Tidal Wetland Prioritization for the Nehalem River Estuary

Tidal wetlands, North Fork Nehalem River. Photo by L. Brophy

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Green Point Consulting
U.S. Fish and Wildlife Service
Pacific Coast Joint Venture

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Abbreviations

ACOE	U.S. Army Corps of Engineers
DEMIS	Digital Estuary Management Information System
DLCD	Department of Land Conservation and Development
DSL	Department of State Lands
EPB	Estuary Plan Book
GIS	Geographic Information Systems
HGM	Hydrogeomorphic (as in the HGM wetland functional assessment method)
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
NWI	National Wetland Inventory
ODA	Oregon Department of Agriculture
ODOT	Oregon Department of Transportation
ONHP	Oregon Natural Heritage Program
OWEB	Oregon Watershed Enhancement Board
PDF	Adobe Portable Document Format
UGB	Urban Growth Boundary
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Introduction

Project goals and approach

Throughout the Pacific Northwest, there is increasing recognition of estuarine contributions to watershed and marine processes. This recognition has generated new interest in tidal wetland conservation and restoration. In Oregon, overall losses of tidal wetlands since the 1850's are estimated at 70% (Christy 2004, Good 2000, Boule and Bierly 1987, Thomas 1983), supporting the need for restoration. Conservation of the small remaining percentage of tidal wetlands is equally important. However, because each estuary offers a wide variety of restoration and conservation opportunities, strategic planning is needed.

This prioritization is designed to provide strategic focus for tidal wetland conservation and restoration actions undertaken in partnership with willing landowners. The study highlights land areas in the Nehalem River estuary where tidal wetland restoration or conservation action may offer the biggest ecological "bang for the buck" – that is, those locations that may offer the highest potential to protect or increase estuary functions. The information provided by this study provides a basis for working with interested landowners to develop site-specific action plans.

This study's products are meant for active use. Information was stored in a Geographic Information System (GIS) and in Excel spreadsheets. The GIS shapefiles, spreadsheets and maps can be used to organize information about tidal wetlands and estuary conservation activities. The estuary is a dynamic place, so we recommend regular updating of site-specific data, as well as verification of the details in this report before site-specific action planning.

This prioritization uses ecological factors to rank sites for both conservation and restoration actions. The study uses an ecosystem perspective, prioritizing wetland areas ("sites") rather than specific restoration projects. Criteria for prioritization included size of site, tidal channel condition, wetland connectivity, salmonid habitat connectivity, historic vegetation type, and diversity of current vegetation types. Information on these characteristics was obtained from publicly available data, field reconnaissance (offsite observation), and aerial photograph interpretation. Number of landowners, ownership type, and proximity to development can also be important factors in restoration planning. These factors are addressed in supplemental analyses.

This study has no regulatory intent or significance; it is intended only to foster conservation and restoration by interested and willing landowners. This project did not delineate jurisdictional wetlands; existing NWI maps were used for site boundaries. NWI maps are based on offsite data, so the mapped areas may contain both wetlands and uplands. The results of this study do not alter the regulatory status of any resources, and the study is not intended to replace existing regulatory planning processes. For example, this study can not substitute for regulatory resource evaluations such as determinations of significance in the context of comprehensive planning programs. This prioritization is not intended to be an assessment of site functions. Assessment of tidal wetland functions is a complex and technical field (Simenstad et al. 1991, Adamus 2005a, b, c) and not within the scope of this analysis. However, the criteria used for prioritization were selected because they strongly influence a broad range of tidal wetland functions.

This study strives for transparent methods and usability. The data sources, data manipulations, scoring methods, and results are thoroughly documented and all analyses are repeatable. All of the data used are stored in the site information tables and can be accessed, checked for accuracy, and updated as needed. Sufficient data are provided for fine-tuning site selection and action planning; these data (and additional new data) can also be used to re-rank sites using alternative methods if desired.

This prioritization is intended to provide a broad perspective and help guide decisions; it should not be used to eliminate any site from consideration for restoration or conservation. Even sites ranked low in this study are important, because so many tidal wetlands have been lost or converted to other habitat types. All tidal wetlands offer valuable ecological services to people and wildlife.

To improve the accuracy and usefulness of this study, **we actively sought input from local landowners, residents and resource specialists.** Information gleaned from landowner meetings and other forums has been included in the site characterization and prioritization, the site information table, and this written report.

Study area description

This study included all historic tidal wetlands in the Nehalem River Estuary up to the head of tide. ("Historic tidal wetlands" means areas that are currently tidal wetlands, or were formerly tidal wetlands before human alteration.) Emergent, scrub-shrub and forested tidal wetlands were included, but consistent with statewide methods (Brophy 2005a), aquatic beds (eelgrass and algae beds) and mud flats were excluded. This study also excluded former tidal wetlands that have been completely filled and converted to developed uses such as industrial, commercial and residential sites.

Several definitions of tidal wetlands have been used through the years, but for this study, the following definition is used: "A tidal wetland is a vegetated wetland that is periodically inundated by tidal waters, generally daily at high tide or monthly during spring tides, but at least annually." Since the frequency of tidal inundation could not be directly determined in this study, many data sources were used to create the map of tidal wetlands, including existing data, aerial photographs, field observation, and local knowledge.

Summary of results

Using geospatial data, field observation, and aerial photograph interpretation, we identified 1,350 hectares (ha) (3,336 acres) of current and former tidal wetlands in the Nehalem River estuary. This figure is 59% larger than the previous estimate of total historic tidal wetland area (Good 2000). The difference is primarily due to the new data generated during this study through the use of aerial photograph analysis, local knowledge, and field reconnaissance.

Using landscape ecology principles, we defined and characterized 45 sites within the estuary. The results show that 72% of the estuary's historic tidal wetlands (970 ha) have undergone major site alterations that greatly restrict or alter tidal flows, such as diking and ditching. About 3% (37 ha) have undergone minor alterations like culverted drainages and road crossings; and 25% percent (343 ha) are relatively undisturbed. Unlike more developed estuaries, little of the Nehalem's historic tidal wetland area has been filled.

We prioritized sites for conservation and restoration using ecological criteria, creating five priority groups with nine sites each. The highest priority group comprised 23% of the historic tidal wetland area (310 ha); 13% of the historic tidal wetland area (174 ha) fell into the medium-high priority group. About half the historic wetland area (47%, 638 ha) fell into the medium priority group. The remaining 17% (228 ha) fell into the medium-low or low priority groups.

Products

The following products are provided with this report:

1. **Written report** (paper and PDF formats). Contains background, methods, results, and the following appendices:
   - **Appendix A. Restoration principles.** Principles of tidal wetland restoration.
   - **Appendix B. Restoration approaches.** General recommendations for restoration in Oregon's tidal wetlands south of the Columbia.
   - **Appendix C. Site ranking tables** (excerpted from Excel spreadsheet, n_tidalw.xls):
     - Table C1: Site rankings, sorted by ranking (top down)
     - Table C2: Site rankings, sorted by site number
   - **Appendix D. Data details (metadata)**
     - Table D1. Data sources
     - Table D2. Key to site information table fields
     - Table D3. Key to plant species codes used in site information table
     - Data limitations
     - Notes on site information table fields
   - **Appendix E. Site information table**, including ranking factor scores and other site details (also contained in Excel spreadsheet described below)
   - **Appendix F. Figures (maps)**
     - Figure 1. Total score
     - Figure 2. Number of landowners
     - Figure 3. Land ownership type
     - Figure 4. Size of site
     - Figure 5. Tidal channel condition
     - Figure 6. Wetland connectivity
     - Figure 7. Salmon habitat connectivity
     - Figure 8. Historic vegetation type (% of site that was historically spruce swamp)
     - Figure 9. Diversity of vegetation classes

2. **Excel spreadsheet of site information** (n_tidalw.xls) containing all attributes in the tidal wetland shapefile.

3. GIS shapefile of study sites (ArcView shapefile: n_tidalw.shp). Metadata are provided with the shapefile.

All of the report components listed above are necessary for accurate understanding of results. If any of the above products are missing, please contact us. Contact information is listed on page 2.

Background

Tidal wetlands of the Nehalem River estuary

The Nehalem River estuary is classified by the Oregon Department of Land Conservation and Development (DLCD) as a Shallow Draft Development estuary (Cortright et al. 1987). Other estuaries in this category include Tillamook Bay, Depoe Bay, Siuslaw River, Umpqua River, Coquille River, Rogue River, and Chetco River. These estuaries are managed for navigation and other public needs consistent with overall estuary management rules (OR Administrative Rules 660-017-0025).

Like many of Oregon's estuaries, the Nehalem is a "drowned river mouth" system, with broad tide flats located low in the system. All of the major types of tidal wetlands in Oregon are found in the Nehalem River estuary, including mud flats, aquatic beds (eelgrass and algae beds, exposed only briefly during lower low tides), emergent marsh (low and high marsh), scrub-shrub wetlands, and forested wetlands. Consistent with statewide methods (Brophy 2005a), this study does not address aquatic bed habitats, for which management issues are quite distinct.

Although the best-known type of tidal wetland is the "salt marsh," tidal wetlands are found throughout the full range of salinities, from the marine salinity zone up to the freshwater tidal zone near head of tide. Many tidal wetlands in the upper estuary (low-brackish or freshwater tidal zone) are scrub-shrub and forested wetlands -- collectively known as "tidal swamps." The upper estuary is the least studied, but contains substantial areas of former tidal wetlands that are now pastures or other agricultural lands. These areas were converted to agricultural use early in the estuary's history, because they are at relatively high elevations and have less frequent tidal flooding compared to tidal marshes in the lower estuary.

The Nehalem watershed supports spawning runs of spring and fall chinook, chum, winter steelhead, and coho (ODFW 2004). As these fish move through the estuary on their way to the ocean, they all use the estuary to acclimate to ocean salinities. Tidal wetlands in the estuary provide opportunities for this osmotic transition, as well as a rich foraging environment.

The Nehalem River estuary has been more closely studied than many other Oregon estuaries. Johannessen (1973) found that sediment deposition on the broad tide flats of Nehalem Bay has led to expansion of low tidal marsh in the bay since the 1850s. Eilers (1975) studied the relationships of tidal marsh plant communities to elevation and tidal influence. A database of potential restoration sites was developed by the Oregon Department of Land Conservation and

Development as part of its Dynamic Estuary Management Information System (DEMIS) project (Crowley 2000), but no report was published from that effort. A recent summary of the Nehalem watershed (Ferdun 2003) included a prioritization of potential tidal wetland restoration sites, using the sites identified in the DEMIS project.

Tidal wetland functions

Tidal wetlands serve many vital functions in the watershed. Some of the most widely recognized functions are included in the HGM (hydrogeomorphic) functional assessment method for tidal wetlands of the Oregon coast (Adamus 2005a). These functions include water quality (sediment detention and stabilization, nutrient and contaminant stabilization and processing), ecological support (food chain support, native vegetation support), and wildlife habitat (habitat for fish, birds, invertebrates, and mammals).

The value of tidal wetland functions may be enhanced by the location of these wetlands in a critical landscape position -- low in the watershed, in an economically important nursery zone for anadromous and marine organisms, and immediately below concentrations of the agricultural and rural residential land uses that can generate warmed, polluted surface waters.

In Oregon, interest in salmon has brought attention to the salmon habitat functions of tidal wetlands. Tidal wetlands are important to salmon population size, diversity and viability. The health of Pacific Northwest salmon populations depends on a continuum of diverse habitats across freshwater, estuarine and marine zones (Simenstad and Bottom 2004). Tidal wetlands are considered crucial link in this chain, providing rearing habitat characterized by a highly productive food web, deep meandering channels for shelter from predators and high velocity river flows, cool water temperatures, and a brackish-freshwater interface for physiological adaptation to marine salinities. These tidal wetland features contribute to accelerated juvenile salmon growth during estuarine rearing, in turn supporting increased ocean survival (Miller and Sadro 2003).

The full value of tidal wetland functions is not generally recognized in our economic system. Costanza et al. (1997) estimated that of all ecosystems on earth, tidal marshes and swamps rank by far the highest in waste treatment (recovery and removal of excess, mobile nutrients), providing a minimum estimated value of $6696/ha/yr for this function. Tidal and freshwater marshes and swamps together form the world's most important environmental "capacitors;" that is, these ecosystems absorb and moderate drastic environmental fluctuations like flooding, storm damage, and drought (estimated value, at least $4539/ha/yr). Tidal marshes are the second-highest ranking ecosystems in the world for food production ($466/ha/yr), habitat and refuge for rare organisms ($169/ha/yr), and recreation ($658/ha/yr). Overall, the ecosystem services valuation of tidal marsh is estimated at a minimum of $9,990/ha/yr, placing it fourth among the highest-valued ecosystems on earth. (The top three ecosystems as ranked by Costanza et al. are open-water estuarine habitats, freshwater swamps and floodplains, and seagrass and algae beds.)

Human uses and alteration types

People have always used Oregon's estuaries intensively. Native Americans built villages on the lowlands near the sea, where easy-to-access waters with abundant fish and shellfish provided food, shelter, and transportation. After European settlement, many estuary lands were filled for towns and industrial sites, diked and converted to agriculture, dredged for navigation, or otherwise altered. Grassy tidal marshes were diked early for pasture. In the tidal swamp zone, trees were harvested and tidal channels blocked so that the lands could be converted to pasture or homesites. Estimates by several experts show that about 70% of Oregon's tidal wetlands have been converted to other human uses (Christy 2004, Good 2000, Boule and Bierly 1987) since the 1850s. However, the rate of change has slowed in recent years. Estuary zoning and wetland protection regulations have helped reduce human impacts to tidal wetlands (Good 1997). Today, many groups are attempting to restore tidal wetlands to their original functions. An example in the Nehalem River estuary is the wetland restoration at Alder Creek Farm.

Estuary-wide alterations

Alterations to estuaries can be site-specific (diking, ditching, etc.) or estuary-wide. Estuary-wide alterations can affect all tidal wetlands in an estuary, even those with no site-specific changes. Examples of estuary-wide alterations include altered sediment deposition patterns; changed peak flows, water circulation patterns, and flooding regimes; water and sediment contamination; impermeable surfaces like urban areas and road systems; and invasive species. Quantifying the effect of such large-scale changes on individual tidal wetland sites is difficult. Consistent with statewide methods (Brophy 2005a), this study addresses only site-specific alterations, but estuary-wide factors should be considered when planning a site-specific restoration project.

Site-specific alterations and their effects on tidal wetland functions

The main types of site-specific tidal wetland alterations on the Oregon coast are dikes, tidegates, ditches, restrictive culverts, fill (including dredged material disposal), road and railroad crossings and embankments, dams, channel armor, excavation, tillage, grazing, driftwood removal, and logging and brush clearing in tidal swamps. Invasive species are another site-specific alteration, though generally not a deliberate one.

Alterations that remove, reduce or redirect tidal flows (***dikes, tidegates, and restrictive culverts)*** cause the broadest impacts to wetland functions. By definition, tidal flows create the unique functions of tidal wetlands, so these three types of alterations reduce, alter or eliminate those unique tidal wetland functions. Wetland changes due to altered tidal flow can include a decrease in tidal channel complexity, shifts in the composition and distribution of vegetation communities, changes in soil biology and chemistry, altered salinity, and altered patterns of sediment erosion and deposition. In many cases, sites where tidal flows have been reduced or eliminated undergo soil subsidence. This is a gradual lowering of the soil surface elevation caused by soil compaction, decomposition (oxidation) of organic plant material in the soil, and loss of buoyancy when tidal influence is removed (Frenkel and Morlan 1991). Many of Oregon's diked tidelands have undergone 2 to 4 feet of subsidence.

Sites that are no longer tidally influenced because of human alteration may still be wetlands, and may still perform many wetland functions. Freshwater wetlands often develop in diked areas, due to soil subsidence and impeded freshwater drainage. However, many of the original functions (such as salmonid habitat and osmotic transition zones) may be greatly reduced or completely lost.

Even where tidal flows are still present, human alterations can strongly affect tidal wetland functions. ***Ditches*** change tidal flow patterns, inundation regimes, and channel morphology, affecting nearly all tidal wetland functions. For example, ditches are usually shallower and broader than natural tidal wetland channels, creating warmer water conditions that reduce habitat value for juvenile salmon. Ditches speed water flow off a site, reducing duration of inundation and diminishing wetland area. ***Road and railroad crossings*** can greatly affect water flow patterns by blocking channels and redirecting or impeding both subsurface flows and "sheet flow" (nonchannelized surface flow). ***Tillage*** and ***grazing*** compact soils, contribute to erosion of channel banks, and reduce vegetation diversity and wildlife habitat. ***Channel armor*** and ***riprap*** reduce vegetation diversity and channel shading, eliminate "edge" foraging for salmon and other aquatic organisms, and can cause erosion in adjacent areas. ***Excavation, fill*** and ***dredged material disposal*** change site elevations, inundation regimes, water flow patterns, and soil biology, altering the many wetland functions that depend on these basic physical characteristics of tidal wetlands. ***Logging*** and ***driftwood removal*** directly reduce wildlife habitat, alter productivity and food webs, and reduce channel shading. ***Invasive species*** can completely alter the character of a tidal wetland. For example, smooth cordgrass can convert a former mud flat into a low marsh, greatly reducing shorebird habitat functions.

Restoring tidal wetland functions

Tidal wetland restoration generally focuses on removal of human alterations. Dikes can be breached or removed; tidegates can be replaced with fish-friendly models or self-regulating gates which remain open except during extreme high tides. Restrictive culverts can be upgraded to allow free exchange of tidal flow. Ditches can be filled, and meandering channel remnants reconnected. Removal of human alterations is the most practical restoration approach, often the most economical, and generally the approach with the highest chances of success (Simenstad and Bottom 2004, Mitsch 2000).

The goal of removing human alterations is to re-establish the natural forces that create tidal wetlands. These natural forces (tidal flows, sediment deposition, and so on) are necessary for the return of tidal wetland functions over time (see **Restoration Principles,** Appendix A).

Restoration of tidal flow is the most important component of tidal wetland restoration design, but other restoration techniques may be needed, such as restoration of freshwater flow, removal of invasive species, planting of woody (tidal swamp) species, and meander restoration to carry tidal flow throughout a site. Table 7 in **Restoration recommendations** at the end of this report shows potential restoration actions corresponding to site alterations. Other details are provided in Appendix B, **Restoration approaches.**

Methods

This study prioritized tidal wetland sites for conservation and restoration, using existing data, aerial photograph interpretation, field reconnaissance, and local knowledge.

Information sources

We located and described tidal wetland sites by using publicly accessible data, local knowledge, and new information from aerial photograph interpretation and field reconnaissance (generally from offsite vantage points). Site characterization was conducted during 2003-2004. Table D1, Appendix D summarizes the existing data sources used; further details on data sources and methods are found below.

We used geographic information systems (GIS) software to organize, analyze and display data for this study. GIS data came from a variety of publicly available sources (Table D1, Appendix D). The GIS database included landforms, elevation, wetland inventories, soil type, historic vegetation, habitat type, salmon distribution, hydrography, salinity, land ownership, and urban areas mapping.

This project's map of tidal wetland sites was developed from 1:24,000 scale National Wetland Inventory maps. Using the information described above, we merged and split the NWI mapped wetlands to create analysis units (sites) that met this project's needs (see **Site definition** below). We included only those NWI wetlands that appeared to be current or former tidal wetlands based on available information.

We characterized sites using aerial photographs, field reconnaissance, local knowledge, and other sources. Color infrared aerial photographs taken in May 2001 (1:24,000 scale) were obtained from the U.S. Army Corps of Engineers. Interviews with local residents and other regional experts provided a historical context and other details for individual sites and for the estuary as a whole. The Lower Nehalem Watershed Council organized several meetings for landowners and the public, at which we presented information about this project and gathered input from local residents. Input included both information about the estuary, and concerns about watershed issues. The information gathered is contained in this report. We also used field observations (generally from offsite vantage points) to determine current site conditions. A few sites were visited with landowner permission.

Site characterization included identification of alterations to historic tidal wetlands. Alterations identified in the Nehalem River estuary included dikes, ditches, culverts, tidegates, and excavation. Two other alteration types that are widespread in the Nehalem River estuary are logging and grazing. We did not evaluate logging and grazing separately, for two reasons. First, grazing is usually accompanied by structural alterations (diking, ditching, and culverting). Tidal wetland restoration in diked or ditched pastures usually consists of removing those structural alterations to restore tidal flow, and cessation of grazing generally accompanies structural restoration. Second, logging is difficult to detect using current aerial photographs; widespread logging preceded the earliest historic photographs available for the Oregon coast. Impacts from logging and grazing are best addressed during site-specific restoration design; some suggestions are found in **Restoration approaches** below.

Site definition

To provide strategic guidance for tidal wetland restoration and conservation, we defined analysis units called "sites." In general, a site is a contiguous wetland area with internally connected water flow (internal hydrologic connectivity), a homogeneous level of alteration, and consistent land use history. The goal of site definition was to provide an action planning tool that recognizes the ecological importance of large contiguous blocks of wetland, while still providing units of small enough size to be practical for taking action. Land ownership in itself was generally not used to define sites, but since different landowners often use the land differently, site boundaries often follow ownership boundaries.

Sites within the Nehalem River estuary were numbered from 1 through 47; there were no sites numbered 13 or 14. Site numbers were created in sequence as sites were defined, and site numbers have no relationship to site locations in the estuary. Each map (Figures 1 through 9) shows site numbers in boxes with pointers to the sites.

Prioritization method development and review

The prioritization method used in this study has been extensively reviewed and tested, and follows statewide standards. The Lower Nehalem Watershed Council's technical team reviewed the method during its implementation in the Nehalem River estuary to ensure it met local needs. Development of the Estuary Assessment module of the OWEB Watershed Assessment Manual (Brophy 2005a) was based on the methods used in this prioritization, as well as our prioritizations in the Umpqua River and Siuslaw River estuaries (Brophy and So 2005a, 2005b; Brophy 2005b). The OWEB manual method was reviewed by a team of regional experts in tidal wetland ecology and restoration.

Restoration sites vs. conservation sites and joint prioritization

This study, like the statewide method (Brophy 2005a), prioritizes restoration sites and conservation sites jointly. The goal of our prioritization method is to identify areas of high current or potential ecological function, and this goal is best accomplished by considering all sites together. Although prioritizing conservation and restoration sites separately might seem advisable, in reality every estuary presents a continuous spectrum of degree of alteration. Many sites are altered and offer restoration opportunities, but also currently provide substantial wetland functions. Many relatively undisturbed sites offer some restoration opportunities, such as improved culverts on the upslope side or removal of introduced (non-native) species.

Even though restoration and conservation sites have been prioritized jointly, the site information table (Appendix E) can be used to develop separate conservation and restoration action plans. For example, to develop an action plan for conservation of existing high-functioning tidal wetlands, select the highest-ranking wetlands that have no alterations listed in the site information table. To develop a restoration action plan, select the highest-ranking wetlands that have alterations shown.

Prioritization criteria

The following ecological criteria were used to prioritize sites:

1. Size of site
2. Tidal channel condition
3. Wetland connectivity
4. Salmonid habitat connectivity
5. Historic wetland type
6. Diversity of vegetation classes

Each site was scored for each of these criteria on a consistent scale, so that all criteria were equally weighted. The criterion scores were summed for a total site score, which represents a site's likelihood of contributing to tidal wetland functions in the estuary. After scoring, the sites were grouped into five priority categories: High, medium-high, medium, medium-low, and low (Figure 1). These rankings are intended to provide a broad perspective and help guide decisions. **The rankings should not be used to eliminate any site from consideration for restoration or conservation actions. In other words, all tidal wetlands are important**; prioritization is simply a way to focus action planning on sites where the return on conservation or restoration efforts may be the greatest.

Non-ecological criteria, such as number of landowners, landowner type, and proximity to urbanization also affect restoration decision-making. These factors are addressed in the "Supplemental Analyses" section below.

Table 1 shows a summary of the criteria used to prioritize sites, the data sources, and the scoring levels for each criterion.

Table 1. Summary of prioritization criteria

Factor	Data source	Description	Levels
Size of site	Map of sites	Size in hectares. Threshold size for including a site is 1 ha.	Convert full range of values for study area to scores of 1 (smallest) to 5 (largest).
Tidal channel condition	Aerial photograph interpretation	Observe aerial photographs for visible tidal flow restrictions, ditching, and dikes.	Scale of 1 to 5 (1= poor channel condition/tidal exchange; 5=good condition, full tidal exchange). See scoring categories in text.

Factor	Data source	Description	Levels
Wetland connectivity	National Wetland Inventory, Estuary Plan Book Habitat types mapping	Total area of other wetlands (emergent, scrub-shrub, and forested wetlands, plus EPB-mapped eelgrass and algae beds) outside site and within 1 mile buffer around center of site.	Convert full range of values for study area to scores of 1 (smallest area) to 5 (largest area).
Salmonid habitat connectivity	Oregon Dept. of Fish and Wildlife salmon habitat mapping	See components of salmonid habitat connectivity score below (Table 2)	See Table 2.
Historic wetland type	Oregon Natural Heritage Program historic vegetation mapping	Proportion of site that was historically spruce swamp	Convert full range of values for study area to scores of 1 (smallest proportion) to 5 (largest proportion).
Diversity of current vegetation types	National Wetland Inventory/Aerial photograph interpretation	Number of Cowardin vegetation classes (emergent, scrub-shrub, forested wetlands) mapped on site.	One Cowardin class = score of 1 Two Cowardin classes = 3 Three Cowardin classes = 5
TOTAL SCORE			Add all 6 criteria scores (maximum possible score = 30; minimum possible score = 6)

Table 2. Components of salmon habitat connectivity factor

Factor	Data source	Description	Levels
Number of salmonid types spawning upstream	Oregon Dept. of Fish and Wildlife salmon habitat mapping	Number of salmonid types (species-run combinations) spawning upstream of site in stream system feeding site (main stem or tributary). Range: 0 to 5.	Convert full range of values for study area to scale of 1 (0 stocks) to 5 (5 stocks).
Distance to spawning	Oregon Dept. of Fish and Wildlife salmon habitat mapping	Average distance from site to nearest ODFW mapped spawning and rearing habitat (averaged over all salmonid types).	Convert full range of values for study area to scores of 1 (longest distance) to 5 (shortest distance). Take average of 5 salmonid type scores for each site. NOTE INVERSE SCORING.
TOTAL			Add both salmon habitat connectivity scores and rescale to a range of 1 to 5.

Figure 1 shows the results of the prioritization; see **Results and discussion** for details and interpretation.

Size of site

Site size is recognized as an important factor in wetland prioritization methods (White et al. 1998; Schreffler and Thom 1993; Lebovitz 1992; Brophy 1999; Costa et al. 2002). The size of a wetland is closely related to the level of functions it provides. All other factors being equal, bigger is better when it comes to providing ecosystem services. The science of biogeography (McArthur and Wilson, 1967) has established that larger sites are more self-sustaining, have higher diversity of plant and animal species, and have greater ability to buffer against outside pressures and disturbances such as pollution and invasive species. Larger sites can also present an efficiency of scale, reducing the per-acre cost of restoration.

Site size in hectares was calculated using the site maps. The threshold for including a site in this study was one hectare. Site size was rescaled to obtain a size score ranging from 1 (smallest site in study area) to 5 (largest site in study area). Figure 4 shows the results of the site size scoring.

Tidal channel condition

Channel morphology and tidal connectivity are important indicators of tidal wetland function and overall hydrologic condition. Site alterations such as ditching, diking, tidegates, restrictive culverts, and roads impede or prevent tidal flow and alter tidal channel structure, resulting in lower channel complexity and shorter total channel length. Highly altered channels and blocked tidal flow reduce tidal wetland functions, and also make restoration more difficult and expensive.

Remnant channels were considered in the channel condition score, since their presence may indicate a lower level of alteration and potentially faster return of functions after restoration. In addition, sites with prominent remnant channels may require only relatively low-cost restoration methods (such as grazing setasides) to return to full wetland functions. More highly altered sites, by contrast, may be require more expensive and technically complex restoration techniques such as dike breaching, ditch filling, and excavation of tidal channels.

Aerial photographs and offsite field reconnaissance were used to determine whether a site within the tidal zone had high (good), medium or low (poor) channel condition. Human alterations to tidal exchange (blockages like dikes and tidegates) were also considered in evaluating this criterion. Channel condition and tidal flow blockages were generally visible in aerial photographs, either directly (visible ditching, diking, tidegates, etc.) or indirectly as a change in the appearance of channels or vegetation compared to undisturbed areas. The categories for this factor are defined as follows:

1. Limited or no tidal exchange, heavily ditched: The site is either no longer hydrologically connected to the estuary and receives no tidal influence, or it is hydrologically altered but still allowing some amount of tidal flow to the interior of the site, either through a leaky tidegate or culvert or through small breaches in the dike. A combination of dikes, ditches, tidegates, culverts and other hydrologic barriers affect the site. Few or no remnant meandering channels are visible. Score = 1

2. Limited tidal exchange, not heavily ditched: The site has been hydrologically altered, but either that alteration is minimal (such as a bridge or nonrestrictive culvert), or events such as dike breaches, tidegate failure, or tidegate removal have allowed partial reestablishment of tidal flow. The site is not ditched; tidal flow is carried in meandering channels. Score = 3

3. Tidal flow intact (or existing tidal wetland restoration site): Air photo interpretation and field reconnaissance reveal no obvious signs of hydrologic alteration. The site is relatively undisturbed with sinuous, meandering tidal channels. Score = 5

Figure 5 shows the results of the classification of tidal channel condition.

Wetland connectivity

In landscape ecology terms, connectivity (spatial connection of habitats to one another) is the opposite of fragmentation (isolation of habitats). Sites with good wetland connectivity – those located near other wetlands and connected via stream or narrow wetland corridors – can perform many of their functions better, compared to isolated wetlands (Amezaga et al. 2002, Adamus 2005a, Adamus and Field 2001). If a particular wetland is disturbed, the creatures that depend on it for shelter and livelihood may need to move to another nearby wetland. Mobile species such as anadromous fish, shorebirds, waterfowl, and native landbirds and mammals often feed and rest in several wetlands, so a single isolated wetland does not serve their needs. For many species, interconnected wetlands offer important opportunities for juvenile dispersal. Interconnected wetlands of different salinity regimes (e.g. salt, brackish and freshwater wetlands) offer juvenile salmon the opportunity to gradually adjust to ocean salinities before migrating to the sea.

Wetland connectivity also buffers environmental change. Each type of tidal wetland occupies a specific elevation range relative to sea level, but sea level itself is slowly changing. Land uplift and subsidence due to tectonic activity are fairly rapid in places; for example, Cape Blanco is estimated to be rising at a rate of about a foot every 100 years (Komar 1998). At the same time, the world's sea level is also rising, though land uplift is generally keeping up in Oregon. However, periodic earthquakes can change this relationship radically; the earthquake of 1700 caused a subsidence of about 3 feet in the land surface across much of the Oregon coast (Komar 1998). Adding to these geologic scale changes, human activities may also have caused major changes in the location of head of tide in some estuaries. For example, head of tide in the Coquille River estuary appears to have shifted about 4 miles downstream since the 1850's (Benner 1992). Because of these current and potential changes, wetlands that are well-connected to a range of other wetland types at different elevations were prioritized in this study.

NWI-mapped wetlands in the emergent, scrub-shrub, and forested wetland classes were considered together with Estuary Plan Book (EPB) mapped eelgrass beds (EPB attributes 1.3.9 and 2.3.9) for this analysis. Eelgrass beds were included in the connectivity criterion because of their importance as habitat for invertebrates, anadromous and other fish, shorebirds, and waterfowl (Phillips 1984, Rozas and Odum 1987). To determine connectivity, the total area of EPB- and NWI-mapped wetlands within a one-mile buffer around each site was calculated.

Figure 6 shows the results of the wetland connectivity analysis.

Salmonid habitat connectivity

The Nehalem watershed supports spawning populations of coho, chum, winter steelhead, and fall and spring chinook salmon. All five of these anadromous stocks must migrate through the estuary; therefore, all tidal wetland sites within the estuary could potentially provide salmonid habitat functions. In order to discriminate between relative levels of importance in terms of fish use, we scored sites on their connectivity to salmon spawning habitat. The connectivity metric was composed of two subscores: 1) **Number of salmonid stocks spawning upstream**, and 2) **Distance to spawning** (Table 2).

Our source data for this analysis was the Oregon Department of Fish and Wildlife 1:100,000 scale salmon distribution mapping (ODFW 2004). Since ODFW data are not available for sea-run cutthroat, cutthroat were not considered in the analysis. The number of stocks spawning upstream of each site was determined from the ODFW data, and distance to the nearest ODFW-mapped spawning and rearing habitat was determined using GIS network analysis. (Spawning and rearing habitat is defined by ODFW as habitat where "eggs are deposited and fertilized, where gravel emergence occurs, and where at least some juvenile development occurs.") The range of distances within the study area was rescaled to a range of 1 to 5 for each stock's score, and scores for all stocks were averaged for the final distance to spawning score. The final **salmonid habitat connectivity score** was obtained by averaging the two subscores (number of salmonid stocks, and distance to spawning).

The salmonid habitat connectivity score is not intended to evaluate actual use levels. Salmonid use of Oregon tidal wetlands is currently being actively investigated, with much new information being generated (e.g., Bottom et al. 2004). To help address the many unknowns in salmon use of tidal wetlands, we selected prioritization criteria that would have broad influence over use levels, such as site size, channel condition, and wetland connectivity.

The results of the salmon habitat connectivity scoring are shown in Figure 7.

Historic vegetation type

We use the term "historic vegetation type" to mean the type of wetland vegetation that was present on a site prior to human alteration. For this analysis, "type" means Cowardin cover class. The three Cowardin cover classes are emergent (herbaceous), scrub-shrub, and forested.

A major goal of estuarine restoration is to re-establish the full suite of habitat types that were historically present within the planning area. Simenstad and Bottom (2004) state that "Restoration plans should be designed to restore ecosystem complexity, diversity, and riparian-flood plain connectivity based on the historic estuarine landscape structure." In other words, restoration planning should attempt to restore the "chain of habitats" from headwaters to ocean. This chain is broken when human alterations to the landscape eliminate or greatly reduce a particular habitat type.

In Oregon, one tidal wetland type that has been disproportionately affected by human activity is tidal swamp (forested or scrub-shrub wetland). In the Columbia River estuary, the Youngs Bay, Baker Bay, Grays Bay, and Upper Estuary subbasins lost 80 to 100% of their tidal swamps between the 1850s and 1980s (Thomas 1983); the only subbasin that retained more than 50% of its tidal swamp in the 1980s was Cathlamet Bay. Preliminary estimates for Oregon estuaries south of the Columbia show tidal swamp losses around 90 to 95% since the 1850s, compared to about 70% for tidal marshes (Brophy, unpublished).

Tidal swamps have unique characteristics supporting salmonid habitat functions. In addition to providing the usual benefits of brackish-to-freshwater tidal wetlands -- an osmotic transition zone, a rich foraging environment, and deep, cool channels with overhanging banks for shelter from predators -- tidal forests also have trees and shrubs that provide shade, physical shelter and large woody debris. Woody vegetation, leaf fall, and root masses provide habitat structure and detrital contributions to the food web. Because of these characteristics, and because of their disproportionate losses to development, former tidal swamps were prioritized within this study.

Most of the tidal swamp historically found in Oregon was spruce swamp or tideland spruce meadow, with Sitka spruce (*Picea sitchensis*) as the dominant tree species (Jefferson 1975, Thomas 1983). Nearly all of these swamp areas were cleared early in this century. We used historic vegetation mapping (Hawes et al. 2002, Christy et al. 2001) to locate areas of former tidal swamp. We intersected the historic vegetation layer and the sites layer to determine the proportion of each site that was historically swamp. This proportion was then rescaled to obtain the historic vegetation score ranging from 1 (0% swamp) to 5 (100% swamp).

The results of the historic vegetation type analysis are shown in Figure 8.

Diversity of current vegetation types

Many wetland functional assessment methods use diversity and interspersion of vegetation cover classes as an indicator of functional level (Adamus 2005a, Adamus and Field 2001, Roth et al. 1996). A diversity of cover classes provides a variety of habitat types, resulting in more ecological niches and presumably higher animal species diversity. Cowardin cover classes (Cowardin 1992) were used to define vegetation diversity for this project. The three Cowardin classes included in this study are emergent (dominated by herbaceous vegetation like grasses and sedges), scrub-shrub (dominated by shrubs), or forested (dominated by trees).

To obtain a vegetation diversity score, the NWI layer was intersected with the sites layer. The proportion of each Cowardin class within each site was determined; classes present on less than 10% of a site were excluded since these often represented dikes or road embankments. The total number of cover classes on a site was rescaled to obtain each site's score, ranging from 1 (1 cover class) to 5 (3 cover classes).

Figure 9 shows the results of the vegetation diversity analysis.

Scoring method

Each prioritization factor (criterion) was scored for each site on a scale of 1 to 5. On the scoring scale, 1 represents relatively poor condition and 5 corresponds to the best condition based on this study's prioritization factors. For example, a score of 5 for each criterion would indicate large site size; relatively unaltered channel morhpology and tidal exchange; high wetland connectivity; high salmonid habitat connectivity; high percent historic swamp, and high current vegetation diversity.

For the total score, all six scores were added:

> Total score = size of site + channel condition + wetland connectivity + salmon habitat connectivity + historic wetland type + diversity of vegetation classes

After scoring, the sites were separated into the "ranking groups" shown in Figure 1. These groups provide an easy way of visualizing scores on a map. Five ranking groups were created, with an equal number of sites assigned to each group. Differences of one group (e.g., medium versus medium-low or medium versus medium-high) should not be considered significant, because sites on both sides of the group boundary may have very similar scores. Individual criterion and total scores can be found in the site ranking tables (Appendix C) and in the site information table (Appendix E).

It is important to note that the priority groups and the underlying scores should be used as a **general guide** for action planning, not a final arbiter of the absolute priority or ecological value of each site. To fine-tune action planning decisions, we recommend reviewing the details contained in the site information table and the supplemental data contained in the next section of this report.

Supplemental analyses

Land ownership and proximity to urbanization can strongly affect restoration logistics, timing and opportunities. Through discussion with several watershed councils and other advisors, we decided to use these factors as supplemental analyses, keeping the prioritization focused on ecological criteria. We recommend consideration of land ownership and proximity to urbanization in the next step of action planning (site choice and site-specific planning).

Land ownership

To assist in action planning, we determined the number of major landowners and the type of ownership for each site. The number of landowners at a site can affect the ease of restoration, because the more landowners are involved, the more difficult it can be to coordinate restoration activities. The type of ownership of a site affects decision-making in two different ways. Ownership type (private *versus* public) may influence the potential for loss of a wetland since it influences the likelihood of development. Ownership type may also influence the cost of restoration and the appropriate avenues and strategies for restoration.

Some authors (Lebovitz 1992, Dean et al. 2000) have theorized that land ownership type relates directly to cost or logistical complexity of site acquisition and/or restoration. However, in our experience, there is actually a complex, multidimensional relationship between land ownership type, restoration potential, cost, and other factors. Privately owned sites (particularly those near urban areas) may be under high development pressure, increasing the urgency of both conservation and restoration. Private lands may present greater challenges, but also more diverse opportunities for conservation and restoration, compared to public lands. Many funding sources are limited to use on private lands. Conservation actions accomplished through work with willing private landowners can open doors to community involvement and education. Projects on public lands present very different opportunities and challenges. These projects may involve longer timelines due to public review, and more complex administrative hurdles. Given the complexity of these issues, we decided not to use land ownership in the prioritization scoring.

Land ownership was determined using assessor's maps available online (http://www.gis.state.or.us/data/ormap/statemap.htm) and parcel data from the Tillamook County Department of Assessment and Taxation. A list of tax lots for each site was compiled and used to determine the number of major landowners within a site and the ownership type. Although tax lots for each site were determined as accurately as possible, ownership number and type should be verified when developing site-specific action plans. Also, where roads or railroads cross sites, the landowner layer did not show ownership for the road/railroad right-of-way. It is important to contact appropriate authorities before planning conservation or restoration actions that could affect roads and railroads.

Number of landowners for each site is shown in Figure 2. Land ownership types (based on landowner name) are listed in Table 3 below and mapped in Figure 3.

Table 3. Ownership categories

Factor	Data source	Levels	Description
Ownership category	Land ownership data from County assessor's office	Tribe Federal State Port County City	Specific categories of public ownership
		Private/mixed	Private ownership, or a mixture of public and private ownership

Some high-priority restoration sites have multiple landowners. If some landowners do not want to participate in restoration or conservation of the site, it may be possible to take action on some parcels (sub-areas of the site) without affecting other parcels. The feasibility of such partial restoration or conservation depends on the characteristics of the site.

Proximity to urbanization

We used proximity to the Urban Growth Boundary (UGB) as a simple index of site vulnerability to development pressure. In this context, development pressure means the likelihood of a tidal wetland site becoming converted or lost due to urban development. Sites converted to urban uses are usually filled, and are therefore difficult or impossible to restore. Table 4 describes the data source and levels for proximity to urbanization.

Table 4. Proximity to urbanization

Factor	Data source	Levels	Description
Proximity to urban areas	Urban Growth Boundary mapping from ODOT/DLCD	Outside UGB	Entire site is outside Urban Growth Boundaries
		Inside UGB	Part of all of the site is inside an Urban Growth Boundary

Each site's proximity to the Urban Growth Boundary can be see in Figure 3; we highlighted sites inside or on the boundary in the site information table (Appendix E) in the field "In/On UGB?"

Results and discussion

The final site prioritization is shown in Figure 1. The scores for the six individual prioritization criteria are shown for each site in the ranking tables (Appendix C) and illustrated in Maps 4 through 9. A detailed site information table containing all data used in the prioritization is provided in Appendix E. Narrative descriptions of high-ranked sites are provided later in the Results section. A general discussion of results follows.

Total historic tidal wetland area

We use the term "historic tidal wetlands" to refer to areas that were tidal wetlands prior to European settlement. Historic tidal wetlands include current tidal wetlands, as well as former tidal wetlands that have been converted to nontidal or nonwetland status through human alterations to the landscape.

About 1,350 ha of historic tidal wetlands were identified in the Nehalem River estuary in this study. This figure is 59% larger than the previous estimate of total historic tidal wetland area (Good 2000). The difference is primarily due to the new data generated during this study through the use of aerial photograph analysis, field reconnaissance and local knowledge.

Alterations to Nehalem tidal wetlands

We used aerial photographs, field reconnaissance and local input to determine the types of alterations to historic tidal wetlands. The types of alterations identified in the estuary are shown in Table 7. As described in **Methods** above, we did not attempt to determine whether sites had been altered by logging, since this alteration is common but difficult to detect using aerial photographs.

Table 5 shows the area of historic tidal wetlands affected by different types of alterations in the Nehalem River Estuary. Of the historic tidal wetlands identified in this study, 72% (970 ha) have undergone major site alterations such as diking and ditching. These sites generally have highly altered plant communities – usually non-native pasture grasses and weeds. About 3% (37 ha) have more natural plant communities, but are affected by less-intensive "minor" site alterations like culverted drainages and road crossings. Twenty-five percent of the historic tidal wetlands

(343 ha) are relatively undisturbed and do not have major or minor onsite alterations. The specific alterations identified at each site are listed in the ranking tables (Appendix C) and site information table (Appendix E).

It is important to remember that all tidal wetlands -- even the "unaltered" sites -- are affected by overall estuary changes such as sediment regime changes, water contamination, and large-scale hydrologic alterations caused by human land uses. Due to lack of detailed, site-specific data and information on how such changes affect wetland functions, and in accordance with statewide methods (Brophy 2005a), this study did not address estuary-wide alterations. However, estuary-wide alterations should be considered in site-specific planning.

Table 5. Tidal wetland areas and alterations, Nehalem River estuary.

In this table, sites are categorized by the most intensive alteration type present; alterations are listed in decreasing order of intensity. For example, most diked wetlands are also ditched, so the category "diked" includes wetlands that are diked and ditched. The category "ditched" includes wetlands that are ditched but not diked.

Alteration category	Alteration type	# of sites	Area (ha)	% of total area
Major alterations	Diked		474.3	35.1
	Ditched		495.6	36.7
Total major alterations			969.9	71.8
Minor alterations	Culvert		27.2	2.0
	Road/RR crossing		10.0	0.7
Total minor alterations			37.2	2.8
Unaltered			343.2	25.4
Grand Total			1350.2	100.0

Plant communities are often good indicators of site disturbance or alteration. During field reconnaissance, we observed plant communities from offsite and used the information to help us characterize site alterations. Dominant species that we observed on the study sites are listed in the site information table (Appendix E); also see Appendix D, **Notes on site information table fields** for details. Codes for plant species are found in Table D3 of Appendix D.

Prioritized sites

Figure 1 shows the study sites divided into five ranking groups: High priority, medium-high, medium, medium-low, and low priority. The ranking groups were obtained by dividing the total number of sites into five equal-sized groups, so there are nine sites within each group. Table 6 shows the land area within each priority group. As described in **Methods** above, the ranking groups can be used as general guides for planning conservation and restoration actions in the estuary, but it is important to consider site details as well. Many site details are found in the site information table (Appendix E) and in the **Site narratives** below. Other information must be obtained through further investigations, including onsite assessments.

Table 6. Ranking group area summary

Ranking group	Number of sites	Area (ha)	% of total area
High	9	310.2	23.0
Low	9	35.9	2.7
Med	9	638.2	47.3
Med-High	9	174.0	12.9
Med-Low	9	192.0	14.2
Grand Total	45	1350.2	100.0

In the Nehalem River estuary, most of the high-priority sites are located near the confluence of the North Fork and the mainstem. This area was historically a forested tidal wetland (spruce swamp), and wetlands in this zone have good connectivity to other wetlands and to salmon spawning areas. The high-priority sites are individually described in the site narratives below.

The next step: Landowner outreach and site-specific planning

This prioritization is a first step in strategic planning for conservation and restoration in the estuary. The next step in action planning involves outreach to find those landowners interested in restoring or conserving the identified sites. Once willing and interested landowners are located, a variety of site-specific activities can begin, including preliminary onsite assessment visits, verification of land ownership boundaries, monitoring to determine current conditions, regulatory contacts to determine required permits, archaeological investigations, and many other steps to maximize the chances of successful action.

More detailed guidance for landowner outreach and site-specific planning can be found in Appendices A and B, Brophy (1999), and Brophy (2005a), as well as many technical documents related to tidal wetland restoration such as Simenstad and Bottom (2004), Zedler (2001), and Schreffler and Thom (1993).

Lower-priority sites are important, too

Although this study prioritizes sites to assist in conservation and restoration planning, **no tidal wetland is unimportant**. Conservation of all existing tidal wetlands is recommended, because the majority of tidal wetlands in the estuary have been converted to other uses, and those being restored may take decades or more to recover their original functions (Frenkel and Morlan 1991). Similarly, restoration of all tidal wetlands is important. A "low" priority ranking in this project does not mean that the low-ranked wetland is ecologically unimportant, nor does it imply that the site should be given reduced protection in a regulatory context. As discussed above, this study has no regulatory significance or intent. It is intended only to provide a strategic approach to conservation and restoration of tidal wetlands in the estuary.

Restoration recommendations

Planning restoration for altered sites is a technically demanding task. Some principles and general recommendations are provided in Appendices 1 and 2, **Restoration Principles** and **Restoration Approaches**. Additional guidance is found in the Oregon Watershed Assessment Manual's Estuary Assessment module (Brophy 2005a) and in other resources listed there.

This study does not provide site-specific restoration design recommendations, because additional data from field monitoring are needed to develop restoration plans. However, **for all sites, the top priority for site action is protection of existing wetlands.** After that is accomplished, further action may be taken to restore resources (see Table 7).

Tidal wetland restoration generally focuses on restoring tidal flow; this is the highest priority action for sites where tidal flow is restricted. For grazed sites, an important restoration option is simply removal of grazing or setback of grazing from the wettest areas (including channels). For every site, riparian plantings should be considered in portions of the site where the elevation is appropriate for growth of shrubs or trees. Woody plantings are often appropriate on natural levees, along interior tidal channels (which often have their own natural levees), and along the upland edge of the site. All sites would also benefit from protection or establishment of a native vegetated buffer around the margins of the site. Many sites in the study area already have such a buffer, but some do not.

The choice of restoration methods depends on the alterations present at each site. Alterations observed in the estuary are listed in the column "ALTTYPE" in the site information table (Appendix E). Abbreviations and examples of some potential restoration actions for each type of alteration are listed in Table 7 below. Specific decisions among these options (and others) will require careful consideration of site characteristics and restoration goals. Some of the listed restoration actions may be inappropriate for particular sites; only careful onsite assessment can determine the appropriate actions.

Table 7. Restoration options for specific site alterations

Alteration type	Abbreviation	Potential restoration alternatives, from least to most intensive (not a complete list)
Diking	Y	Dike breaching; dike removal; dike setbacks
Ditching	D	Channel meander reconnection; ditch filling; meander restoration
Restrictive culvert/tidegate	C	Tidegate removal; culvert upgrade; installation of fish-friendly tidegate; installation of self-regulating tidegate for tidal exchange up to a preset maximum water level; replace restrictive culvert with bridge
Road/railroad crossing	R	Culvert upgrade; install bridge; raise road/railroad on causeway; realign road/railroad and remove fill
Grazing	(not separately listed)	Pasture management; riparian fencing and plantings; remove livestock (Note: Grazing is not separately listed as an alteration in the site information table)

Alteration type	Abbreviation	Potential restoration alternatives, from least to most intensive (not a complete list)
None	N	No restoration action needed, but protect existing wetland, establish buffers, plant trees/shrubs where appropriate in former swamp areas or on natural levees

Beyond the site-specific actions listed above, it is important to consider conservation and restoration of nontidal wetlands and other habitats near the tidal sites in this study. The most effective conservation and restoration projects are those which protect or restore habitat linkages and connections (see Appendix A, **Restoration Principles**). The slightly-brackish to freshwater tidal zone of the estuary may offer particularly high habitat values (Simenstad and Bottom 2004), so linking sites in this zone to adjacent nontidal wetlands may offer great benefits.

Archaeological sites

Before European settlement, Oregon's estuaries were widely used by Native American peoples for dwelling and gathering places and a source of livelihood. Therefore, every estuary restoration project should be conducted with awareness that there may be archaeological sites within or near the project area. State and federal laws prohibit destruction or disturbance of known archaeological sites. In the case of inadvertent discovery of cultural resources, state and federal laws require that the project be halted and the appropriate Tribe be contacted immediately. To understand the historic and cultural context of each site, and to avoid possible impacts to cultural resources, we recommend early consultation with the Tribes for the Tillamook County area. Contacts are the Cultural Resource Department of the Confederated Tribes of Grand Ronde (Khani Schultz, 503-879-2185); and Robert Kentta, Cultural Specialist at the Confederated Tribes of Siletz (541-444-2532).

Natural levees and sediment deposition

Sediment deposition during high river flows can lead to the formation of "natural levees" along riverbanks. Natural levees are common features of the estuary; they are created gradually through repeated sediment deposition each time a flooding river overtops its bank. The sudden decrease in velocity as the flow crosses the bank causes deposition of coarse sediments on the top of the riverbank. Natural levees are further described in the OWEB Estuary Assessment module (Brophy 2005a).

Natural levees are easily confused with dikes or filled areas, but it is important to distinguish between these features in order to develop appropriate restoration plans. Tidal wetland restoration often involves removal or breaching of manmade dikes, but natural levees should generally be left in place. In this study, we used field experience, aerial photograph interpretation, and published information to identify dikes as site alterations and distinguish them from natural levees. Characteristics like slope profile, vegetation, and soil disturbance were used to identify likely dikes. Sites where the existence of a dike was possible but could not be determined in this study are noted in the site information tables (field "ALTTYP" includes the abbreviation "Y?").

Site narratives

In this section, we provide brief narratives describing the highest-ranked sites in the study area, and some other sites of interest. This information may be important for decision-making, and should be reviewed before contacting landowners or taking other actions in the estuary. **For all of these sites, the highest priority action is conservation of the existing wetlands.** Other potential actions are described below and in **Restoration recommendations** above.

Site 9 (Dean's Marsh): This site is located on the north side of Nehalem Bay, just north of West Island. The native high and low marsh habitats that are found here are described by Eilers (1975). This site is unaltered except for hydrologic effects of adjacent alterations such as the dike around Site 46, and the earthen dam between sites 9 and 7 (which has been breached). Conservation of the existing wetlands is the highest priority for this site. In addition, this site is hydrologically connected to Sites 15, 43, 44, and 46; conservation and restoration actions taken at those sites will enhance the functions of this high-priority site.

Site 16: This island is located adjacent to the City of Nehalem. Most of the island is forested, with Sitka spruce dominant. The forested areas are classified in the NWI as tidally-influenced forested freshwater wetland (i.e., tidal swamp). Tidally-influenced forested wetlands are now very rare in Oregon, so their conservation is a high priority. The degree of tidal influence within the forest on the island could not be determined in this study; field evaluation is recommended.

Site 18: This site and Site 35 were the two highest-ranking sites in this study, and because of their substantial size, they are sites of statewide significance. Conservation of the existing wetlands at both sites is a very high priority. Site 18 consists mainly of tidal swamp, with some emergent tidal marsh at the mouth of the main tidal channel. The site is located at the confluence of the North Fork and the mainstem Nehalem River. Tidal swamp is very rare in Oregon, so conservation is a high priority here. Study of this site's hydrology, soils, plant communities, and wildlife would provide very valuable scientific information, as it is one of very few remaining tidal swamps of substantial size in Oregon.

Site 20: This relatively small island scored high for all of the prioritization factors except size. It is well connected to salmon spawning and other wetlands, has moderately diverse vegetation, is unditched, and was historically a Sitka spruce swamp. The site currently lacks spruce, probably due to logging and/or grazing in the past. Conservation of the existing wetlands is the first priority for this site. Another logical restoration action here would be to plant spruce and other appropriate shrubs (e.g. black twinberry, Pacific crabapple) where the hydrology is appropriate.

Site 29: This site has characteristics similar to Site 20. It was historically Sitka spruce swamp, and some of it remains forested – a high priority for conservation. Tidegates at the mouth of the slough just south of the site have greatly reduced tidal exchange. Other alterations include a dike along the North Fork on the south part of the site, and ditching of some of the drainages on the northwest portion. Thus, a wide variety of potential actions are available for this site, including conservation of the existing wetlands, particularly the forested area; dike removal; tidegate removal or modification; and reconnection of drainages to their historic meanders. Tidegate removal would also affect Sites 30 and 31 – see discussion in Site 30 below.

Site 30: This site is the only substantial scrub-shrub wetland in the Nehalem River estuary. Oregon Natural Heritage Program historic vegetation mapping shows the whole site as spruce swamp, but spruce is now present only on the north half of the site, which appears to be drier than the south half. The change to scrub-shrub wetland on the south half of the site is probably due to hydrologic changes caused by the tidegates downstream, ditching, culverts, changes to drainage caused by the road to the east, and other on or off-site hydrologic modifications.

Conservation of the existing wetlands is the first priority here. In addition, restoration potential exists. Removal or modification of the tidegates at the mouth of the slough between Sites 29 and 31 would restore tidal flow to the site. However, tidegate changes or removal would also affect the farm land to the west (Site 31). A possible solution might lie in removal of the large tidegates at the mouth of the slough and installation of smaller tidegates at strategic locations on sites 29 and 31. Such an approach might allow preservation of agricultural use while also allowing restoration of tidal flow to the forested and shrub swamps on Sites 29 and 30. Additional technical information is required before considering such a restoration approach, in order to protect existing land uses. This information would need to describe site hydrology, elevations, and potential tidal range, among other factors.

Site 32: Located at the mouth of Anderson Creek, this site is a remnant spruce swamp, a very rare plant community in Oregon (Kagan et al. 2005). One of the site's two major drainages is ditched (along the road that crosses the site). Tidal exchange is somewhat restricted where the road crosses the main tidal slough, which has probably affected the site's ecosystem. Despite this restriction, the site remains a very valuable resource, due to the rarity of its plant community. Conservation of the existing wetlands is the top priority. Field evaluation of the nature of the tidal restriction is recommended. Depending on the degree of restriction, restoration action might include installation of a larger culvert or bridge to improve tidal exchange.

Site 34: This site consists of tidal marsh and pasture on the west bank of the North Fork, just above its confluence with the mainstem Nehalem River. The site's tidal channels have been ditched. Although the site appears to be undiked, tidal flow may be somewhat restricted at the mouths of the tidal ditches. The site was historically spruce swamp, so trees were probably removed early. As for all former tidal wetlands, restoration potential depends on site elevation, tidal influence, freshwater input and hydrology, soils, and many other factors. If the ditched tidal channels were tidegated in the past, the resulting hydrologic alteration could have caused subsidence, which could affect restoration potential. Some woody vegetation (willows, black twinberry) is currently developing on the site, indicating that it may be possible to re-establish the forested tidal habitat that once existed here.

Site 35 (Coal Creek Swamp): This site and Site 18 were the two highest-ranking sites in this study, and they are sites of statewide significance. Conservation of the existing wetlands at these sites is a very high priority. This site is also prioritized for conservation in Ferdun (2003). According to Christy (personal communication), this site is a relict stand of undiked coastal tidal swamp. Sitka spruce swamp is a rare plant community in Oregon; the Oregon Natural Heritage Program describes it as "Critically imperiled because of extreme rarity" (Kagan et al. 2005).

Study of this site's hydrology, soils, plant communities, and wildlife would provide very valuable scientific information that would help guide restoration in many other locations.

Notes on some lower-priority sites mentioned in other reports:

Site 4: This site is a tidally-influenced deflation plain wetland; tidal influence is limited to the lower section. The freshwater deflation plain wetland extends beyond the zone of tidal influence. The wetland areas (both tidal and nontidal) have typical native plant communities that show no sign of site alterations. However, recent aerial photographs show some ponding at the north end of the site which could be the result either of site manipulation (grading) or natural sand movement. The site is shown as a potential mitigation site in the Estuary Plan Book (Cortright et al. 1987), with suggested restoration consisting of removing logs at the tidal inlet and grading the site to increase tidal flows. These recommendations are repeated in the DEMIS report (Crowley, unpublished) and in Ferdun (2003). **Unless there is documented evidence that the site was filled or graded in the past, we recommend that action here be limited to conservation of the existing wetlands in their current condition.** Site grading could greatly reduce existing wetland functions and would damage native plant communities. If past site manipulation is documented, we recommend designing a restoration plan that reverses past alterations but does not alter the remainder of the site. It's worth noting that grading the general surface of a site to increase tidal influence does not qualify as restoration unless the site was previously filled (see Restoration Principles, Appendix A). Such grading would be classified as conversion of one wetland type to another.

Site 44 (Alder Creek Farm): Wetland and riparian habitat restoration is underway at Alder Creek Farm (www.http://www.nehalemtrust.org/1%20LandAcquisition/AlderCreekFarm.html). Although this site is not prioritized in this study, it offers an excellent opportunity for restoration of the full range of habitats along the gradient from tidal marsh up into tidal swamp, freshwater swamp, and finally upland. Historically, the southwest portion of the site was a coastal sphagnum bog, which is a very rare plant community on the Oregon coast. Site 44 is located next to one of the highest-priority sites in the study (Dean's Marsh). Because of the excellent connectivity to Dean's Marsh (via Alder Creek), restoration at Site 44 has the potential to add substantially to the existing wetland functions at Dean's Marsh.

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Appendix A. Restoration principles

Tidal wetland restoration is most likely to be successful if it follows basic principles of restoration design. The titles of the following principles are taken directly from the document, “Guiding ecological principles for restoration of salmon habitat in the Columbia River Estuary” (Simenstad and Bottom, 2004). The discussion of each principle is tailored to reflect concerns specific to Oregon estuaries south of the Columbia River. These principles should be carefully incorporated into every restoration project.

Protect first – restore second

The most immediate need for every current and former tidal wetland site in Oregon is protection of existing wetlands. This is particularly true for unaltered sites, but must also be considered for every altered site. Many former tidal wetlands are currently freshwater wetlands, and many are partially tidal (“muted tidal”) wetlands. Restoration should not result in a net loss of wetland area or functions.

To conserve existing wetlands, the water sources, flow restrictions, and potential hydrologic effects of restoration actions must be carefully considered. In particular, freshwater wetlands formed by impoundment behind a tidal flow restriction (tidegate or restrictive culvert) should be carefully analyzed to determine the likely effects of removing the tidegate or upgrading the culvert. Tidal range outside the restriction must be compared to site elevations within the freshwater wetland, to ensure that restoration will in fact restore tidal wetland and not merely drain the current freshwater wetland.

Do no harm

The Natural Resource Council (1992) defines restoration as "Return of an ecosystem to a close approximation of its condition prior to disturbance.” According to the NRC, “Restoration is ... a holistic process not achieved through the isolated manipulation of individual elements.” It is important to avoid manipulations that may harm existing wetland functions or prevent recovery of original functions. For example, some tidal wetland restoration projects have included construction of features (such as excavated ponds) that would not have been found in the original, pre-disturbance wetland. Pond excavation may provide more waterfowl habitat (a valued function), but may decrease foraging habitat and protective shelter for juvenile salmon. Excavation of ponds may also prevent recovery of the original site hydrology, and may alter associated functions such as nutrient processing and water temperature moderation.

Use natural processes to restore and maintain structure

Tidal wetlands are created by natural processes. The most distinctive and basic of these is tidal flow; others include freshwater input, and deposition of sediment and detritus. The goal of restoration is to re-establish these natural processes where they have been altered by human disturbance. Restoration is generally more successful, more sustainable, and more cost-effective when it uses natural processes rather than engineered solutions (Simenstad and Bottom 2004; Mitsch 2000).

Restore rather than enhance or create

Enhancement is "the modification of specific structural features of an existing wetland to increase one or more functions based on management objectives, typically done by modifying site elevations or the proportion of open water" (Gwin et al. 1999). Gwin goes on to state that "Although this term [enhancement] implies gain or improvement, a positive change in one wetland function may negatively affect other wetland functions." Enhancement should not be implemented if it results in a net loss of wetland functions or detracts from the main goal of restoration: to re-establish site conditions that existed prior to disturbance.

Wetland creation means making a wetland where one did not previously exist. By definition, wetland creation sites lack the natural processes that normally create tidal wetlands, so a much higher level of site manipulation is required to attempt to replicate those natural processes. Wetland creation is often unsuccessful and unsustainable, particularly in the long term, because it relies on human intervention and engineering rather than pre-existing natural forces (Mitsch 2000).

Incorporate salmon life history

Current research is rapidly expanding our knowledge of how salmon use Oregon's tidal wetlands, but our knowledge base is still very limited. To restore tidal wetlands for salmon habitat functions, a landscape approach is needed, focusing on connectivity of habitats and restoration of the full continuum of habitats needed by rearing and migrating juveniles. Experts have suggested that the slightly brackish (oligohaline) zone of the estuary may be particularly important for osmotic transition, and may need to be strategically targeted for restoration (Simenstad and Bottom 2004). The oligohaline zone includes the tidal swamp habitat that is prioritized in this study.

Develop a comprehensive, strategic restoration plan

This study uses landscape-scale analysis and ecological principles to establish priorities for restoration – an approach that has been called "strategic planning for restoration." Strategic planning is preferable to "opportunistic restoration," which selects sites simply because they are available for restoration. Subsequent action planning should continue to address ecosystem issues such as habitat interconnections, the effects of nearby (or distant) disturbance on project sites, and the relative scarcity of different habitats within the study area.

An important example of a strategic approach is combining tidal and nontidal wetland conservation and restoration actions. Sites in this study that have adjacent nontidal wetlands offer particularly valuable opportunities for protecting or restoring vital habitat connections and linkages. Planning for tidal wetland conservation and restoration should include adjacent nontidal wetlands, adjacent upland buffers and connected upland habitats whenever possible.

Use history as a guide, but recognize irreversible change

This study identifies all historic tidal wetlands. While most of the altered sites can probably be restored, some sites may be difficult to restore to their historic wetland type. Subsidence (sinking of the soil surface) can mean that former high marsh and tidal swamp sites may restore to mud flats or low marsh rather than their original habitat types. Subsided sites may slowly return to their original elevations through accretion of sediment, but the process may be very slow (Frenkel and Morlan 1991).

Besides site-specific changes like subsidence, human activities in estuaries and watersheds have caused long-term, estuary-wide changes. Examples include altered sediment and detritus deposition patterns; changed peak flows, water circulation patterns, and flooding regimes; and widespread fill, urbanization, and road building. These changes to the fundamental processes that historically created tidal wetlands may affect the “restorability” of some areas.

Field investigations are recommended as followup to this study, to help determine which areas have appropriate elevations and tidal ranges for restoration of tidal wetlands. Field investigation is particularly important in the upper estuary, where tidal velocities and/or ranges were low even prior to disturbance. These studies should include elevation surveys, water level (tidal range) measurements, plant community analysis, and other measurements as needed to determine the feasibility of restoring tidal influence and tidal wetland habitats at the site. Freshwater inflow to restoration sites should also be evaluated, because these flows also structure tidal wetlands and affect their functions. These analyses are highly technical, so expert assistance is recommended.

Monitor performance both independently and comprehensively

Every tidal wetland restoration site should be monitored using established monitoring protocols (Thayer et al. 2005; Simenstad et al. 1991; Zedler 2001). Monitoring must begin before restoration is designed, because baseline information is needed for critical design decisions. Monitoring should continue long after restoration to determine whether restoration was successful, and to assist in adaptive management. Post-restoration monitoring will also help guide future restoration efforts, because tidal wetland restoration is still a developing science.

Use interdisciplinary science and peer review

Interdisciplinary technical assistance is needed for restoration design. Expertise is needed in biology (botany, fish ecology, landscape ecology), hydrology, geology, geophysics, sedimentology, chemistry, statistics, engineering, and other fields. The best approach is to assemble an interdisciplinary team as the first step in the design process. Such a team can help evaluate the soundness and feasibility of restoration goals and design, and can advise on baseline and followup monitoring.

Early consultation with the team is needed to establish baseline monitoring protocols, because baseline data are needed to develop a restoration design. Baseline monitoring will provide solid data on site characteristics critical to restoration design, such as site topography (elevations), tidal range, groundwater hydrology, current fish use, and plant communities (which are good indicators of long-term tidal and hydrologic conditions).

Appendix B. Restoration approaches

This section provides some general considerations for conservation and restoration actions. We recommend consultation with appropriate technical experts for any conservation or restoration project.

Permits and regulatory coordination

Restoration activities often require extensive coordination with many different regulatory agencies. Numerous permits and approvals may be needed, so it's important to start this process early to avoid unexpected obstacles or delays. Early contact with land use planning officials at the City, Port, County, and State levels is recommended to obtain comprehensive information. The Wetlands Division of the Oregon Department of State Lands, (503)-378-3805, can provide information about the process and recommended contacts. Further information is found in the OWEB Estuary Assessment module (Brophy 2005a).

Archaeological sites

Before European settlement, Oregon's estuaries were widely used by Native American peoples for dwelling and gathering places and a source of livelihood. Therefore, every estuary restoration project should consider the possibility that there may be archaeological sites within or near the project area. State and federal laws prohibit destruction or disturbance of known archaeological sites. In the case of inadvertent discovery of cultural resources, state and federal laws require that the project be halted and the appropriate Tribe be contacted immediately. To understand the historic and cultural context of each site, and to avoid possible impacts to cultural resources, every restoration project should begin with consultation with the appropriate tribal groups.

Conservation and habitat linkages

The most immediate need for every site in the study area is conservation of the existing wetlands. This is particularly true for the unaltered sites. Written landowner agreements for conservation (such as conservation easements and deed restrictions) are among the many useful tools for wetland conservation. At a minimum, current stewardship should be continued; additional conservation actions such as establishment of protective buffers may also be important to maintain existing functions.

It's important to identify and conserve adjacent nontidal wetlands as well as upland habitats when planning conservation at tidal wetland sites. The best conservation plans protect the linkages and connections that are vital to wetland and upland habitat functions. Protecting the gradient from tidal to nontidal wetlands may also help prevent loss of tidal wetlands in the event of sea-level rise due to sudden or gradual geomorphic change, or large-scale hydrologic change.

Education

Many conservation and restoration sites offer good opportunities for education. School groups and local organizations can assist in planning, implementing, and monitoring conservation and restoration activities at tidal wetland sites. Public understanding helps build public support for wetland conservation.

Dike breaching and dike removal

The majority of Oregon's tidal wetlands were diked to block tidal flows, then converted to pastures. To restore tidal flow to diked sites, dikes can be breached at selected locations, preferably at locations of former natural tidal channels. Or, dikes can be removed completely, enhancing sheet flow, nutrient cycling and natural sedimentation patterns.

Dike breaching and removal can be technically challenging operations, with complex trade-offs in biological functions, hydrology, erosion and deposition patterns, and engineering constraints. Techniques for successful dike breaching and dike removal are still evolving in Oregon, so early consultation with experts (such as wetland scientists, hydrologists, and engineers) is recommended before designing restoration.

Ditch filling and meander restoration

If a site has extensive ditching that has eliminated flow through meandering channels, ditch filling and meander restoration should be considered. Deep, winding natural tidal channels with overhanging banks offer a higher quantity and quality of habitat for fish and other organisms, compared to shallow, broad, straight ditches. To redirect water through meandering remnant or restored channels, ditches may be filled or blocked. Ditch filling is generally more effective than plugging, because the relentless force of tidal ebb and flow will usually erode blockages placed in ditches (Cornu 2005, Brophy 2004). This is particularly true if the ditches are deeper than the remnant tidal channels – generally the case on grazing land where remnant channels are often filled with sediment and ditches are "scoured."

Partial excavation of meandering channels, preferably following visible or historic remnant channels, may speed the restoration process. However, excavation is not always recommended, and this process presents complex design questions and challenges. Excessive excavation of channels may dewater adjacent areas, much as ditching can. Input from experts (such as tidal wetland scientists, hydrologists, geomorphologists, and engineers) is required for this aspect of restoration.

If tidal action is strong at a site, excavation of remnant channels maybe unnecessary. "Self-design," in which water flows are allowed to create their own meandering path through processes of erosion and deposition, may be the best approach in many cases (Mitsch 2000). Self-design avoids the dilemma of water "not going where the engineers want it to go." Self-design also encourages diffuse flow of water across the site, which contributes to natural restoration of wetlands.

Culvert and tidegate upgrades

It can be difficult for basin-wide tidal wetland studies to assess conditions at specific tidegates and restrictive culverts. These structures can't be directly viewed on aerial photographs, and they are difficult to characterize during brief field trips because they are often underwater at mid- to high tide, and/or hidden under overhanging vegetation.

During initial site-specific planning, careful evaluation is needed for all water inlets and outlets to and from candidate restoration or conservation sites. Particular attention should be paid to culvert invert elevations (the elevation of the bottom of the culvert above the streambed), the action of tidegates (free or impeded), differences in water levels at the upstream and downstream ends of culverts, impounded water on the upslope side, velocities of flows relative to surrounding water bodies, and other characteristics that reveal flow restrictions. Where existing culverts are impounding water on the upslope side, culvert upgrades can sometimes cause drainage and loss of freshwater wetlands. If a proposed culvert upgrade might drain impounded wetlands, this loss should be balanced against the ecological functions that would be improved by the upgrade.

One restoration option is installation of “fish-friendly” tidegates, which increase fish access to streams and wetlands above the gate. Such devices may be a good choice where a landowner does not want to restore tidal flow. However, providing fish access to a site does not restore the ecological functions of tidal wetlands if tidal flow is still impeded. Tidegate removal (often accompanied by a culvert upgrade) is a better option for restoration of the full tidal wetland ecosystem, but the caveats above apply in all cases.

Water flow issues and property protection

Tidal wetland restoration usually alters surface water flows, and careful planning is necessary to ensure this does not damage property. Many tidal wetlands can be restored with no risk to adjacent properties, because the restoration sites are usually at a considerably lower elevation than nearby structures. However, it is still important to accurately assess existing conditions and proposed changes to site hydrology and flow patterns when planning restoration. Particular attention should be paid to topography, elevations of structures, tidal range, water table depths, and surface and subsurface water flow. Tidal range should be monitored during both normal and extreme events of tidal action, river or stream flow, and precipitation. The potential effects of water flow changes on nearby structures and properties should be carefully considered. Hydrologists and engineers experienced in the tidal zone can offer very useful advice.

Buffer establishment

Buffers around wetlands can greatly improve their functions by protecting habitats from sediment and nutrient-laden runoff, invasive species, fill intrusion, and other disruptive effects of human land uses. In addition, interfaces between wetlands and uplands are heavily used by many species of wildlife.

Buffer establishment around the margins of wetland sites should preferentially use native upland plantings. Native plantings generally require a weed control plan and ongoing maintenance during establishment. Technical help from experts in native plant restoration and weed control is recommended.

Fill removal

The most expensive type of restoration is removal of large areas of fill material. Former wetlands that have been entirely filled were excluded from this study. Most of these areas have been converted to economically valuable uses like residential developments and commercial operations. Besides the expense and controversy that would surround restoration proposals in such areas, restoration is also less likely to succeed, because the original soils are gone and there be few native plant communities nearby to provide seeds and propagules for revegetation.

However, some sites have small areas of fill which could be removed to improve wetland functions. Old roadways that are no longer used, former home sites abandoned due to frequent flooding, broken-down dike remnants, and small areas of dredged material offer such opportunities.

Woody plantings and large wood placement

Logging and driftwood removal have radically reduced the availability of large woody debris in Oregon estuaries. Most Oregon tidal swamps dominated by Sitka spruce were logged early during European settlement, because these sites were very accessible and log transport was easy on the adjacent rivers. Driftwood removal for lumber and firewood has also been widespread in Oregon tidal marshes and swamps. Changes in large wood volumes may have caused major changes in channel dynamics and hydrology. Therefore, woody plantings and large wood placement may be an appropriate restoration strategy for tidal marshes and swamps, along with efforts to increase the general supply of large wood to the basin. Woody plantings should be carefully designed to avoid areas that are too wet or too dry for the species used. Species chosen should be appropriate for the specific tidal wetland habitats being restored. For example, three native species that are tolerant of wet conditions and slightly brackish water are Sitka spruce, black twinberry, and Pacific crabapple. In freshwater tidal swamps, a wide range of wetland shrubs and trees are appropriate, such as Sitka spruce, shore pine, Western red cedar, willows, and dogwoods.

Grazing reduction

Many coastal agricultural lands are used for pastures, and the resulting livestock production contributes to the local economy. However, grazing by livestock alters plant communities and the physical structure of tidal and formerly tidal wetlands. Livestock degrade tidal channels, lowering the quality of fish habitat and altering water characteristics. Grazing compacts soils, leading to oxidation of soil organic matter and major changes in biological soil processes. Because grazing greatly reduces many wetland functions, removal or reduction of grazing is an important component of many tidal wetland restoration projects. The lowest, wettest portions of pastures may provide poor grazing and little economic return, so they are good candidates for grazing reductions and setasides. Expansion of grazing setasides beyond the boundaries of wetlands is also desirable, in order to establish upland buffers that enhance the biological functions of the wetland (see **Buffer establishment** above).

Appendix C. Ranking tables

Table C1. Ranking factor scores and total score, sorted by rank (top to bottom)

Site ID	Site size score	Salmon habitat connectivity score	Wetland connectivity score	Historic vegeta-tion score	Veg. diversity score	Channel condition score	Alteration types	Final ecological prioritization score	Ranking group
18	1.43	4.76	4.36	4.93	5	5	None	25.48	High
35	1.62	4.82	3.39	4.87	3	5	None	22.70	High
20	1.01	4.82	4.20	3.93	3	5	None	21.96	High
9	2.26	4.06	3.95	1.00	5	5	None	21.26	High
32	1.27	4.94	3.73	4.69	3	3	D, C, R	20.64	High
30	1.32	2.12	3.95	4.88	5	3	C	20.27	High
29	1.29	4.88	4.02	3.95	3	3	Y, C	20.15	High
16	1.08	4.50	3.76	2.75	3	5	None	20.09	High
34	1.36	4.90	3.62	4.94	3	1	D, C, R	18.82	High
17	1.13	4.54	3.35	1.00	5	3	Y, D (C?)	18.02	Med-High
22	1.24	4.79	2.99	4.88	3	1	D, C	17.91	Med-High
42	1.51	4.35	4.73	4.93	1	1	D, C, R (Y?)	17.52	Med-High
36	1.04	2.38	3.36	2.66	5	3	D, C, R	17.43	Med-High
46	1.06	4.09	5.00	1.00	3	3	Y	17.15	Med-High
8	1.16	3.93	3.04	1.00	3	5	Y, D, R	17.14	Med-High
31	1.52	4.59	4.13	4.87	1	1	Y, D, C, R	17.12	Med-High
23	1.13	4.86	3.70	4.96	1	1	D, C	16.65	Med-High
33	1.19	4.41	3.79	5.00	1	1	D, C,R	16.40	Med-High
7	2.35	3.89	3.10	1.00	1	5	None	16.35	Med
40	2.36	4.10	4.24	3.56	1	1	D, C, R (Y?)	16.26	Med
10	1.02	3.99	4.05	1.00	1	5	None	16.07	Med
21	1.11	3.90	3.01	3.72	3	1	D, C, R	15.75	Med
43	1.10	2.59	4.79	1.00	3	3	Y, C	15.48	Med
39	1.39	1.72	3.33	5.00	1	3	D, C	15.44	Med
4	1.22	3.66	1.00	1.00	3	5	None	14.88	Med
19	5.00	4.14	2.37	1.21	1	1	Y, D, C, R	14.72	Med
28	1.06	4.81	3.60	1.00	3	1	Y, D, C, R	14.48	Med
41	1.04	4.55	1.79	1.00	1	5	None	14.39	Med-Low
5	1.00	3.87	2.39	1.00	3	3	Y, R	14.26	Med-Low
24	2.06	5.00	2.29	2.86	1	1	D, C	14.21	Med-Low
37	1.02	4.45	3.82	2.88	1	1	D, C, R	14.17	Med-Low
12	1.01	4.03	4.03	1.00	3	1	Y, D, C, R	14.07	Med-Low
47	1.12	2.56	3.16	1.00	3	3	D	13.84	Med-Low
38	1.87	4.97	2.74	1.47	1	1	D, C, R	13.05	Med-Low
6	1.02	3.93	2.86	1.00	1	3	Y, R	12.81	Med-Low
15	1.07	1.58	3.11	1.00	5	1	D, C, R (Y?)	12.76	Med-Low
25	1.07	3.81	2.11	1.00	1	3	Y, R	11.99	Low
26	1.02	1.45	2.48	1.00	3	3	Y, C, R	11.96	Low
11	1.01	4.00	3.83	1.00	1	1	Y, R	11.84	Low
45	1.11	1.59	3.39	1.00	1	3	R, X	11.09	Low
3	1.00	3.58	1.21	1.00	1	3	Y (C?)	10.79	Low
2	1.01	3.55	1.17	1.00	1	3	Y	10.73	Low
44	1.04	2.59	3.99	1.00	1	1	Y, C	10.62	Low
27	1.00	1.00	1.14	1.00	3	3	Y	10.14	Low
1	1.05	3.53	1.11	1.00	1	1	D, C, R	8.69	Low

*Table C2. Ranking factor scores and total score, sorted by site number**

Site ID	Site size score	Salmon habitat connectivity score	Wetland connectivity score	Historic vegeta-tion score	Veg. diversity score	Channel condition score	Alteration types	Final ecological prioritization score	Ranking group
1	1.05	3.53	1.11	1.00	1	1	D, C, R	8.69	Low
2	1.01	3.55	1.17	1.00	1	3	Y	10.73	Low
3	1.00	3.58	1.21	1.00	1	3	Y (C?)	10.79	Low
4	1.22	3.66	1.00	1.00	3	5	None	14.88	Med
5	1.00	3.87	2.39	1.00	3	3	Y, R	14.26	Med-Low
6	1.02	3.93	2.86	1.00	1	3	Y, R	12.81	Med-Low
7	2.35	3.89	3.10	1.00	1	5	None	16.35	Med
8	1.16	3.93	3.04	1.00	3	5	Y, D, R	17.14	Med-High
9	2.26	4.06	3.95	1.00	5	5	None	21.26	High
10	1.02	3.99	4.05	1.00	1	5	None	16.07	Med
11	1.01	4.00	3.83	1.00	1	1	Y, R	11.84	Low
12	1.01	4.03	4.03	1.00	3	1	Y, D, C, R	14.07	Med-Low
15	1.07	1.58	3.11	1.00	5	1	D, C, R (Y?)	12.76	Med-Low
16	1.08	4.50	3.76	2.75	3	5	None	20.09	High
17	1.13	4.54	3.35	1.00	5	3	Y, D (C?)	18.02	Med-High
18	1.43	4.76	4.36	4.93	5	5	None	25.48	High
19	5.00	4.14	2.37	1.21	1	1	Y, D, C, R	14.72	Med
20	1.01	4.82	4.20	3.93	3	5	None	21.96	High
21	1.11	3.90	3.01	3.72	3	1	D, C, R	15.75	Med
22	1.24	4.79	2.99	4.88	3	1	D, C	17.91	Med-High
23	1.13	4.86	3.70	4.96	1	1	D, C	16.65	Med-High
24	2.06	5.00	2.29	2.86	1	1	D, C	14.21	Med-Low
25	1.07	3.81	2.11	1.00	1	3	Y, R	11.99	Low
26	1.02	1.45	2.48	1.00	3	3	Y, C, R	11.96	Low
27	1.00	1.00	1.14	1.00	3	3	Y	10.14	Low
28	1.06	4.81	3.60	1.00	3	1	Y, D, C, R	14.48	Med
29	1.29	4.88	4.02	3.95	3	3	Y, C	20.15	High
30	1.32	2.12	3.95	4.88	5	3	C	20.27	High
31	1.52	4.59	4.13	4.87	1	1	Y, D, C, R	17.12	Med-High
32	1.27	4.94	3.73	4.69	3	3	D, C, R	20.64	High
33	1.19	4.41	3.79	5.00	1	1	D, C,R	16.40	Med-High
34	1.36	4.90	3.62	4.94	3	1	D, C, R	18.82	High
35	1.62	4.82	3.39	4.87	3	5	None	22.70	High
36	1.04	2.38	3.36	2.66	5	3	D, C, R	17.43	Med-High
37	1.02	4.45	3.82	2.88	1	1	D, C, R	14.17	Med-Low
38	1.87	4.97	2.74	1.47	1	1	D, C, R	13.05	Med-Low
39	1.39	1.72	3.33	5.00	1	3	D, C	15.44	Med
40	2.36	4.10	4.24	3.56	1	1	D, C, R (Y?)	16.26	Med
41	1.04	4.55	1.79	1.00	1	5	None	14.39	Med-Low
42	1.51	4.35	4.73	4.93	1	1	D, C, R (Y?)	17.52	Med-High
43	1.10	2.59	4.79	1.00	3	3	Y, C	15.48	Med
44	1.04	2.59	3.99	1.00	1	1	Y, C	10.62	Low
45	1.11	1.59	3.39	1.00	1	3	R, X	11.09	Low
46	1.06	4.09	5.00	1.00	3	3	Y	17.15	Med-High
47	1.12	2.56	3.16	1.00	3	3	D	13.84	Med-Low

* There are no sites numbered 13 or 14 in the study.

Appendix D. Data details (metadata)

Table D1. Table of data sources

Title	Source	Data type	Scale	Metadata Availability? (Y/N)	Complete? (Y/N)
Digital Ortho Quadrangles (digital aerial photographs)	USGS	Raster	1:24,000	Yes	Yes
Digital Raster Graphics (digitized USGS quadrangle maps)	USGS	Raster	1:24,000	Yes	Yes
May 2001 Infrared aerial photography https://www.nwp.usace.army.mil/ec/ts/aerial.htm	ACOE	Hardcopy	1:24,000	No	No
Head of tide for the mainstem river and for all tributaries http://statelands.dsl.state.or.us/tidally.htm	OR DSL	Tabular	Scale independent	No	No
National Wetlands Inventory http://wetlands.fws.gov/downloads.htm	USFWS	Coverage	1:24,000	Yes	Yes
SSURGO soil survey http://www.or.nrcs.usda.gov/pnw_soil/or_data.html	NRCS	Coverage and Tabular	1:24,000	Yes	Yes
Historic vegetation	ONHP	Shapefile	1:24,000	No	No
Oregon Estuary Plan Book: base shoreline, habitat types, mitigation sites, shoreline mgmt units, estuary mgmt units, vectorized shorelines (1:5000) http://www.inforain.org/mapsatwork/oregonestuary/	OR DSL	Shapefile	1:1000 unless noted	Yes	Yes
Salmon distribution and habitat use types http://rainbow.dfw.state.or.us/nrimp/information/fishdistdata.htm	ODFW	Coverage	Generally 1:100,000	Yes	Yes
Hydrography http://rainbow.dfw.state.or.us/nrimp/information/index.htm	ODFW	Coverage	1:100,000	Yes	Yes
3-Zone Average Annual Salinity	NOAA	Shapefile	unknown	Yes	Yes
Urban Growth Boundary http://www.gis.state.or.us/data/index.html	ODOT/DLCD	Shapefile	1:24,000	Yes	Yes
Tillamook County tax lot maps http://www.ormap.org/	State of Oregon	Scanned images (non-GIS)	varies	No	Yes

Table D2. Key to site information table fields

This table lists all fields found in the tidal wetlands shapefile attribute table and the Excel spreadsheet of site data. A subset of these fields (marked with an asterisk) are shown in the printed site information table (Appendix E).

Column heading	Brief description	Full description
ID*	Site ID	Site number. Reflects order of site definition, not location in estuary. Some numbers are omitted.
Area	Site area (m2)	Site area in sq m
Perimeter	Site perimeter (m)	Site perimeter in m
Acres*	Site size (A)	Site size in acres
Hectares*	Site size (ha)	Site size in hectares
SIZE_SCOR*	Site size score	Site size score (scale of 1 to 5)
NUM_OWN*	Number of owners	Number of landowners (field verification recommended)
OWN_TYPE*	Ownership Type	Ownership type
UGB*	In/On UGB?	Is site within or crossed by the Urban Growth Boundary?
CHUM_V12	Chum?	Do chum spawn upstream of the site (in the tributary on which the site is located)?
COHO_V12	Coho?	Do coho spawn upstream of the site (in the tributary on which the site is located)?
CH_F_V12	Fall chinook?	Do fall chinook spawn upstream of the site (in the tributary on which the site is located)?
CH_S_V12	Spring chinook?	Do spring steelhead spawn upstream of the site (in the tributary on which the site is located)?
ST_W_V12	Winter steelhead?	Do winter steelhead spawn upstream of the site (in the tributary on which the site is located)?
NSTOCKS*	# of salmon biotypes	Number of salmon stocks spawning upstream (in the tributary on which the site is located)
SNPNCHUM	Distance to spawning score - chum	Score for distance to nearest ODFW-mapped spawning habitat - chum
SNPNCOHO	Distance to spawning score - coho	Score for distance to spawning - coho
SNPNCHF	Distance to spawning score - fall chinook	Score for distance to spawning - fall chinook
SNPNCHS	Distance to spawning score - spring chinook	Score for distance to spawning - spring chinook
SNPNSTW	Distance to spawning score - winter steelhead	Score for distance to spawning - winter steelhead
AVG_SNP*	Avg. distance to spawning	Average score for distance to spawning of all biotypes
SUM_CONS	Salmonid habitat connectivity score sum	Sum of two subscores for salmonid habitat connectivity
CONS_SCOR*	Salmon connectivity score	Salmon connectivity score (sum of subscores, rescaled to scale of 1 to 5)
DIF_AREA1M*	Wetland area w/in 1 mile (sq m)	Wetlands (other than site itself) within 1 mile circle around center of site (in square meters)

Column heading	Brief description	Full description
CONW1M_A*	Wetland area w/in 1 mile (A)	Wetlands (other than site itself) within 1 mile circle around center of site (in acres)
CONW1M_SCO*	Wetland connectivity score	Wetland connectivity score (scale of 1 to 5)
P_HISTVEG	% of each historic vegetation type	Percent of site occupied by each historic vegetation type (from ONHP mapping)
PCT_FSL*	% historic spruce swamp	Percent of site that was historically spruce swamp
HVT_SCOR*	Historic vegetation score	Historic vegetation score (from % historic spruce swamp) (scale of 1 to 5)
NWICLASS*	% of each NWI class	Percent of site occupied by each NWI wetland type
DIVRSTY10*	Number of Cowardin classes	Number of Cowardin classes, excluding types <10% of site
DIVR_SCOR*	Vegetation diversity score	Vegetation diversity score (from # of Cowardin classes) (scale of 1 to 5)
HYDCOND*	Channel condition	Channel condition (1=low, 2=medium, 3=high)
CHAN_SCOR*	Channel condition score	Channel condition score (scale of 1 to 5)
ALTTYPE*	Alteration types	Types of alterations present on site (field verification recommended). Alteration type (Y=dike, C=culvert/tidegate, D=ditch, R=road/RR, F=fill, X=excavation) (reflects the highest-intensity alteration present on the site)
AltType2*	Highest intensity alteration type	Abbreviation for the highest-intensity alteration present on the site
Alt_group*	Alteration group	Alteration group: major or minor (reflects the highest-intensity alteration present on the site)
NOTES*	Notes	Notes on site conditions
VEGNOTES*	Vegetation notes	Notes on site vegetation as observed from offsite (field verification recommended)
ECOL_SUM*	Final ecological prioritization score	Final score used in prioritization (sum of all sub-scores; potential range 6 to 30)
Rank_Grp*	Ranking group	Ranking group as determined in ArcView using quantile method (equal numbers of sites in each group)

* Field contained in printed site information table (Appendix E).

Table D3. Key to plant species codes in site information table

Scientific names follow those in the USDA plants guide (www.plants.usda.gov). This is not a complete species list for the study area; it lists only those plants recorded in field notes during site reconnaissance.

Abbreviation	Species	Common name
ALNRUB	*Alnus rubra*	red alder
ALOGEN	*Alopecurus geniculatus*	water foxtail
ARGEGE	*Argentina egedii*	Pacific silverweed
CARLYN	*Carex lyngbyei*	Lyngbye's sedge
CAROBN	*Carex obnupta*	slough sedge
DESCES	*Deschampsia caespitosa*	tufted hairgrass
DISSPI	*Distichlis spicata*	seashore saltgrass
JUNBAL	*Juncus balticus*	Baltic rush
JUNEFF	*Juncus effusus*	soft rush
LONINV	*Lonicera involucrata*	black twinberry
LYSAME	*Lysichiton americanus*	skunk cabbage
MALFUS	*Malus fusca*	Pacific crabapple
PHAARU	*Phalaris arundinacea*	reed canarygrass
PICSIT	*Picea sitchensis*	Sitka spruce
RUBSPE	*Rubus spectabilis*	salmonberry
SALVIR	*Salicornia virginica*	pickleweed
Salix	*Salix spp.*	willows
SALHOO	*Salix hookeriana*	dune willow
SALSIT	*Salix sitchensis*	Sitka willow
SPIDOU	*Spiraea douglasii*	rose spiraea
TRIMAR	*Triglochin maritimum*	seaside arrowgrass

Data limitations

The accuracy of scoring in this study depends on the quality of the source data. Errors in the original data could have been carried forward through data processing steps, resulting in some inaccuracies in the final results. Positional and registration errors were apparent in some GIS analyses. However, the processing methods used in this study reduced the potential for errors, because the broad conclusions drawn (i.e., ranking groups) are not dependent on exact registration between layers. In other words, the data used appear to be adequate for the analyses conducted.

This study used aerial photograph interpretation, existing data, and field investigation (usually observation from offsite) to characterize the sites in this study. Such “remote” data are inherently less accurate than data collected onsite in the field. Therefore, landowner contacts and site visits are recommended early in the restoration or conservation planning process, to verify the data presented in this report.

Although this prioritization uses criteria that are strongly related to wetland functions, the prioritization is not intended to assess specific site functions. Assessment of tidal wetland functions requires onsite field work for each site assessed (Adamus 2005a, Simenstad et al. 1991) and is not within the scope of this study.

The study area included the full historic extent of tidal wetlands in the estuary. However, it may not be possible to restore the full historic range of tidal influence at every site. (See Appendix A, **Restoration Principles** for details.) Factors such as subsidence, agricultural activities (e.g., cultivation, ditching, draining, and channeling), remaining dikes and other obstructions (e.g., roads), and basin-wide hydrologic changes all affect the potential to restore tidal exchange on a site. Field investigation is needed at any site where restoration is planned. Field investigation should include elevation surveys, water level (tidal range) measurements, plant community analysis, and other measurements as needed to determine the feasibility of restoring tidal influence and tidal wetland habitats at the site.

Notes on site information table fields

A key to fields in the site information table is provided in Appendix D (Table D2). Additional notes about specific fields are found below.

ALTTYPE (alteration types)

The field "ALTTYPE" shows the types of alterations present on each site, based on aerial photograph interpretation, field reconnaissance (generally offsite observation), and other data sources. Abbreviations used for the alteration types are shown in Table 7. Grazing is not listed as an alteration unless the site is free of structural alterations like dikes, ditches, tidegates and restrictive culverts.

Logging and driftwood removal were widespread in the accessible tidal forests and marshes of the estuary, but very few site-specific accounts of these activities are available, and widespread logging predated the earliest available aerial photos (1939). Therefore, logging and driftwood removal are not listed as alterations for specific sites, but can be assumed for most of the sites in this study.

Many sites in the study are bordered by roads, homesites, railroads, or other developments. These are commonly located at the base of an adjacent hillslope. In many cases, these developments involved fill material placed in the margins of the wetland, so many of the tidal wetlands are currently smaller than they were historically. However, as explained in **Study area** above, filled and developed areas were not included in this study, so fill is not listed as an alteration type.

NOTES

This column contains notes about the characteristics of sites, based on aerial photograph interpretation, field reconnaissance (generally from offsite), and local knowledge.

VEGNOTES (vegetation notes)

Plant species which appear to be dominant on the site are listed here. This information was based on offsite observation, except in a few cases where sites were visited with landowner permission. In many cases, only part of the site could be seen, so this should not be considered a final or complete description of plant communities. Onsite evaluation of plant communities is recommended for every site before any site-specific planning is begun.

Appendix E. Site Information table

Tidal Wetland Prioritization for the Nehalem River Estuary of Oregon, December 2005

Contacts: Laura Brophy, Green Point Consulting, 541-752-7671; Fred Seavey, USFWS Oregon Coastal Program, 541-867-4558

See Appendix D, Table D2 for field descriptions; see full report for details

There are no sites numbered 13 or 14 in the study.

Site ID	Location	Site size (A)	Site size (ha)	Site size score	Number of owners	Ownership Type	In/On UGB?	# of salmon stocks	Avg. distance to spawning score	Salmon hab. connectivity score	Wetland area w/in 1 mi (sq m)	Wetland area w/in 1 mile (A)	Wetland connectivity score	% historic spruce swamp	Historic vegetation score	% of each NWI class
1	McMillan Creek	12.6	5.1	1.05	4	Tribe/Private	y	5	1.87	3.53	256670	63.4	1.11	0.00	1.00	1.0000 PSSC
2	McMillan Creek	4.5	1.8	1.01	3	Private	n	5	1.92	3.55	326510	80.7	1.17	0.00	1.00	1.0000 E2EMN
3	North Jetty	3.3	1.3	1.00	1	State	n	5	1.97	3.58	379910	93.9	1.21	0.00	1.00	1.0000 E2EMP
4	Nehalem Bay State Park	47.9	19.4	1.22	1	State	n	5	2.13	3.66	134715	33.3	1.00	0.00	1.00	0.64689 PEMC, 0.32619 PSSC
5	Wheeler Heights	2.7	1.1	1.00	1	Private	y	5	2.57	3.87	1733761	428.4	2.39	0.00	1.00	0.33297 E2EMP, 0.66703 PFOR
6	S side of Bay	5.8	2.3	1.02	1	Private	y	5	2.69	3.93	2276756	562.6	2.86	0.00	1.00	0.92086 E2EMP, 0.07914 PFOR
7	Lazarus & West Islands	279.0	112.9	2.35	2	County/ Private	n	5	2.61	3.89	2553979	631.1	3.10	0.00	1.00	0.67936 E2EMN, 0.26414 E2EMP, 0.00791 E2SSN, .00364 2.3.9, .04495 2.3.9/10
8	Botts Marsh	35.9	14.5	1.16	2	Private	y	5	2.69	3.93	2484628	614.0	3.04	0.00	1.00	0.22121 E2EMN, 0.65130 E2EMP, 0.10986 PSSR, .01762 2.3.9
9	North Bay	258.7	104.7	2.26	4	State/ County/ Private	y	5	2.95	4.06	3523460	870.6	3.95	0.00	1.00	0.42742 E2EMN, 0.22514 E2EMP, 0.00111 E2SSN, 0.01042 PEMC, 0.10522 PFOC, .11138 2.3.9, .11932 2.3.9/10
10	Island N of Lazarus Is.	7.1	2.9	1.02	1	State	n	5	2.82	3.99	3645510	900.8	4.05	0.00	1.00	0.66172 E2EMP, 0.33828 E2EMN
11	Diked marsh at N end of Botts Marsh	4.4	1.8	1.01	1	Private	n	5	2.83	4.00	3392913	838.4	3.83	0.00	1.00	1.0000 PEMCh
12	Intersection of Hwy 101 and Hwy 53	5.1	2.1	1.01	1	Private	n	5	2.88	4.03	3622129	895.0	4.03	0.00	1.00	0.36937 PFOA, 0.63063 PEMC
15	Bayside Gardens, west	17.2	7.0	1.07	6	State/ Private	y	0	2.88	1.58	2560867	632.8	3.11	0.00	1.00	0.42697 PEMC, 0.44392 PFOC, 0.12459 PSSC, 0.00452 2.3.9
16	Island near City of Nehalem	19.4	7.9	1.08	1	Private	n	5	3.85	4.50	3313026	818.6	3.76	43.70	2.75	0.34443 PEMR, 0.62825 PFOR, 0.02732 PSSR
17	W bank of river N of Nehalem	28.3	11.4	1.13	7	Private	y	5	3.93	4.54	2842722	702.4	3.35	0.00	1.00	0.14507 PEMR, 0.31810 PFOR, 0.53684 PSSR
18	Confluence of N Fork and mainstem	89.6	36.3	1.43	2	Private	n	5	4.39	4.76	3993922	986.9	4.36	98.34	4.93	0.13858 PEMR, 0.62656 PFOA, 0.23109 PSSR
19	Sunset Drainage District	818.4	331.2	5.00	11	Port/ Private	n	5	3.12	4.14	1711825	423.0	2.37	5.26	1.21	0.88200 PEMADH, 0.01152 PEMCD, 0.08783 PEMCH, 0.00315 PEMCX, 0.00121 PEMFH, 0.00421 PEMR, 0.00194 PFOR, 0.00816 PSSC
20	Island at McDonald Rd. bridge	4.8	1.9	1.01	1	Private	n	5	4.51	4.82	3812609	942.1	4.20	73.32	3.93	1.0000 PEM/SSA
21	Anderson Cr.	26.0	10.5	1.11	3	Private	n	3	4.63	3.90	2451770	605.8	3.01	67.92	3.72	0.42013 PEMA, 0.31702 PEMC, 0.26285 PFOA
22	N Fork RM 2	52.3	21.2	1.24	6	Private	n	5	4.45	4.79	2427478	599.8	2.99	97.01	4.88	0.28296 PEMA, 0.28680 PEMCD, 0.43024 PSSCD
23	Cleared area N of Coal Cr. Swamp	29.4	11.9	1.13	2	Private	n	5	4.60	4.86	3240473	800.7	3.70	98.93	4.96	0.71101 PEMAD, 0.23434 PEMCD, 0.05465 PFOCD

Site ID	Number of Cowardin classes	Vegetation diversity score	Channel condition	Channel condition score	Alteration types	Most intensive alteration	Alt_Group	General notes	Vegetation notes	Final ecological prioritization score	Ranking group
1	1	1	1	1	D, C, R	D	Major	Ditched drainage bisects residential development	Wet areas: PICSIT/ALNRUB/CAROBN	8.69	Low
2	1	1	2	3	Y	Y	Major	S Jetty restricts tidal exchange	Native tidal marsh: DISSPI, CARLYN, TRIMAR	10.73	Low
3	1	1	2	3	Y (C?)	Y	Major	N Jetty restricts tidal exchange		10.79	Low
4	2	3	3	5	None	None	None	Undisturbed deflation plain wetland, limited tidal influence	Low SALVIR/DISSPI; mid-elev. JUNBAL-DESCES	14.88	Med
5	2	3	2	3	Y, R	Y	Major	RR embankment forms dike; bridge allows good tidal exchange		14.26	Med-Low
6	1	1	2	3	Y, R	Y	Major	RR embankment forms dike; culvert/bridge is restrictive		12.81	Med-Low
7	1	1	3	5	None	None	None	Breached earthen berm at E side doesn't seem to block tides		16.35	Med
8	2	3	3	5	Y, D, R	Y	Major	Old dike is partial/widely breached; tidal exchange intact	Low CARLYN-TRIMAR-DISSPI; mid-elev DESCES	17.14	Med-High
9	3	5	3	5	None	None	None	Breached earthen berm at E side doesn't seem to block tides	Native low to high tidal marsh.	21.26	High
10	1	1	3	5	None	None	None			16.07	Med
11	1	1	1	1	Y, R	Y	Major	Dike at S edge blocks tidal entry. Hwy 101 immed. to N.		11.84	Low
12	2	3	1	1	Y, D, C, R	Y	Major	Surrounded by roads which act as dikes.		14.07	Med-Low
15	3	5	1	1	D, C, R (Y?)	D	Major	Partly forested, partly mowed (or grazed?)		12.76	Med-Low
16	2	3	3	5	None	None	None	Island just N of Nehalem.	Undisturbed spruce tidal swamp island	20.09	High
17	3	5	2	3	Y, D (C?)	Y	Major	Perimeter & cross-dike, deep ditch at S end		18.02	Med-High
18	3	5	3	5	None	None	None	Hydrology intact, sm ditch on S edge has minimal effect	PICSIT-ALNRUB forest; CARLYN-DESCES, CAROBN-PHAARU on W edge	25.48	High
19	1	1	1	1	Y, D, C, R	Y	Major	Site is under intensive ag use.	Mostly introduced pasture grasses. Wet areas: JUNEFF, PHAARU	14.72	Med
20	2	3	3	5	None	None	None	Island at E end of McDonald Road bridge	Native brackish to fresh marsh: JUNBAL,ARGEGE,DESCES, CAROBN	21.96	High
21	2	3	1	1	D, C, R	D	Major			15.75	Med
22	2	3	1	1	D, C	D	Major	Deep channel excavated.		17.91	Med-High
23	1	1	1	1	D, C	D	Major			16.65	Med-High

Site ID	Location	Site size (A)	Site size (ha)	Site size score	Number of owners	Ownership Type	In/On UGB?	# of salmon stocks	Avg. distance to spawning score	Salmon hab. connectivity score	Wetland area w/in 1 mi (sq m)	Wetland area w/in 1 mile (A)	Wetland connectivity score	% historic spruce swamp	Historic vegetation score	% of each NWI class
24	N Fork RM 2-3	218.7	88.5	2.06	6	State/ Private	n	5	4.88	5.00	1614300	398.9	2.29	46.53	2.86	0.95965 PEMAD, 0.00238 PEMC, 0.01434 PFOA, 0.02363 PFOAD
25	Near Fishery Pt.	17.8	7.2	1.07	1	Private	n	5	2.45	3.81	1406158	347.5	2.11	0.00	1.00	1.0000 E2EMP, .04437 2.3.9, .00097 1.3.9
26	N end of Wheeler	7.4	3.0	1.02	3	Private	y	0	2.61	1.45	1842493	455.3	2.48	0.00	1.00	0.56626 E2EMN, 0.18772 E2EMP, 0.05393 PEMR, 0.19209 PSSR
27	N end of Nedonna Beach	3.3	1.3	1.00	1	Private	n	0	1.69	1.00	293229	72.5	1.14	0.00	1.00	0.21926 PEMC, 0.78074 PSSC
28	Bobs Creek	15.3	6.2	1.06	4	Private	y	5	4.50	4.81	3127462	772.8	3.60	0.00	1.00	0.63539 PEMAD, 0.04705 PEMR, 0.10620 PSSC, 0.21136 PSSR
29	N Fork RM1	62.5	25.3	1.29	1	Private	n	5	4.64	4.88	3604902	890.8	4.02	73.84	3.95	0.25694 PEMA, 0.39272 PEMAD, 0.31454 PFOA, 0.03580 PSSC
30	Hwy 53 N of McDonald Rd.	67.1	27.2	1.32	3	Private	n	0	3.98	2.12	3528172	871.8	3.95	97.05	4.88	0.13832 PEMCD, 0.47190 PFOA, 0.38978 PSSA
31	McDonald Rd. W of Hwy 53	109.2	44.2	1.52	2	Private	n	5	4.05	4.59	3735086	922.9	4.13	96.87	4.87	0.94795 PEMAD, 0.01153 PEMR, 0.02213 PFOA
32	N Fork RM1, W bank	58.3	23.6	1.27	2	Private	n	5	4.76	4.94	3275474	809.4	3.73	92.35	4.69	0.72888 PFOA, 0.27112 PSSA
33	Coal Creek	42.3	17.1	1.19	2	Private	n	4	4.67	4.41	3348699	827.5	3.79	100.00	5.00	0.96682 PEMAD, 0.03318 PFOC
34	Lower Anderson Cr.	76.2	30.8	1.36	3	Private	n	5	4.68	4.90	3149522	778.2	3.62	98.52	4.94	0.33626 PEMAD, 0.25771 PEMCD, 0.01451 PEMR, 0.07702 PFOA, 0.30511 PSSAD, 0.00940 PSSR
35	Coal Creek Spruce Swamp	129.8	52.5	1.62	4	Private	n	5	4.51	4.82	2882865	712.4	3.39	96.65	4.87	0.03527 PEMC, 0.02455 PFOA, 0.61746 PFOC, 0.32272 PSSC
36	Sm. creek betw. Coal & Anderson Crs.	10.7	4.3	1.04	4	County/ Private	n	0	4.51	2.38	2846131	703.3	3.36	41.44	2.66	0.31038 PEMA, 0.03889 PEMF, 0.24039 PFOA, 0.41034 PSSA
37	Coal Creek above road	6.2	2.5	1.02	1	Private	n	4	4.75	4.45	3379113	835.0	3.82	46.95	2.88	1.0000 PEMAD
38	N Fork RM 2-4	180.7	73.1	1.87	2	Private	n	5	4.83	4.97	2133973	527.3	2.74	11.68	1.47	0.97582 PEMAD, 0.00184 PEMC, 0.02234 PSSC
39	Hwy 53, Zaddach Cr. & N	81.3	32.9	1.39	6	Private	n	0	3.17	1.72	2810814	694.6	3.33	100.00	5.00	1.0000 PFOC
40	RM 4-5, E bank	279.6	113.2	2.36	5	Private	n	5	3.04	4.10	3863596	954.7	4.24	64.06	3.56	0.98810 PEMADH, 0.01190 PSSR
41	RM 7	11.7	4.7	1.04	2	Private	n	5	3.96	4.55	1044497	258.1	1.79	0.00	1.00	1.0000 2.1, 2.1.3
42	RM 3-4	106.8	43.2	1.51	1	Private	n	5	3.54	4.35	4428691	1094.3	4.73	98.13	4.93	1.0000 PEMADH
43	Diked wetland just E of Alder Cr.	22.4	9.1	1.10	1	Private	y	2	2.94	2.59	4497250	1111.3	4.79	0.00	1.00	0.31445 PEMC, 0.68555 PFOC
44	Alder Creek	10.7	4.3	1.04	2	Private	n	2	2.94	2.59	3571930	882.6	3.99	0.00	1.00	1.0000 PEMC
45	Bayside Gardens, east	24.8	10.0	1.11	6	Private	y	0	2.90	1.59	2886092	713.2	3.39	0.00	1.00	1.0000 PFOC
46	Dean Point	15.2	6.1	1.06	1	Private	y	5	3.02	4.09	4735623	1170.2	5.00	0.00	1.00	0.65902 E2EMP, 0.02858 E2SSN, 0.31240 PFOC
47	N Fork RM 3-4	26.3	10.6	1.12	1	Private	n	0	4.89	2.56	2618043	646.9	3.16	0.00	1.00	0.12423 PEMCD, 0.87577 PFOCD

Site ID	Number of Cowardin classes	Vegetation diversity score	Channel condition	Channel condition score	Alteration types	Most intensive alteration	Alt_Group	General notes	Vegetation notes	Final ecological prioritization score	Ranking group
24	1	1	1	1	D, C	D	Major			14.21	Med-Low
25	1	1	2	3	Y, R	Y	Major	RR embankment forms dike; bridge allows good tidal exchange	Native tidal marsh: DISSPI, CARLYN, TRIMAR	11.99	Low
26	2	3	2	3	Y, C, R	Y	Major	Restrictive culvert; surrounded by roads		11.96	Low
27	2	3	2	3	Y	Y	Major	Tidal influence naturally low, further restricted by S jetty	Native shrub wetland, mainly SALHOO. Hummocky, some upland.	10.14	Low
28	2	3	1	1	Y, D, C, R	Y	Major		PHAARU at W edge of site	14.48	Med
29	2	3	2	3	Y, C	Y	Major	Drains thru slough betw 29 & 31 (w/tidegates). Part forested	Forested area: PICSIT, ALNRUB. Pasture: PHAARU	20.15	High
30	3	5	2	3	C	C	Minor	Drains thru slough betw 29 & 31 (w/tidegates)	N end: PICSIT-ALNRUB; S end: shrub swamp	20.27	High
31	1	1	1	1	Y, D, C, R	Y	Major	Drains thru slough betw 29 & 31 (w/tidegates)	Introduced pasture grasses	17.12	Med-High
32	2	3	2	3	D, C, R	D	Major	Site remains very wet despite road crossing and ditching	Native spruce swamp: PICSIT-ALNRUB-MALFUS-SALIX-LONINV	20.64	High
33	1	1	1	1	D, C,R	D	Major		Introduced pasture grasses	16.40	Med-High
34	2	3	1	1	D, C, R	D	Major	Area near river currently ungrazed, returning to native veg	Mix of native and introduced grasses; more native near river	18.82	High
35	2	3	3	5	None	None	None	Undisturbed spruce swamp	From Christy et al: PICSIT-SALHOO-SALSIT	22.70	High
36	3	5	2	3	D, C, R	D	Major	Beaver dam at upper edge adds habitat value	PICSIT-SALIX-CAROBN-LYSAME near road, PHAARU above	17.43	Med-High
37	1	1	1	1	D, C, R	D	Major		Introduced pasture grasses	14.17	Med-Low
38	1	1	1	1	D, C, R	D	Major		Mainly pasture; small shrub area at S end	13.05	Med-Low
39	1	1	2	3	D, C	D	Major	Historic veg = crabapple swamp. Drains to N thru site 40	Willow, ALNRUB, SPIDOU	15.44	Med
40	1	1	1	1	D, C, R (Y?)	D	Major	Site drains to N.	Introduced pasture grasses.	16.26	Med
41	1	1	3	5	None	None	None	Flood overwash area	Willow/alder on former river wash.	14.39	Med-Low
42	1	1	1	1	D, C, R (Y?)	D	Major	Site was historically spruce swamp, is now pasture.		17.52	Med-High
43	2	3	2	3	Y, C	Y	Major	Dike has several small breaches.	Native brackish marsh: ARGEGE-JUNBAL-CARLYN-CAROBN	15.48	Med
44	1	1	1	1	Y, C	Y	Major	Grazed until recently.	Coquille soil: DISSPI, JUNBAL, ALOGEN. Upland: Weedy grasses	10.62	Low
45	1	1	2	3	R, X	R	Minor	Excavated ponds at west end.	Native forested wetland: PICSIT-ALNRUB-MALFUS-RUBSPE-CAROBN	11.09	Low
46	2	3	2	3	Y	Y	Major	Dike has several small natural breaches, no ditching.		17.15	Med-High
47	2	3	2	3	D	D	Major		ALNRUB, Salix, PHAARU	13.84	Med-Low

Appendix F. Figures (maps)

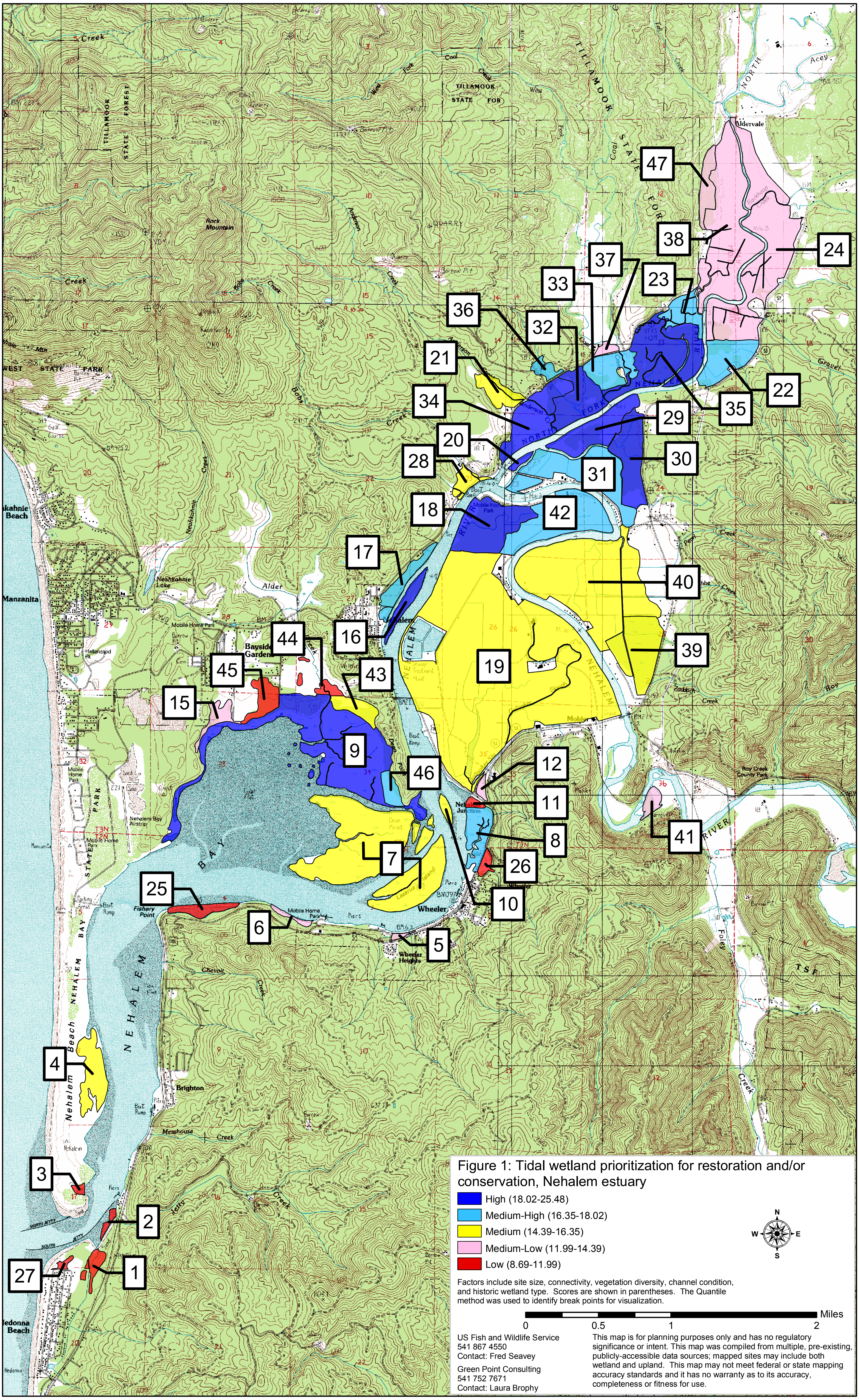

Figure 1: Tidal wetland prioritization for restoration and/or conservation, Nehalem estuary

Factors include site size, connectivity, vegetation diversity, channel condition, and historic wetland type. Scores are shown in parentheses. The Quantile method was used to identify break points for visualization.

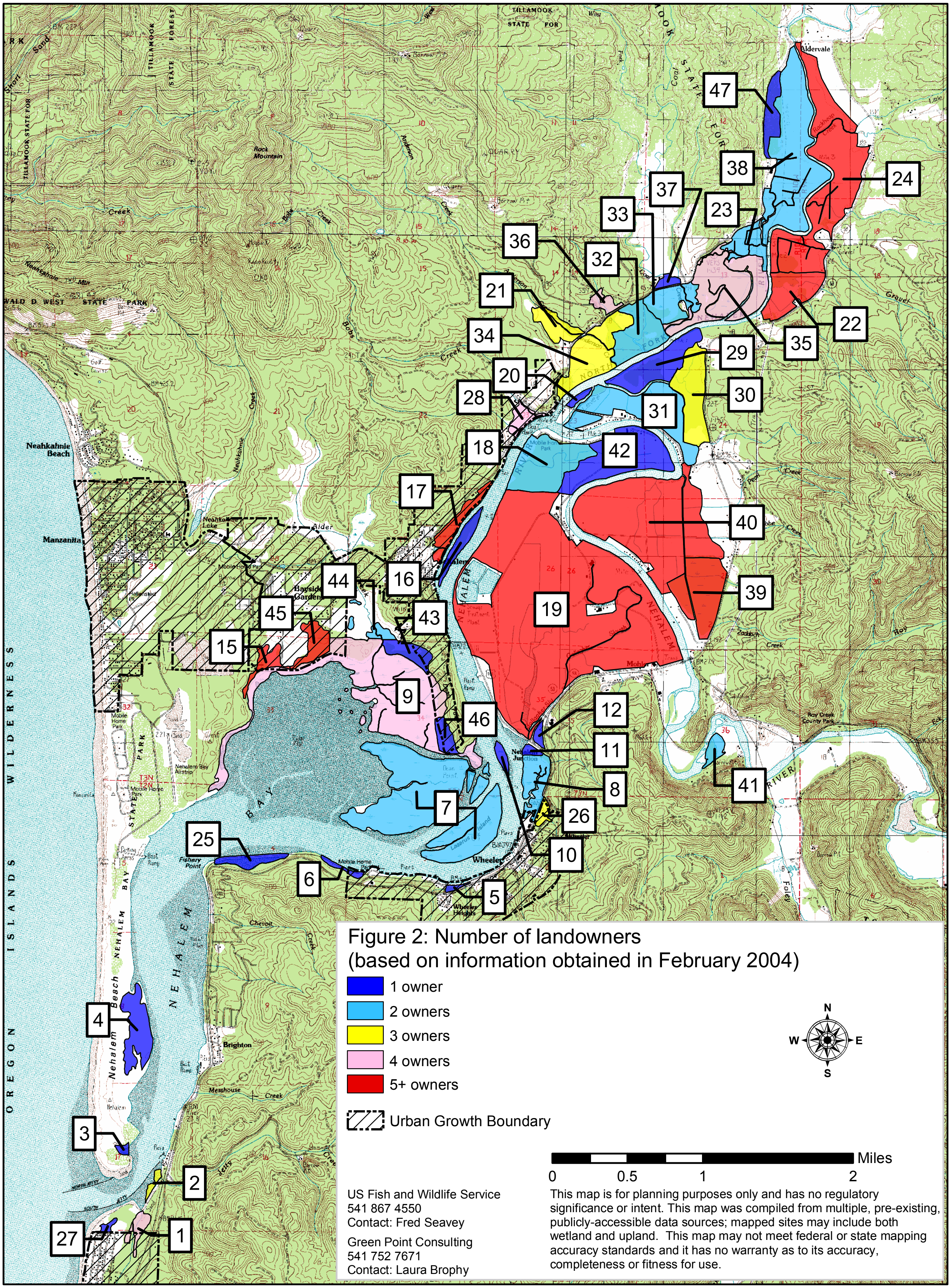

Figure 2: Number of landowners (based on information obtained in February 2004)

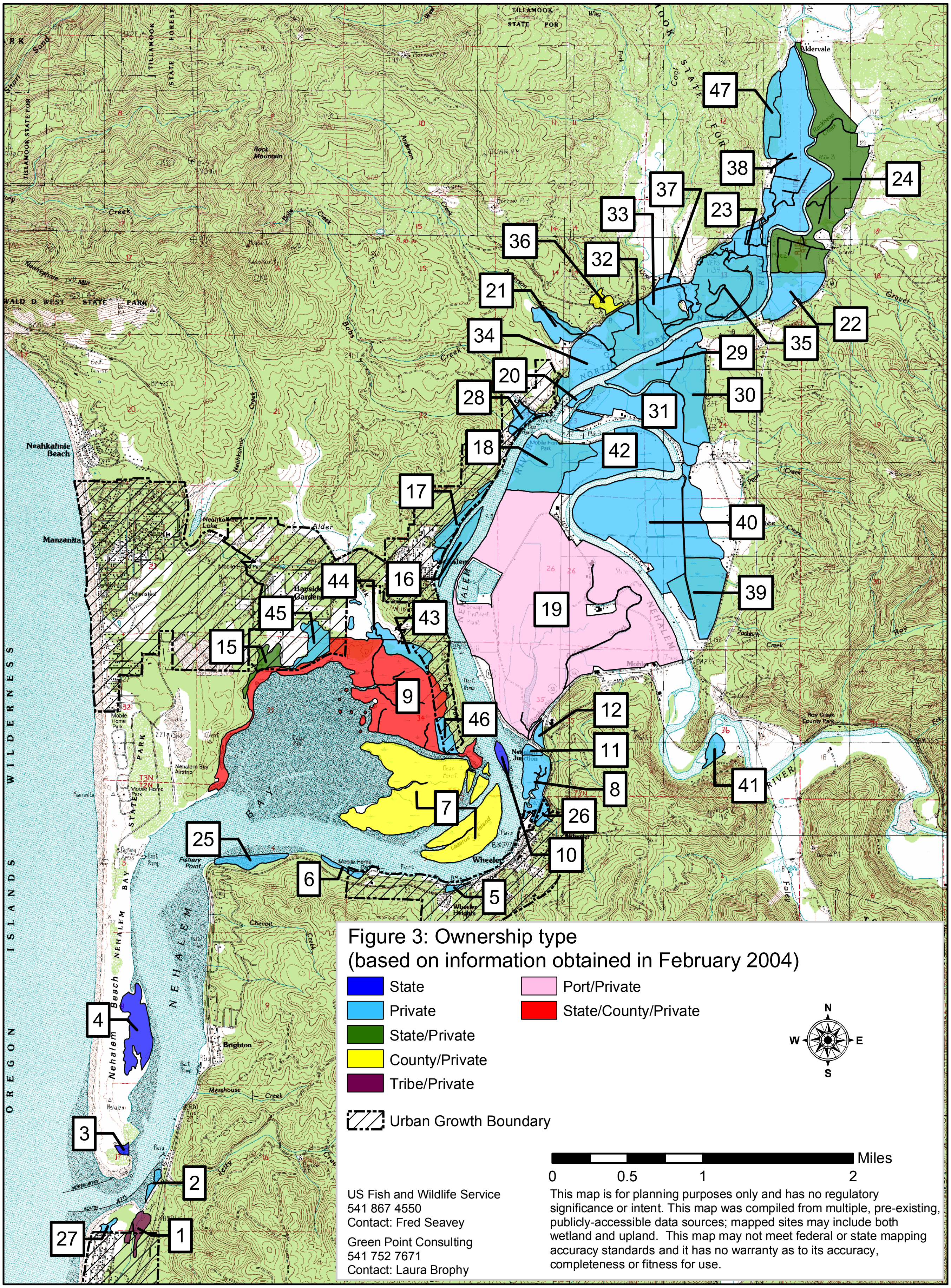

Figure 3: Ownership type
(based on information obtained in February 2004)

US Fish and Wildlife Service
541 867 4550
Contact: Fred Seavey

Green Point Consulting
541 752 7671
Contact: Laura Brophy

This map is for planning purposes only and has no regulatory significance or intent. This map was compiled from multiple, pre-existing, publicly-accessible data sources; mapped sites may include both wetland and upland. This map may not meet federal or state mapping accuracy standards and it has no warranty as to its accuracy, completeness or fitness for use.

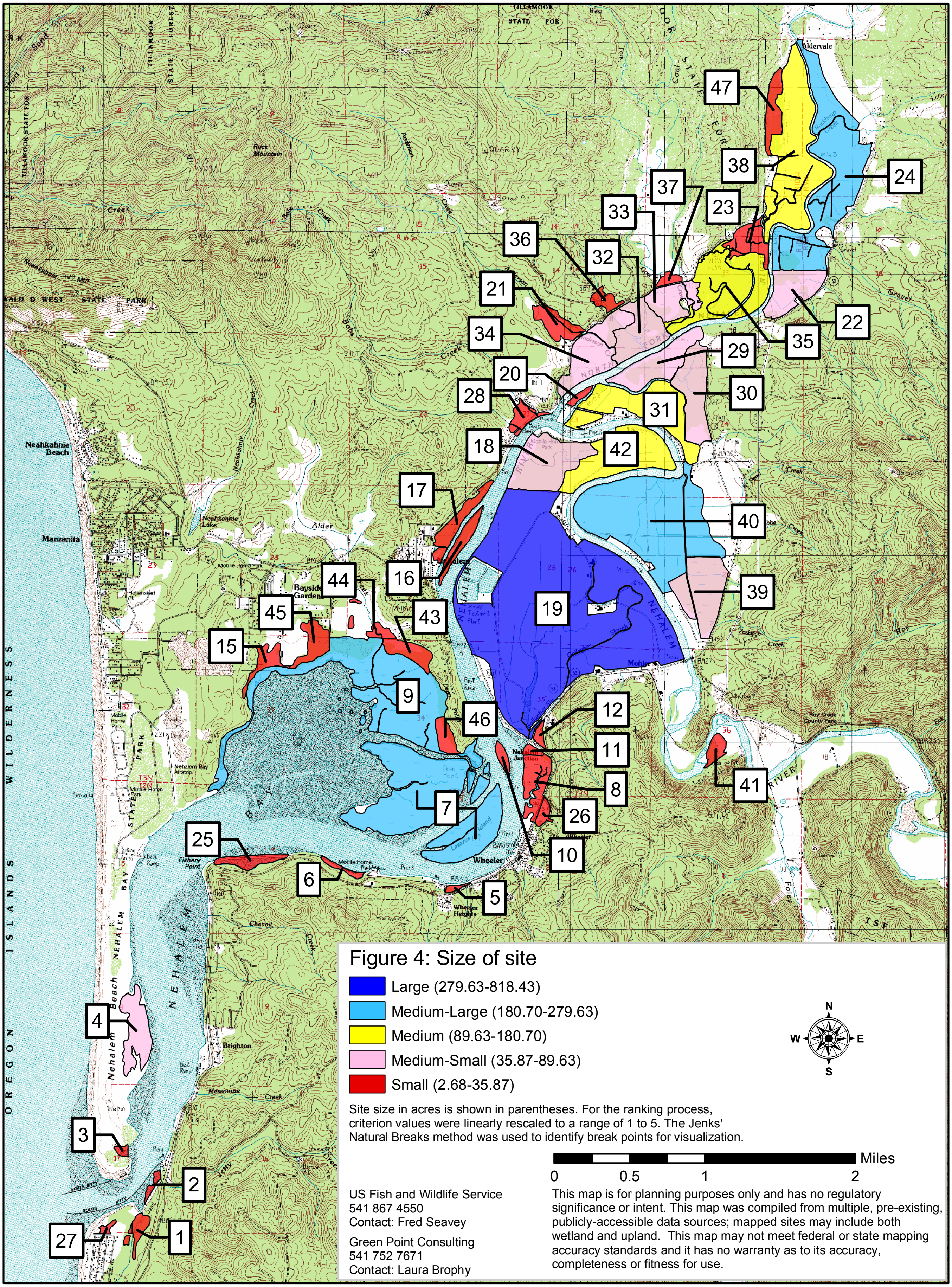

Figure 4: Size of site

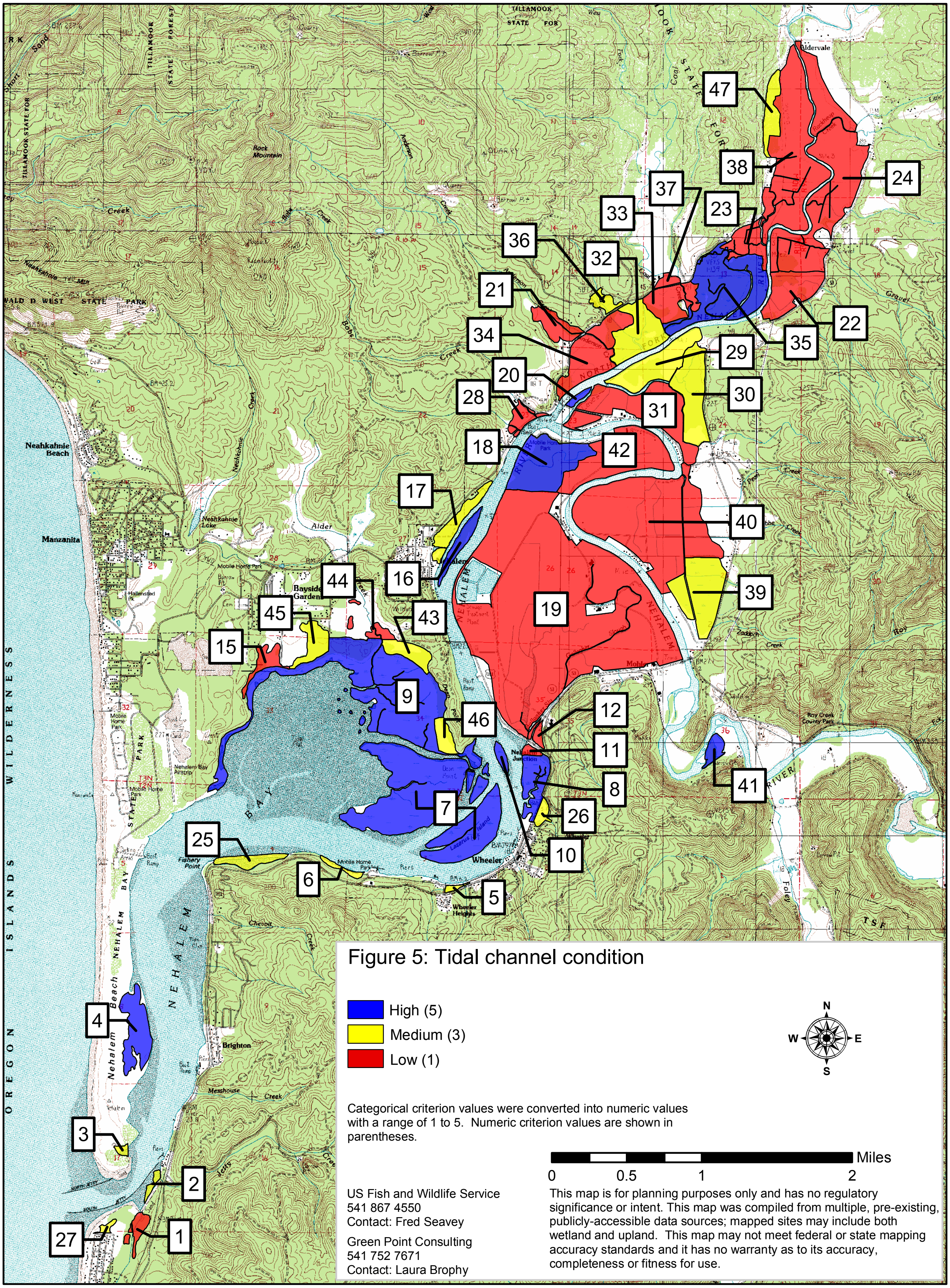

Figure 5: Tidal channel condition

Categorical criterion values were converted into numeric values with a range of 1 to 5. Numeric criterion values are shown in parentheses.

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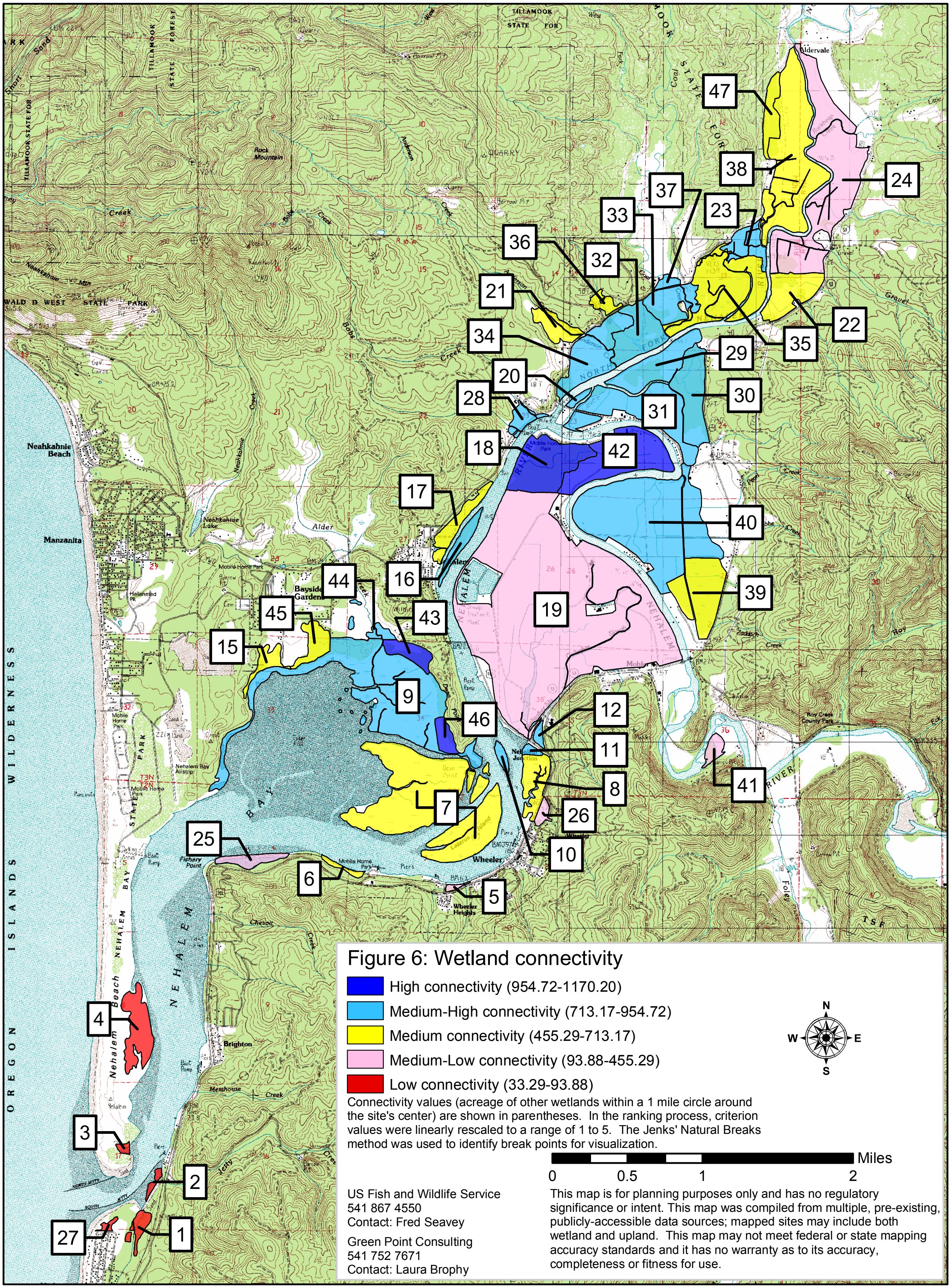

Figure 6: Wetland connectivity

Connectivity values (acreage of other wetlands within a 1 mile circle around the site's center) are shown in parentheses. In the ranking process, criterion values were linearly rescaled to a range of 1 to 5. The Jenks' Natural Breaks method was used to identify break points for visualization.

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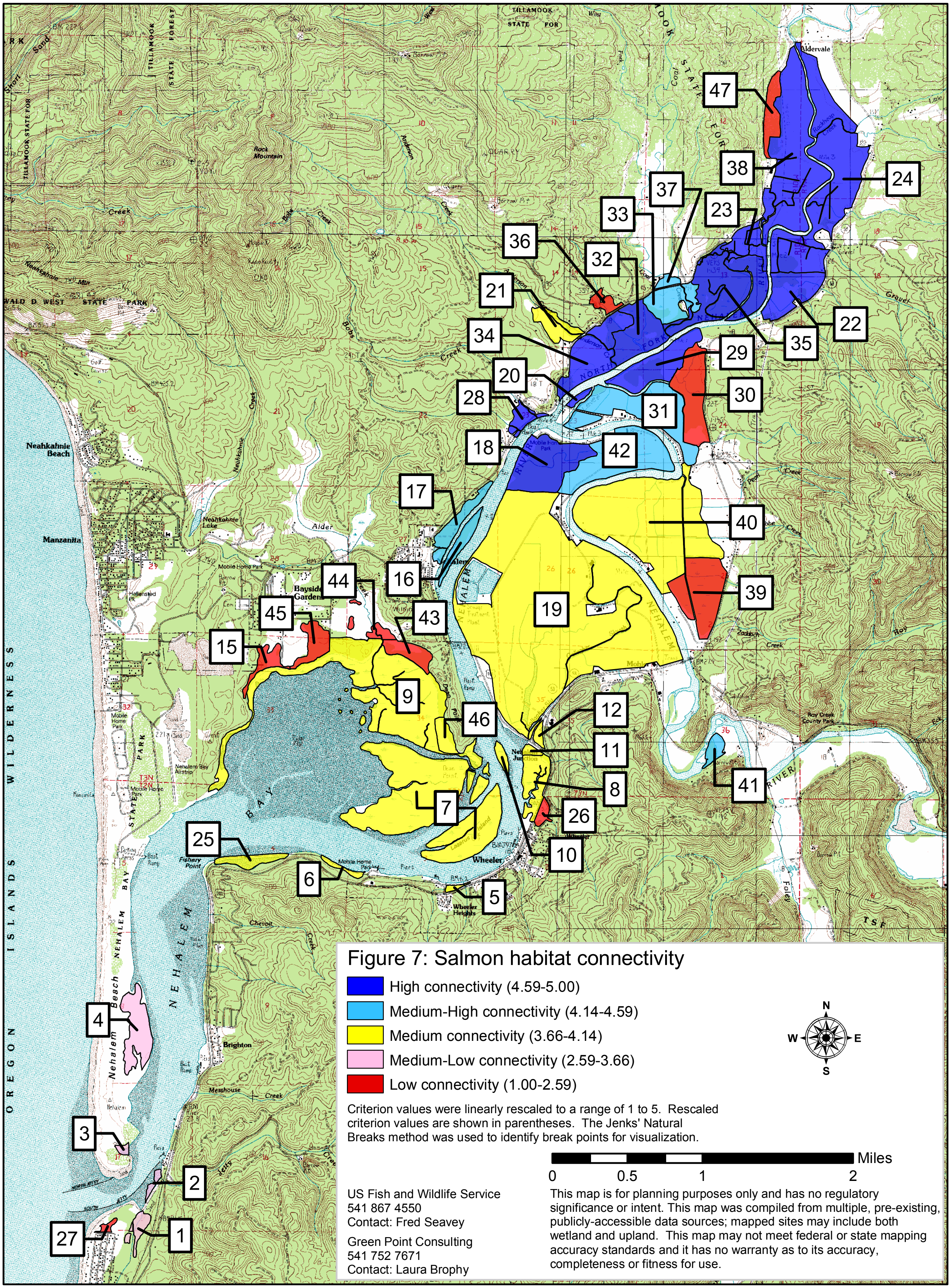

Figure 7: Salmon habitat connectivity

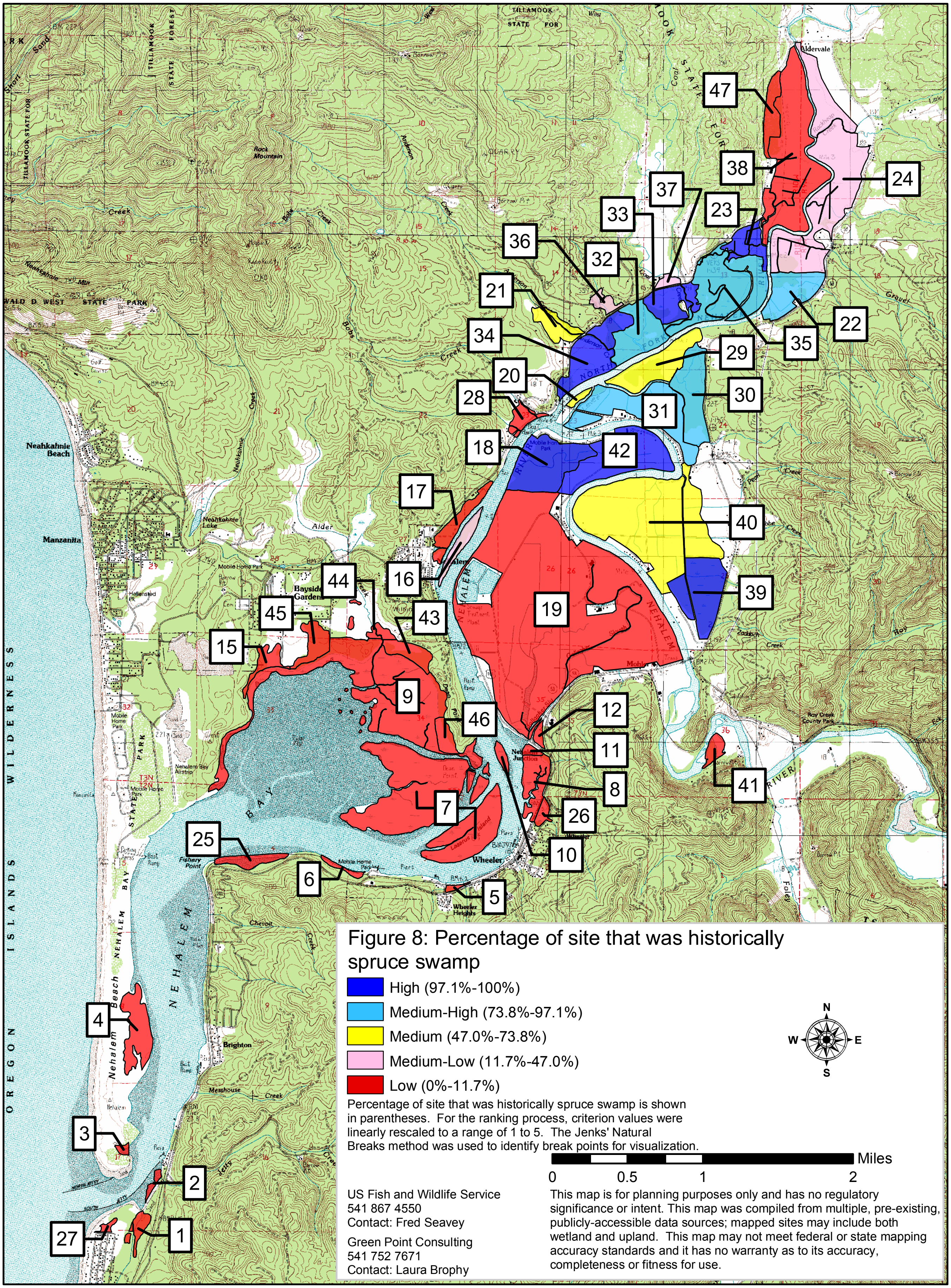

Figure 8: Percentage of site that was historically spruce swamp

- High (97.1%-100%)
- Medium-High (73.8%-97.1%)
- Medium (47.0%-73.8%)
- Medium-Low (11.7%-47.0%)
- Low (0%-11.7%)

Percentage of site that was historically spruce swamp is shown in parentheses. For the ranking process, criterion values were linearly rescaled to a range of 1 to 5. The Jenks' Natural Breaks method was used to identify break points for visualization.

Miles: 0 | 0.5 | 1 | 2

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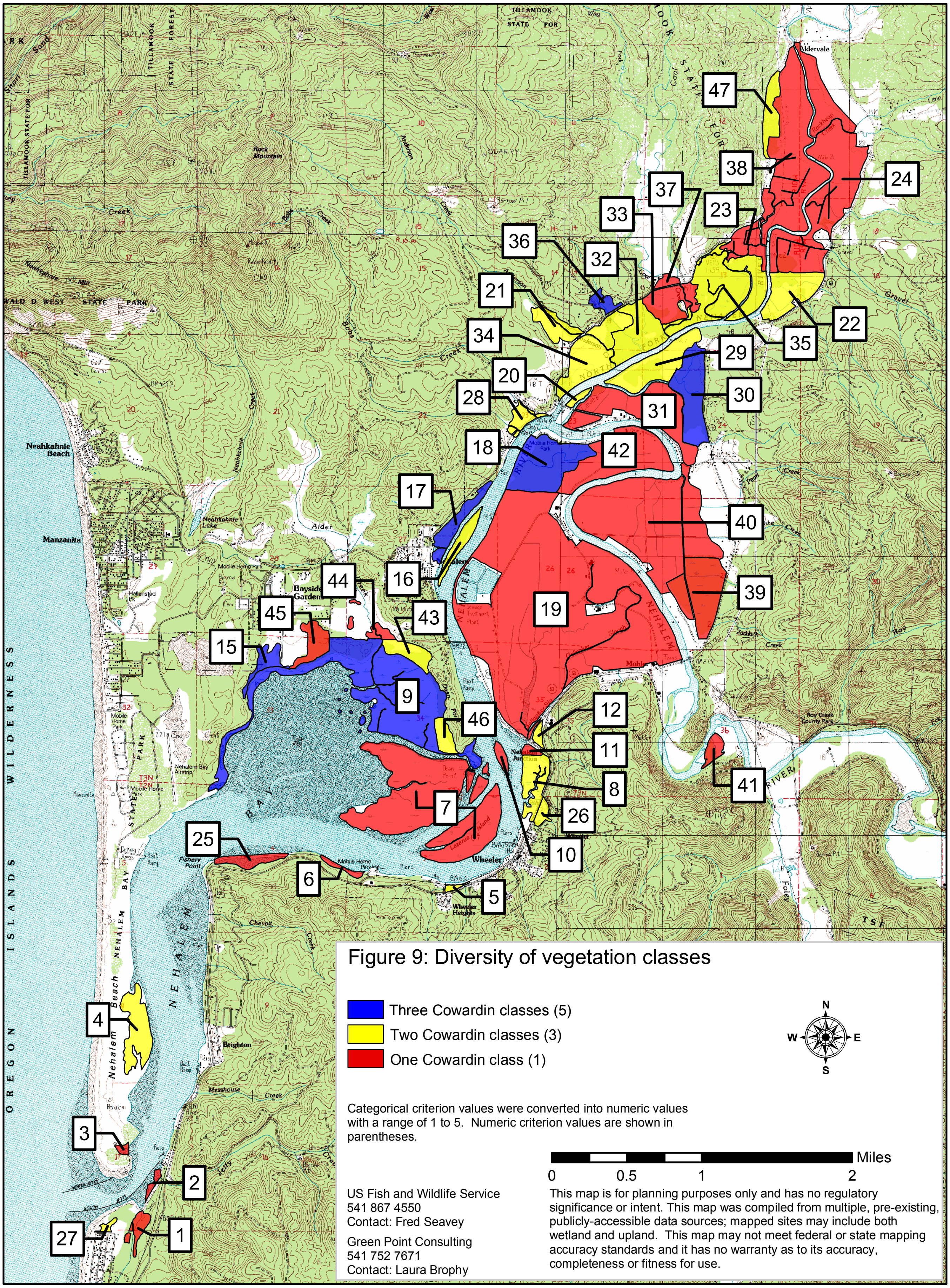

Figure 9: Diversity of vegetation classes

Categorical criterion values were converted into numeric values with a range of 1 to 5. Numeric criterion values are shown in parentheses.

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