Preservation refers to the formal exclusion of activities that may negatively affect the structure and/or functioning of habitats or ecosystems. It can also refer to preservation of a species or group of species through management actions, such as elimination of harm to a species directly or indirectly through damage of its habitat. Marine protected areas (MPAs) can fit within this strategy. Marine protected areas are receiving growing attention as a viable way to preserve fish populations threatened by over-fishing and habitat loss (e.g., Roberts et al. 2001). They are typically established in habitats known to be important for function, such as reproduction or rearing.

Influence of Disturbance on Management Actions

The success of any strategy varies depending on the level of disturbance of the site and the landscape within which the site resides (NRC 1992). Using the findings of the National Research Council (NRC) and a review of the literature on estuarine habitat restoration, Shreffler and Thom (1993) concluded that the strategies of restoration, enhancement, and creation should be applied depending on the degree of disturbance of the site and the landscape (Figure 1). It is assumed that the historical conditions represent the optimal habitat conditions for a particular site. In general, restoration to historical conditions is best accomplished where the sites and the landscape are not heavily altered (Shreffler and Thom 1993; NRC 1992). Creation of new habitat (i.e., habitat not historically present) at a site is done when the site and the landscape are heavily damaged. Sites with a high degree of disturbance on the landscape and site scales (Figure 1), in general, have a low probability for restoration, and creation of a new habitat or ecosystem or perhaps enhancement of selected attributes would be the only viable strategies to apply in these situations. In contrast, where the site and landscape are essentially intact, restoration to historical (i.e., humans present, but insignificant disturbance) or predisturbance (i.e., before man) conditions would be viable options and the probability of success would be high.

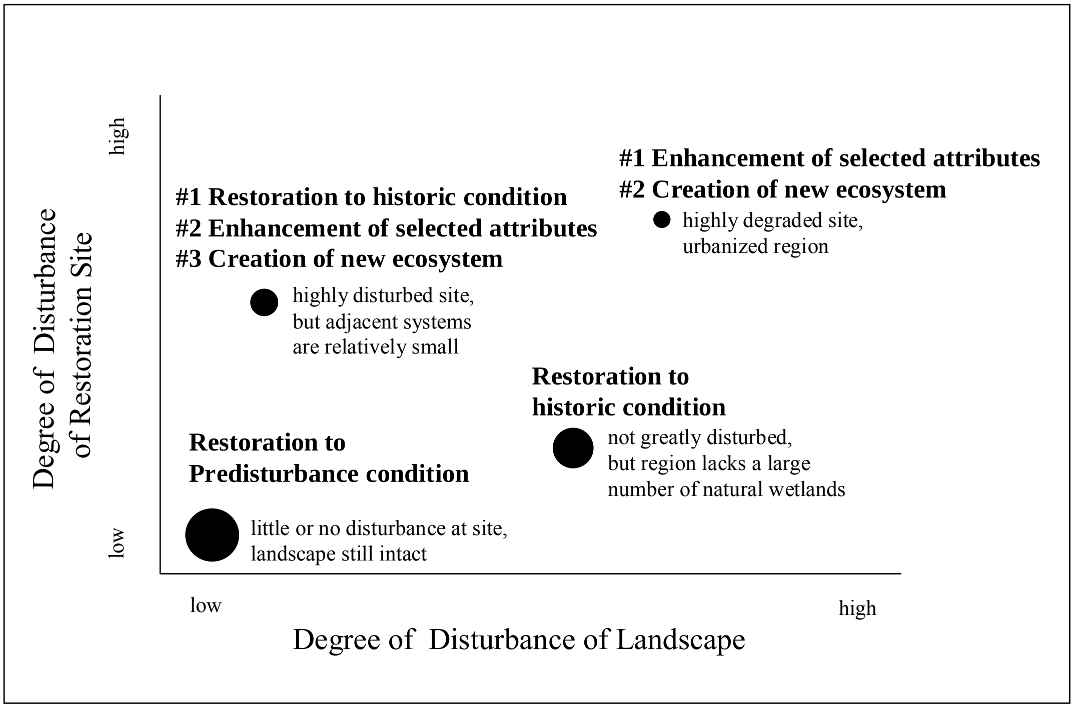

Figure 1. The restoration strategies for nearshore systems relative to disturbance levels on the site and in the landscape (from Shreffler and Thom 1993). The relative chance of success increases with the size of the dot.

Conservation strategy is related to another strategy common in the literature: *sustainable development*. *Development* here means the qualitative change in a systems complexity and configuration as opposed to (sustainable) *growth* which refers to a quantitative increase the size of the system (Meffe et al. 1994). Basically, this means that society conducts itself in a manner that preserves ecosystems for the future by encouraging actions that conserve what exists and that restore what has been damaged or lost (Meffe et al. 1994). Hence, the fields of conservation biology and restoration ecology merge under sustainable development, and, furthermore, are interdependent upon one another.

Some of the practical steps in sustainable development include the following:

- Avoid and minimize damages from any development project through thorough review and refinement of the project–base this on sound understanding of the individual and cumulative effects of the project on the ecosystem. By knowing the sources of stress, one can better provide advice on how to avoid these stresses through engineering and project modifications.

- Devote a strong effort in the planning phase for the restoration project to maximize the assurance of success.
- Execute the restoration project effectively and comprehensively.
- Monitor and adjust the project as needed to better meet the goals.

Finally, effectively achieving the goal may require that several strategies be employed at a site and in the landscape. It is possible that preservation of landscape features, enhancement of selected attributes, and conservation in the nearshore may be highly effective in restoring the controlling factors that affect historical structure, functions, and processes to the system.

Application to the Prioritization Framework

The Prioritization Framework involves an initial assessment of which strategies would have the highest priority of working within each reach (Tier 1), followed by a site specific assessment to refine the strategy and priority (Tier 2). This approach uses landscape ecology and conservation biology principles, and national recommendations on the most applicable restoration strategies as the fundamental underpinnings for prioritization (see above and NRC 1992; Shreffler and Thom 1993). These principles are well established in the ecological literature, and are highly useful in providing comprehensive, larger-scale guidance.

A national assessment showed that the degree of disturbance on the landscape and site scales affected the probability of restoration success, and that the most appropriate restoration strategies varied according to disturbance on these two scales (Figure 1). Restoration of natural aquatic systems can be uncertain (NRC 1992; Thom 2000). Prioritization of sites and management action strategies for these sites are presented here using information designed to reduce this uncertainty as much as possible. For this Framework, site is equated to local scale, and Management Area is equated to landscape scale. Actual restoration projects may be smaller than a “site”, and should be evaluated at the actual scale when developing strategies for that site. Because the Management Area is based on the watershed, a major contributor to habitat-forming processes in sites, Management Areas encompass appropriate landscape-scale processes.

The matrix in Figure 2 identifies the strategies most appropriate under the nine different states of site and Management Area disturbance. Figure 2 integrates the restoration strategies in Figure 1 and the two additional strategies of conservation and preservation discussed above. The strategies most likely to work are indicated, as well as where each strategy might also be applied with a somewhat lower probability of working.

	Low Management Area Disturbance	Moderate Management Area Disturbance	High Management Area Disturbance
High Site Disturbance	Restore Enhance Create	Enhance Create Restore	Enhance Create
Moderate Site Disturbance	Enhance Restore Preserve	Conserve Enhance Create Restore	Enhance Create Restore
Low Site Disturbance	Conserve Preserve	Conserve Enhance Restore	Enhance

Figure 2. Matrix of management action strategies most appropriate for a site based on the degree of disturbance of the Management Area and the site (not listed in any particular order).

As seen in the matrix (Figure 2), multiple strategies are potentially viable under any one of the nine states. This matrix provides general guidance as a first approximation of specific management actions that could be evaluated within a site or Management Area. In developing the matrix in Figure 2, the following logic was used:

- The lower the disturbance on both scales, the greater reliance on preservation, conservation, and restoration
- The greater the disturbance on both scales, the greater reliance on enhancement
- Under the greatest levels of disturbance, greater is the reliance on creation and restricted development.

To demonstrate this concept using the existing data from the Prioritization effort, Management Area scores (the median site controlling factor disturbance score plus watershed hydrologic disturbance score) for each site are plotted against the controlling factor disturbance score for the same site (Figure 3). The scores are broken into three categories based on breaks in the distribution of data points as shown in Figure 3 and as noted in Figure 4. Each point in Figure 3 represents a site. The degree of disturbance on the site scale is represented by the site scale controlling factor score.

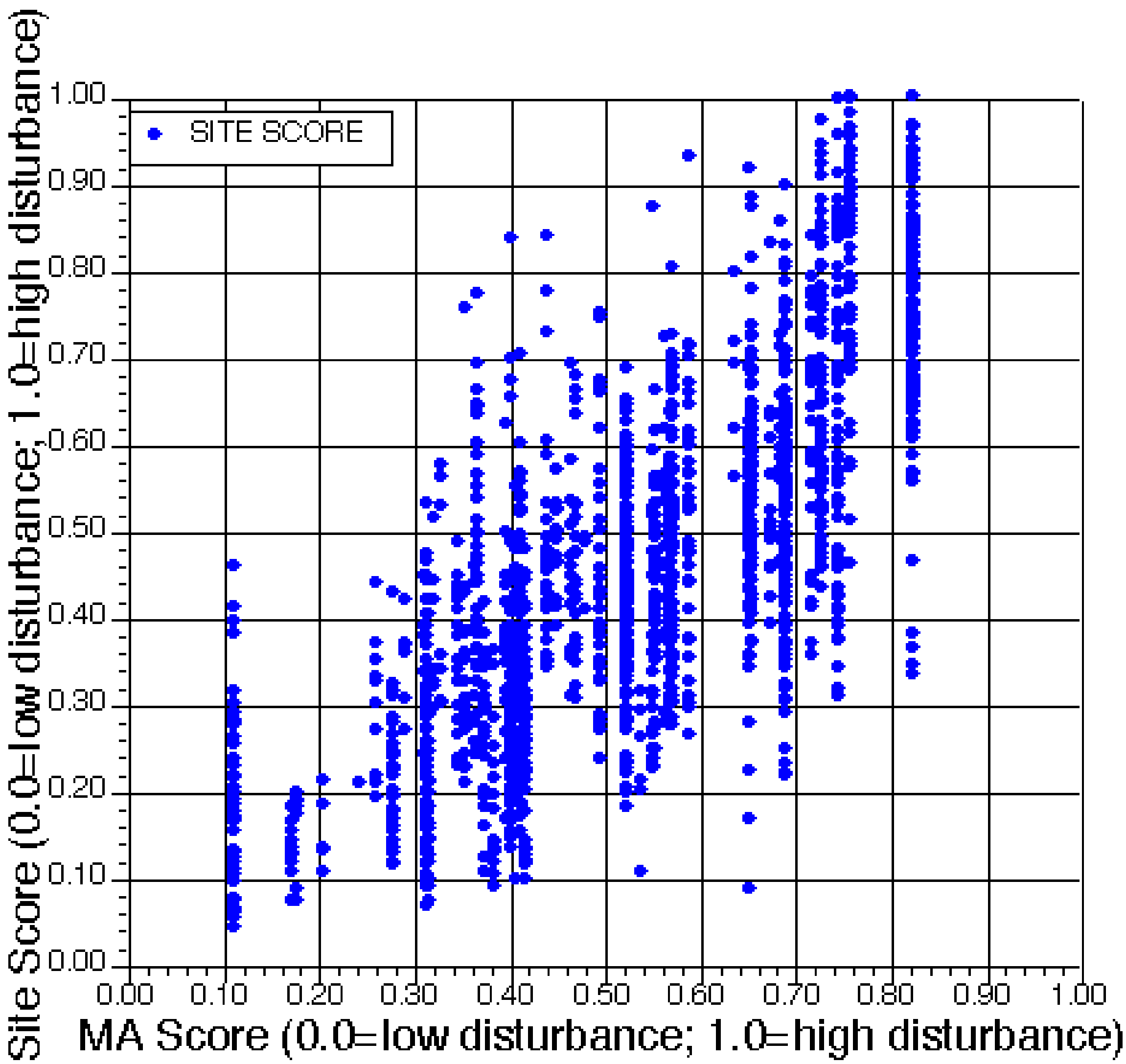

Figure 3. Management Area disturbance score versus site controlling factor disturbance score.

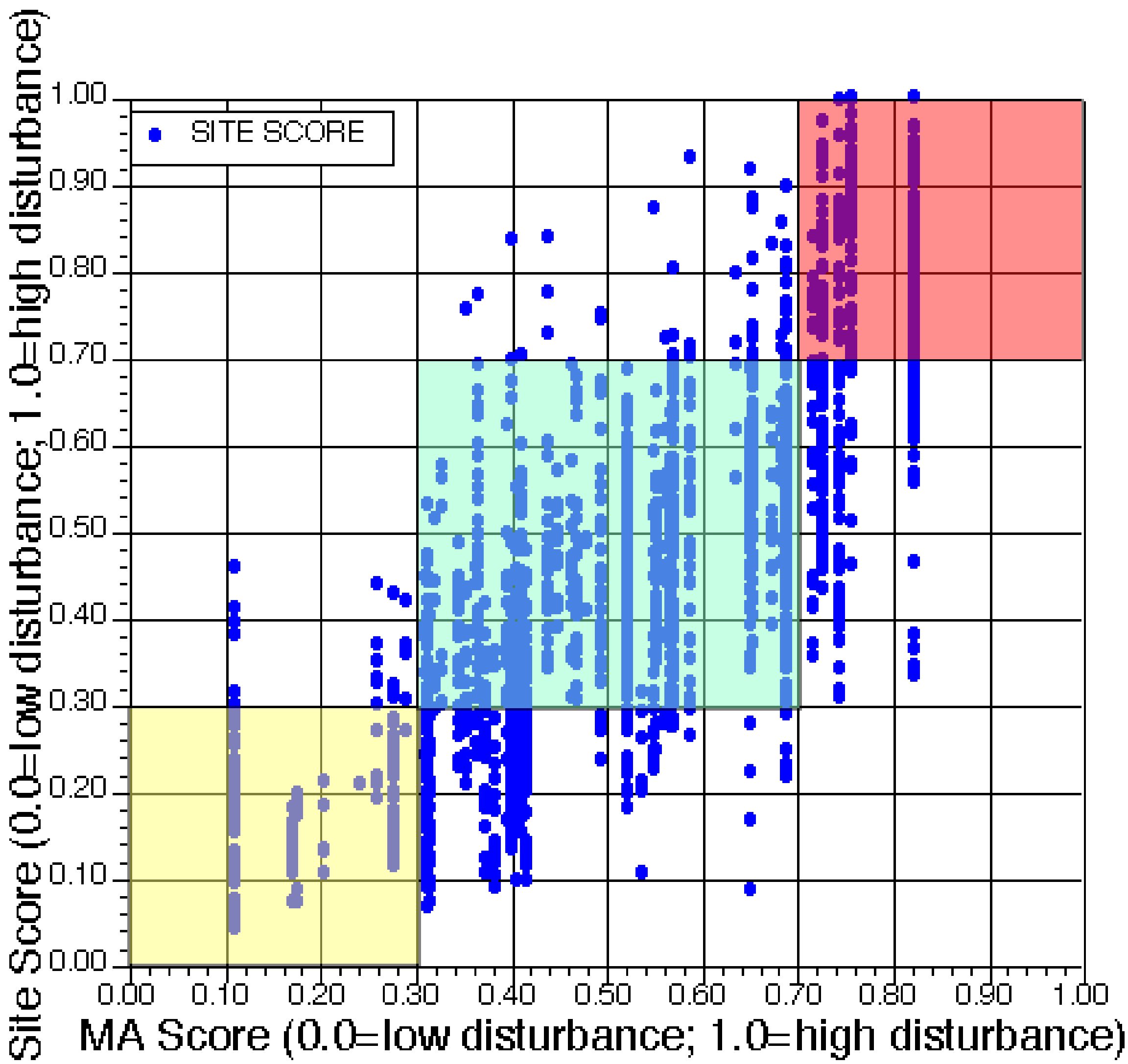

Figure 4. Management Area disturbance score versus site controlling factor disturbance score showing low, moderate and high categories.

Figure 4 corresponds to the matrix of management action strategies in Figure 2 above, and can be used to *prioritize appropriate management action strategies for those sites*. For example, for sites with low controlling-factor disturbance scores on both axes, the most appropriate management action strategies would be to conserve, preserve, and restore (to pre-disturbance or pre-historical conditions). Whereas, sites where controlling-factor disturbance scores are high on both axes, management action strategies of enhancement of selected habitat attributes, creation of new ecosystems, or restricted development are most appropriate. In areas where Management Area controlling-factor scores are high, but site scores are low, the site is in relatively good condition; however, any strategy for restoration needs to be considered relative to the ability of processes afforded by a relatively disturbed landscape to maintain the restored site in the long term. Because the points are continuously distributed (at least on the site scale) and there is a high degree of variability, the management action strategy most appropriate for a particular site needs further project-specific analysis. This degree of variation in the application of strategies is reflected in the general zones illustrated in Figure 5 (from Bainbridge Assessment).

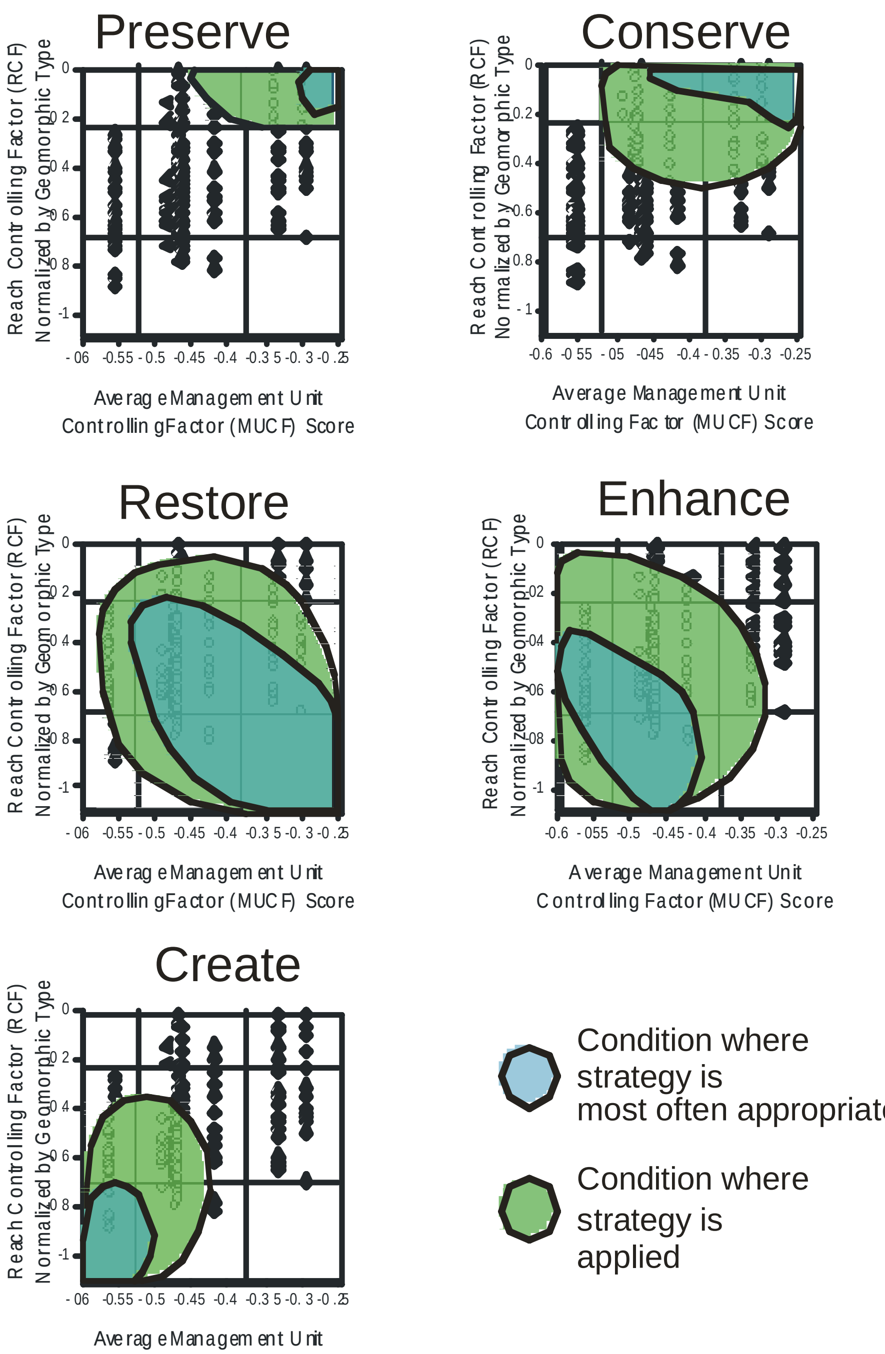

Figure 5. Generalized zones of application of management strategies relative to management unit and reach disturbance (from Bainbridge Island Nearshore Assessment).

Lastly, site scores are compared with those of their immediate (adjacent) neighbors, giving a localized look at site impacts versus the surrounding area (Figure 6). This can help identify "clusters" of sites where low-impact conditions surround a highly impacted site. This is useful in evaluating which site in a location is more likely to succeed based on direct local connections, and can also help define the desired landscape arrangement of a suite of restoration projects.

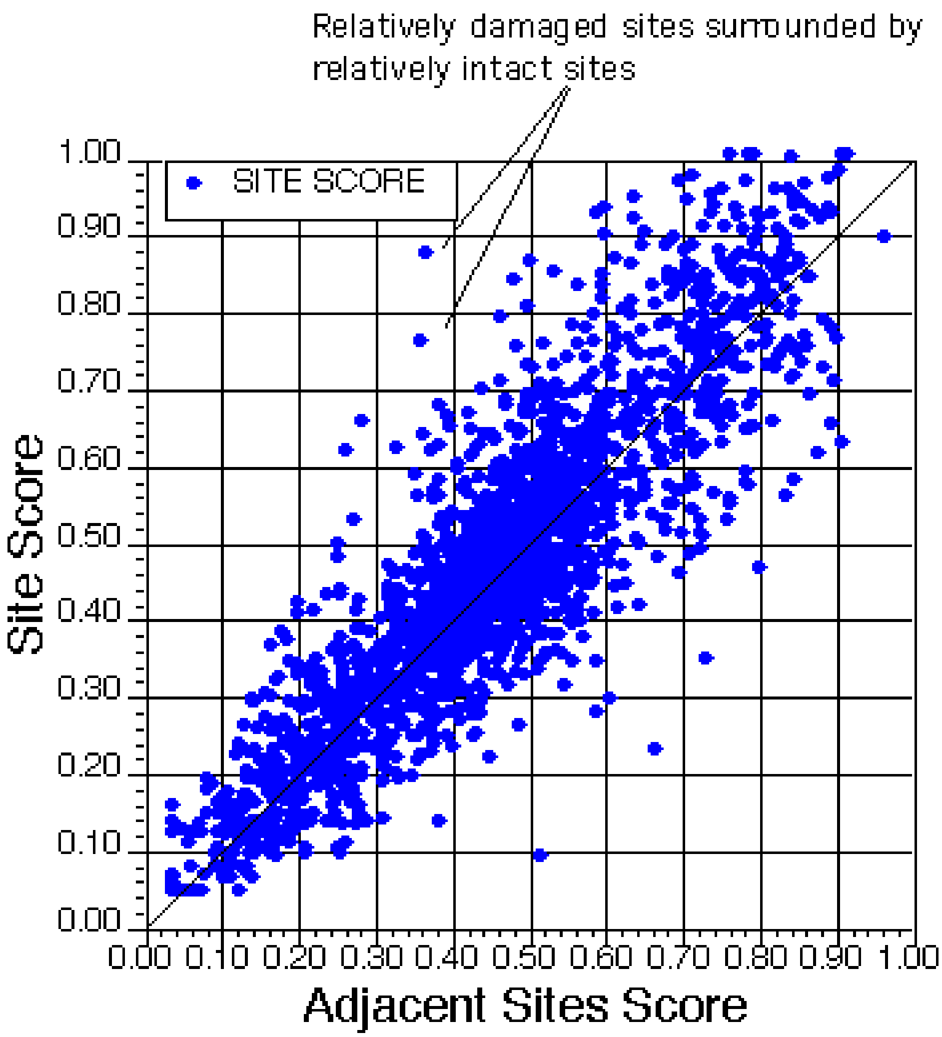

Figure 6. Site score versus mean score of adjacent sites.

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Appendix C: Preliminary Toxics Analysis Summary

Overall Approach

In order to determine the extent and magnitude of toxic chemicals in the LCR study area, analytical sediment chemistry information was evaluated from databases developed by Tetra Tech and linked to the Estuary Partnership website (http://www.lcrep.org/tech_info.htm) and from the Washington State Department of Ecology's SEDQUAL database (http://www.ecy.wa.gov/programs/tcp/smu/sedqualfirst.htm). A total of 21 contaminants were chosen for evaluation based on their known presence in the estuary and the availability of published regulatory benchmarks for freshwater sediment. Contaminants chosen represented polynuclear hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides. Table 1 presents the list of contaminants included in the evaluation, and the threshold effects levels (TELs) and probable effects levels (PELs) for freshwater sediment obtained from the NOAA screening Quick Reference Tables (SQuiRTs) database (http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html).

Table 1. Contaminants Included in Assessment and Regulatory Criteria.

Contaminant	Freshwater Sediment TEL	Freshwater Sediment PEL
Metals (ppm dry)		
Arsenic	5.9	17.0
Cadmium	0.6	3.5
Chromium	37.3	90.0
Copper	35.7	197.0
Lead	35.0	91.3
Mercury	0.174	0.486
Nickel	18.0	35.9
Zinc	123.1	315.0
Pesticides (ppb dry)		
Heptachlor epoxide	0.60	2.74
Endrin	2.67	62.4
Dieldrin	2.85	6.67
Total DDD[a]	3.54	8.51
Total DDE[b]	1.42	6.75
Total DDT	6.98	4450
PAHs and PCBs (ppb dry)		
Pyrene	53	875
Phenanthrene	41.9	515
Fluoranthene	111	2355
Chrysene	57	862
Benza(a)pyrene	32	782
Benzo(a)anthracene	32	385
Total PCBs	34	277

a. p,p-DDD criteria used
b. p,p-DDe criteria used

Impact Assessment and Graphical Display

In order to determine whether selected contaminants in the study area were present at levels of concern, detected concentrations were compared to TEL and PEL criteria for freshwater sediment. The results were then displayed using the GIS platform to show contaminant impact trends in the study area. Four impact categories were developed, based on comparison of individual chemical concentrations to TEL and PEL benchmarks (Table 1). A large potential for adverse impact was predicted when the observed chemical concentration exceeded the probable effects level (PEL) for a given chemical; moderate impacts and small impacts were predicted based on comparison to TEL. When concentrations were undetected or values were qualified, comparisons to regulatory benchmarks were not made, but data were included in the GIS as open circles in order to display spatial sampling coverage in the study area.

Table 1. Impact Assessment Methodology for Sediment Contaminants.

Impact Category	Definition	Score	GIS Color Code
Large potential for adverse impact	Detected concentration of a contaminant ≥ PEL	3	Red
Moderate potential for adverse impact	Detected concentration of a contaminant ≥ TEL but <PEL	2	Yellow
Small potential for adverse impact	Detected concentration of a contaminant <TEL	1	Green
Impact assessment not determined	Concentration of a contaminant undetected or qualified	0	Open circles

Results

Summary results are presented in Figure 1 and Table 2. Additional information is provided in Attachments 1-3. Figure 1 shows the large-scale reach designations developed for the GIS platform; Table 2 provides a semi-qualitative assessment of impact for the four impact categories at the large-scale reach scale. Site specific impacts are not discussed here, but are available by using a query function associated with the GIS platform.

For metals, a moderate potential for adverse impacts is predicted at reaches associated with the mouth of the river, and at some of the middle reaches of the study area. A large potential for adverse impacts is predicted for all metals in sediment samples from Reach G, which is located at the confluence of the Columbia and Willamette rivers (Figure 1). Pesticides were generally undetected or concentrations were qualified at all reaches except Reach G, where there was a high potential for adverse impact based on comparison to TEL and PEL criteria (Figure 1). For PAHs, a moderate potential for adverse impact was predicted at most reaches for pyrene, phenanthrene, fluoranthene, and chrysene, and a small potential was expected for benzo(a)pyrene and benzo(a)anthracene. Moderate impacts associated with total PCBs was predicted at the two reaches near the mouth of the Columbia River. Large impacts were predicted for all PAHs associated with sediment from Reach G (Figure 1).

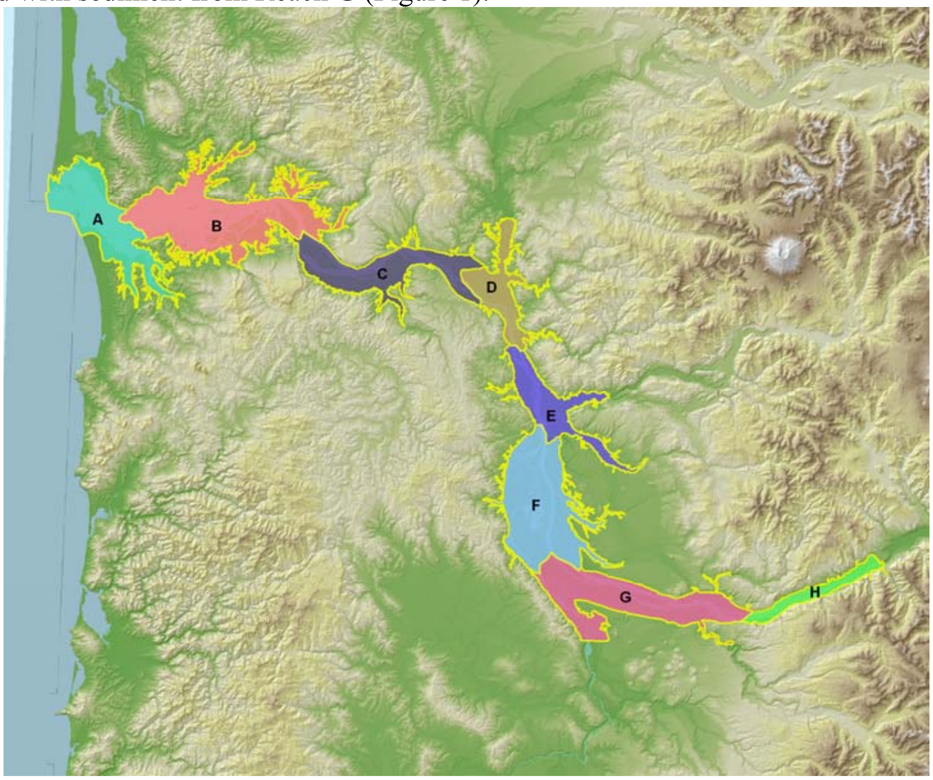

Figure 1. Large-scale Reach Designations.

Table 2. Semi-Quantititave Assessment of Potential for Adverse Impacts at Each Large-scale Reach.

Contaminant	Large-scale Reach Identifier							
	River Mouth		Middle Reaches				Upper Reaches	
	A	B	C	D	E	F	G	H
Arsenic	[yellow]	[yellow]	[green]	[green]	[green]	[yellow]	[red]	[green]
Cadmium	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[red]	[yellow]
Chromium	[yellow]	[yellow]	[green]	[green]	[green]	[green]	[red]	[green]
Copper	[yellow]	[yellow]	[yellow]	[yellow]	[green]	[yellow]	[red]	[green]
Lead	[green]	[green]	[green]	[green]	[green]	[green]	[red]	[green]
Mercury	[yellow]	[green]	[green]	[green]	[green]	[green]	[red]	[green]
Nickel	[red]	[red]	[red]	[yellow]	[yellow]	[yellow]	[red]	[green]
Zinc	[yellow]	[yellow]	[green]	[green]	[green]	[green]	[red]	[green]
Heptachlor epoxide	O	O	O	O	O	O	[red]	O
Endrin	O	O	O	O	O	O	[yellow]	O
Dieldrin	O	O	O	O	O	O	[red]	O
Total DDD[(a)]	O	O	O	O	O	O	[red]	O
Total DDE[(b)]	O	O	O	O	O	O	[red]	O
Total DDT	O	O	No data				[yellow]	No data
Pyrene	[yellow]	[green]	[yellow]	[yellow]	[yellow]	[yellow]	[red]	[green]
Phenanthrene	[yellow]	[green]	[green]	[yellow]	[yellow]	[yellow]	[red]	[green]
Fluoranthene	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[red]	[yellow]
Chrysene	[yellow]	[yellow]	[yellow]	[yellow]	[green]	[green]	[red]	[green]
Benza(a)pyrene	[green]	[green]	[green]	[green]	[green]	[green]	[red]	[green]
Benzo(a)anthracene	[green]	[green]	[green]	[green]	[yellow]	[green]	[red]	[green]
Total PCBs	[yellow]	[yellow]	O	O	O	O	[red]	O

Legend>>>	O = qualified data	Low potential	Moderate potential	High potential

Discussion

Contaminants of potential environmental concern are present in the Lower Columbia River estuary at concentrations that may result in acute or chronic impacts to sensitive freshwater or estuarine species. In some cases, contaminant patterns suggest discreet chemical "hotspots" while in other cases, chemical contamination appears to be present at low but persistent levels throughout the study area. While the data and results presented here suggest a moderate or high potential for adverse effects, it is not possible to quantitatively determine the true impact until the bioavailability of the given chemical or chemicals is known. Factors controlling bioavailability include the measured concentration of the contaminant, the contaminant form (e.g. elemental or methyl mercury), the position of the contamination vertically or horizontally in the sediment (i.e., located at the surface or buried under cleaner material and beyond the biogenic zone), the physical/chemical characteristics of the sediment (grain size, total organic carbon), and the susceptibility of the contaminated material to resuspension and deposition under current conditions or during remediation. Some of this information is available in historical data, come can only be inferred, given the date of the sampling and the general location of the collections.

Because the Lower Columbia River and its tributaries are a dynamic system, our ability to predict adverse impacts is less precise when older information is evaluated. . For example, of the 25 SEDQUAL samples that produced a high potential for adverse impacts for arsenic, 15 were collected between 1989 and 1994, and only 5 were collected within the last 7 years. Similarly, fluoranthene was observed at nearly all reaches at concentrations predicted to result in a moderate to high potential for adverse impacts. Of the 171 observations where fluoranthene concentrations exceeded PEL criteria, 168 samples were collected prior to 2001. Contaminants associated with the edges of the river may represent the greatest risk because they are the most susceptible to mobilization, suspension, and deposition, but the ability to determine the true extent of the environmental risk is difficult because these areas often change the most over time. In order to address this uncertainty, it is likely additional studies in the LCR study area will be necessary to augment historical information and improve our ability to determine impact. It is likely that more recent information on contaminant concentrations is available in the estuary, but at present, this information is not readily available in a georeferenced format.

Scoring for the Impact Assessment

Distribution of Sediment Contaminant Data in LCR Reach G (most contaminated)

Exceeding Probable Effects Levels (PEL)

REACH G	25th percentile	50th percentile	75th percentile
Arsenic	1.2	1.4	3.2
Nickel	1.0	1.1	1.2
Fluoranthene	2.4	5.5	11.9

Dieldrin	1.6	1.6	2.1
Mercury	2.5	3.2	5.7
Lead	1.2	1.7	3.3
Average	1.7	2.4	4.6

Scoring for GIS

Score	Definition
0	Contaminant not detected (U-qualified)
1	Contaminant concentration <TEL
2	Contaminant concentration ≥TEL but <PEL
3	PEL HQ ≥ 1.0 but < 2.0
4	PEL HQ ≥ 2.0 but <5.0
5	PEL HQ ≥ 5.0

HQ is concentration of a contaminant divided by the Threshold Effects Level (TEL) using equivalent units.

ATTACHMENT 1

Descriptive Statistics for SEDQUAL and Tetra Tech (LCREP) Sediment Metals

SEDQUAL Metals (ppm dry) Descriptive Statistics	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Total Observations	1398	1248	1181	1283	1358	1220	1168	1257
Total Detected	1008	791	1047	1149	1113	775	966	1004
Percent Detected	72%	63%	89%	90%	82%	64%	83%	80%
Minimum	0.001	0.02	0.006	0.002	0.001	0.0001	0.01	0.004
Maximum	640	8	1090	9740	1080	4.9	594	7000
Mean	5.80	0.72	30.6	83.3	43.2	0.166	22.7	143.3
25th Quartile	2.8	0.29	19.7	23	11.7	0.060	16.0	70.0
50th Quartile	2.8	0.40	28.4	23	11.7	0.060	16.0	70.0
75th Quartile	5.9	0.92	37	50	35.1	0.160	28.0	150.0
TEL	5.9	0.6	37.3	35.7	35	0.174	18	123.1
PEL	17	3.5	90	197	91.3	0.486	35.9	315
Undetected or Qualified (Score = 0)	390	457	134	134	245	445	202	253
Number < TEL (Score = 1)	739	469	741	543	823	594	302	605
Number ?TEL (Score = 2)	269	322	306	606	290	181	664	399
Number ? PEL (Score = 3)	25	13	25	42	122	41	54	70

Tetra Tech (LCREP) Metals (ppm dry) Descriptive Statistics	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Total Observations	365	244	372	308	372	365	214	308
Total Detected	293	192	309	262	282	150	150	247
Percent Detected	80%	79%	83%	85%	76%	41%	70%	80%
Minimum	0.4	0.0	38.0	1.5	0.4	0.001	0.4	1.1
Maximum	108.0	4.2	1090.0	4870.0	566.0	7.000	431.0	1406.0
Mean	8.0	0.9	61.8	140.9	49.3	0.167	22.1	130.7
25th Quartile	3.6	0.3	40.8	36.0	10.0	0.030	11.0	64.0
50th Quartile	5.4	0.7	46.9	47.6	16.7	0.076	16.9	95.9
75th Quartile	8.1	1.2	61.3	80.0	55.4	0.175	25.0	144.1
TEL	5.9	0.6	37.3	35.7	35	0.174	18	123.1
PEL	17.0	3.5	90.0	197	91.3	0.486	35.9	315
Qualified (Score = 0)	72	52	63	46	90	215	64	61
Number < TEL (Score = 1)	175	94	222	80	192	187	84	164
Number ?TEL (Score = 2)	118	98	87	182	90	53	66	83
Number ? PEL (Score = 3)	15	1	5	12	44	8	13	12

ATTACHMENT 2

Descriptive Statistics for SEDQUAL and Tetra Tech (LCREP) Sediment Pesticides

SEDQUAL Sediment Pesticides (ppb dry) Descriptive Statistics	Heptachlor Epoxide	Endrin	Dieldrin	Total DDD	p,p-DDE	Total DDT
Total Observations	802	774	888	52	52	97
Total Detected	17	16	47	39	34	26
Percent Detected	2%	2%	5%	0.75	65%	27%
Minimum	0.10	0.61	0.10	0.20	0.40	0.20
Maximum	12.00	10.00	29.00	100.00	7.00	94.00
Mean	5.03	3.34	5.70	4.69	1.94	5.45
25th Quartile	0.84	0.76	0.72	0.90	1.00	0.65
50th Quartile	0.84	0.76	3.00	1.30	2.00	1.35
75th Quartile	10.00	5.25	10.50	2.10	2.00	2.08
TEL	0.6	2.67	2.85	3.54	1.42	6.98
PEL	2.74	62.4	6.67	8.51	6.75	4450
Qualified (Score = 0)	785	758	841	13	18	71
Number < TEL (Score = 1)	2	9	23	33	15	24
Number ?TEL (Score = 2)	15	7	24	6	19	2
Number ? PEL (Score = 3)	8	0	15	2	1	0
LCR Assessment		**SEDQUAL**				
Results of Initial Sediment Screen		**PAHs and PCBs**				

Tetra Tech (LCREP) Pesticides (ppm dry) Descriptive Statistics	Heptachlor Epoxide	Endrin	Dieldrin	p,p-DDD	p,p-DDE	Total DDT
Total Observations	180	278	297	208	208	89
Total Detected	4	12	14	29	34	3
Percent Detected	2%	4%	5%	14%	16%	3%
Minimum	0.2	4.5	0.3	0.2	0.1	0.2
Maximum	0.5	350.0	34.0	1400.0	270.0	275.0
Mean	0.2	144.9	7.8	100.4	25.6	91.8
25th Quartile	0.1	25.0	0.5	2.0	2.2	0.2
50th Quartile	0.3	105.0	2.2	9.0	7.1	0.2
75th Quartile	0.4	285.0	10.5	35.0	21.0	137.6
TEL	0.6	2.67	2.85	3.54	1.42	6.98
PEL	2.74	62.4	6.67	8.51	6.75	4450
Qualified (Score = 0)	176	266	283	179	174	86
Number < TEL (Score = 1)	4	0	7	10	5	2
Number ?TEL (Score = 2)	0	12	7	19	29	1
Number ? PEL (Score = 3)	0	6	6	15	17	0

ATTACHMENT 3

Descriptive Statistics for SEDQUAL and Tetra Tech (LCREP) Sediment PAHs and PCBs

SEDQUAL Sediment PAH and PCBs (ppm dry) Descriptive Statistics	Pyrene	Phenenthrene	Fluoranthene	Chrysene	Benzo(a)pyrene	Benzo(a)anthracene	Total PCBs
Total Observations	1415	1416	1251	1286	194	194	759
Total Detected	989	924	882	858	41	42	421
Percent Detected	70%	65%	71%	67%	21%	22%	55%
Minimum	0.32	0.9	0.41	0.7	4.2	5.3	0.003
Maximum	610000	2000000	250000	100000	300000	200000	300000
Mean	9155.3	10177.0	4978.3	2448.1	7955.0	5426.0	1270.8
25th Quartile	62.0	37.0	57.0	36.0	10.0	11.6	5.7
50th Quartile	270.0	160.5	200.0	130.0	29.0	33.5	50.4
75th Quartile	1800.0	1300.0	1200.0	787.5	340.0	557.5	224.0
TEL	53	41.9	111	57	32	32	34
PEL	875	515	2355	862	782	385	277
Qualified (Score = 0)	426	492	369	428	153	152	338
Number < TEL (Score = 1)	210	242	336	312	21	21	189
Number ?TEL (Score = 2)	779	682	546	546	21	21	232
Number ? PEL (Score = 3)	318	323	171	171	12	12	93

Tetra Tech (LCREP) PAHs and PCBs (ppm dry) Descriptive Statistics	Pyrene	Phenenthrene	Fluoranthene	Chrysene	Benzo(a)pyrene	Benzo(a)anthracene	Total PCBs
Total Observations	194	193	194	194	194	194	118
Total Detected	47	50	56	45	41	42	25
Percent Detected	24%	26%	29%	23%	21%	22%	21%
Minimum	7.0	5.0	8.1	6.5	4.2	5.3	2.0
Maximum	500000.0	800000.0	900000.0	300000.0	300000.0	200000.0	979.0
Mean	12700.8	18406.2	18621.1	7463.3	7955.4	5426.4	94.8
25th Quartile	23.0	16.3	29.5	19.4	10.0	11.6	14.0
50th Quartile	110.0	50.0	71.0	48.0	29.0	33.5	45.0
75th Quartile	794.0	565.0	895.0	510.0	340.0	557.5	60.0
TEL	53	41.9	111	57	32	32	34
PEL	875	515	2355	862	782	385	277
Qualified (Score = 0)	147	143	138	149	153	152	93
Number < TEL (Score = 1)	18	25	32	26	24	21	12
Number ?TEL (Score = 2)	29	25	24	19	17	21	13
Number ? PEL (Score = 3)	11	13	8	9	8	12	2