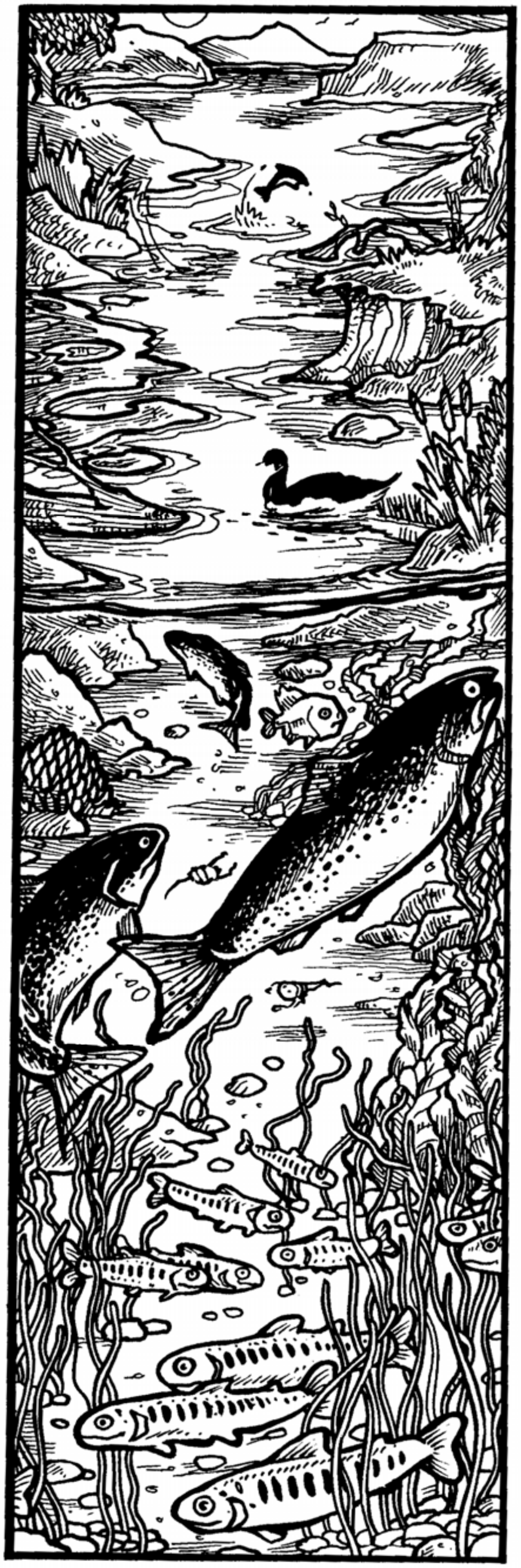

Estuary Assessment

Component XII of the Oregon Watershed Assessment Manual

Prepared for:

Oregon Department of Land Conservation and Development, Salem, OR

and

Oregon Watershed Enhancement Board, Salem, OR.

Prepared by:

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Watershed Professionals Network

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Prefatory note: *As this document went to press, revised digital National Wetlands Inventory (NWI) data for Oregon have become available for most of Oregon. The new NWI data, available at http://www.fws.gov/nwi/, currently include the north and south coast, and will soon cover the entire Oregon coast. This revised NWI is a suitable base layer for this estuary assessment. Therefore, you may choose to use the new NWI rather than the HGM map as your base for this assessment. If you make this choice, clip the NWI layer to eliminate NWI polygons that are entirely outside the HGM mapping, then substitute the term "NWI polygon" for "HGM polygon" throughout this assessment. However, remember that the much more detailed HGM mapping will provide very valuable data for interpretation, so be sure to follow all steps in the assessment, including analysis of HGM map classification.*

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Additional copies: For information on obtaining additional electronic or paper copies of this document, visit the OWEB Watershed Assessment Manual web page, http://www.oregon.gov/OWEB/docs/pubs/ws_assess_manual.shtml, or call OWEB at (503) 986-0178.

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I. OVERVIEW

This estuary assessment and prioritization method constitutes Component XII of the Oregon Watershed Assessment Manual (Watershed Professionals Network 1999). This module can serve as a stand-alone method, but is best used as a component of the larger assessment. Conducting a full assessment provides the best understanding of the watershed continuum from ridgetop to ocean.

Introductory material in this document describes the basic characteristics and functions of estuaries and tidal wetlands. Then, a series of seven steps make up the estuary assessment:

1. Use existing data, and generate new data, to determine the full historic extent of tidal wetlands within your estuary study area.

2. Use existing data, and generate new data, to identify alterations to tidal wetlands.

3. Define estuary analysis units based on alterations you have identified, and other site characteristics.

4. Identify and characterize conservation sites.

5. Identify and characterize restoration sites.

6. Identify land ownership for conservation and restoration sites.

7. Prioritize sites (within a given estuary) for restoration and conservation actions.

This module is lengthy, because it includes considerable material specific to estuaries. For example, the first step in the assessment is to locate the resources to be assessed (tidal wetlands) and determine the probability of tidal influence at each site. This module also contains a method for prioritizing sites, and special information on monitoring tidal wetlands.

Despite its length, this module is designed for use by someone with little familiarity with tidal wetlands. The benefits to your organization will be greatest if you conduct this assessment yourselves, rather than hiring a consultant. Many of the tasks are designed to build your understanding of the estuary, rather than merely produce an end result. Technical assistance may be helpful in particular phases of the assessment, but hiring a contractor to conduct the entire assessment will greatly reduce the benefit to you.

This assessment method was developed specifically for Oregon estuaries south of the Columbia River. For example, the method does not evaluate toxic waste disposal sites or sediment contamination, because industrial land uses are relatively rare in this region. By contrast, agricultural uses (including diking for pasture, ditching, and grazing) are covered in detail, because these are the most common alteration types found in the region. Like other components of the Watershed Assessment Manual, this estuary assessment is nonregulatory in nature and is not intended to replace or supersede existing land use planning regulations, inventories, or assessments.

II. ESTUARY BASICS

This **Estuary Basics** section was condensed and adapted from Good (1999). Further information can be found at the Oregon Coastal Atlas (http://www.coastalatlas.net/), which offers online access to Good (1999), the Oregon Estuary Plan Book (Cortright et al. 1987), Adamus (2006, 2005a, 2005b), Scranton (2004), Bottom et al. (1979), and the Oregon Estuary Inventory series (ODFW 1979). More technical references include Simenstad (1983), Seliskar and Gallagher (1983), Zedler (2001), and U.S. Army Corps of Engineers (2001).

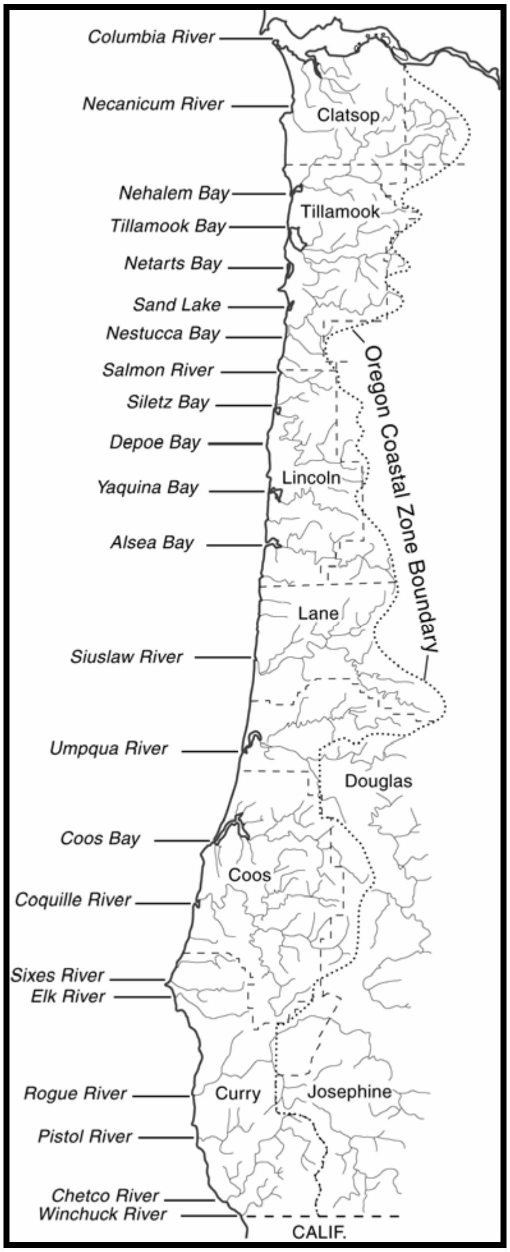


Figure 1: Oregon's Estuaries

A. What is an estuary?

Estuaries are the unique transition ecosystems where ocean waters meet streams flowing off the land. These complex, dynamic, productive systems are different in many ways from either the adjacent ocean or the river upstream. A classic scientific definition is that an estuary is "a semi-enclosed coastal body of water which has a free connection with the open sea and, within which, seawater mixes and usually is measurably diluted with freshwater from land runoff" (Pritchard 1967). Further adding to the definition, Oregon's statewide planning goals state that an estuary "includes estuarine water, tidelands, tidal marshes, and submerged lands," and that "Estuaries extend upstream to the head of tidewater" (OAR 660-017-0005).

B. Oregon's estuaries

Oregon's estuaries (Figure 1) play a vital role in the ecological and economic health of the state. They are ecologically important to many fish and wildlife species. People use estuaries for recreation and for many commercial endeavors. Providing for these and other uses while protecting estuarine ecosystem functions is a key challenge for all Oregonians.

Each of Oregon's estuaries is unique, influenced by many variables – watershed size, geology and land use; estuary shape and size; and annual patterns of precipitation, river runoff, solar heat input, ocean tides, and mixing of fresh and salt water. However, Oregon's estuaries can be classified in three major geomorphological categories: drowned river mouth, bar-built, and blind estuaries. Most of Oregon's large estuaries are drowned river mouth estuaries. These broad estuaries formed when sea level rose after the last ice age. In the Columbia, Umpqua, and Rogue estuaries, freshwater flow from large watersheds dominates, resulting in extensive freshwater tidal wetlands. In the other drowned river mouth estuaries (Necanicum, Nehalem, Tillamook, Nestucca, Salmon, Siletz, Yaquina, Alsea, Siuslaw, Coos, Coquille), freshwater flow tends to dominate in winter and saltwater flow dominates in summer. In many of these drowned river mouth estuaries, large areas of tidal marsh, eelgrass beds, and mud flats provide valuable wildlife habitat.

The Netarts and Sand Lake estuaries are bar-built, with sand spits that partially enclose the estuary. These have minimal freshwater flow. The Sixes River estuary and several other small estuaries are blind estuaries, which are closed at the mouth by sand bars during the summer when river flow is low.

Functions and values of estuaries:

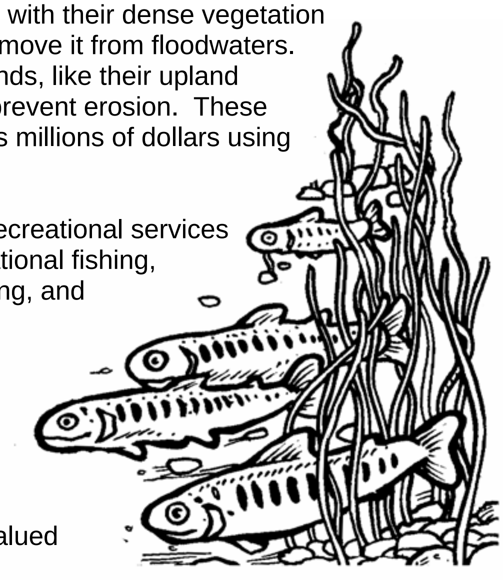
Estuaries provide many highly-valued goods and services to humans and other organisms. Healthy estuaries provide important *habitats* for many species we value such as salmon, herring, flounder, crabs, oysters, clams, wading birds, ducks, geese, shorebirds, and harbor seals. Deep channels, sloughs, tidal flats, tidal marshes, tidal swamps, eelgrass beds, and other habitats provide food, shelter, resting areas, and nursery grounds.

One reason for the diversity and abundance of animal life in estuaries is their *high primary productivity*. Tidal marshes, in particular, produce a prodigious amount of plant material that serves as food for direct consumers of organic detritus. Much of this plant material dies each fall and is recycled in the marsh or transported into estuarine waters. Microscopic bacteria break down this plant debris, contributing to the rich brew we call detritus. Detritus, transported by the tide throughout the estuary and into sloughs and tidal creeks, is the foundation of life in estuarine ecosystems.

Estuaries also help *keep water clean* and *protect property* from flood and storm damage. The plants and animals in estuaries take up excess nutrients from water and soil and use it for growth, effectively immobilizing pollutants. Tidal marshes and swamps, with their dense vegetation and narrow, winding channels, effectively *trap sediment* and remove it from floodwaters. Fringing marshes, riverine swamps, and other estuarine wetlands, like their upland counterparts, also *slow floodwaters* and *stabilize the shore* to prevent erosion. These water-quality and damage control services would cost taxpayers millions of dollars using modern technology, yet estuaries perform them for free.

Finally, estuaries are vital for the more obvious economic and recreational services they provide: transportation, commerce, commercial and recreational fishing, clamming, waterfowl hunting, birding, boating, sailing, sightseeing, and simple enjoyment of nature.

It is difficult to measure the dollar value of the many functions provided by tidal wetlands, but the value is certainly high. Costanza et al. (1997) estimated the economic value of ecosystem services provided by tidal marsh at about $4,000 per acre annually; riverine swamps and floodplains (a category which includes forested and scrub-shrub tidal wetlands) were valued at about double that amount.



C. Human uses and management of estuaries

Human history and economic development are intimately linked to estuaries. Estuaries provide abundant, easy-to-access fish and shellfish. The bays and shores of estuaries are popular sites for cities, homes, and recreation. Native Americans used these lands for centuries before Europeans arrived. Native peoples built their villages along the shore; harvested the abundant salmon, oysters, and other fish and shellfish; and used the estuaries as transportation and trading routes.

Since European settlement, use of the estuary has become much more intensive. Some of the ways we use estuaries change these ecosystems, often significantly. We selectively harvest plants and animals, and we introduce nonnative organisms – some of which are pest species. We dredge navigation channels, build jetties, fill tidelands, dike tidal marshes, channelize streams, log and drain swamps, build impervious surfaces, release water contaminants, and more. Although these uses have economic rewards and other benefits, they often adversely affect the natural goods and services that estuaries provide.

All of Oregon's estuaries have comprehensive land- and water-use management plans that guide where and how development and other uses may occur. The plans were developed through intensive collaborative efforts in the late 1970s and early 1980s. They were guided by Statewide Planning Goals 16 (Estuarine Resources) and 17 (Coastal Shorelands), adopted in 1976 by the Land Conservation and Development Commission. They are implemented through local development ordinances and through state and federal regulation of filling, dredging, in-water construction, and other activities.

Over the past several decades, we have come to understand the value of the goods and services healthy estuaries provide. We also have learned it is not too late to protect what remains and to restore damaged areas to health. All along the Oregon coast, estuarine habitats are being protected and restored, development is being directed to areas where adverse impacts can be avoided or minimized, and new pollution controls are being put in place. This assessment will provide you with the tools to strategically protect and conserve the remaining critical estuarine habitat, and to begin to restore a degraded habitat where that is feasible.

D. Tides and tidal terminology

The powerful daily water movements of the tides are produced by the gravitational pull of the moon and sun. Tides are strongest and the daily tidal range is greatest when the moon and sun align either on the same side of the earth (at the new moon) or on opposite sides of the earth (at the full moon). We call these *spring tides*. At the quarter moon, between new and full moons, tides are weaker, with smaller differences between the highs and lows. These we call *neap tides*. Over the course of a lunar month, there are two periods of spring tides at new and full moon, and two periods of neap tides at quarter moons (Figures 2 & 3).

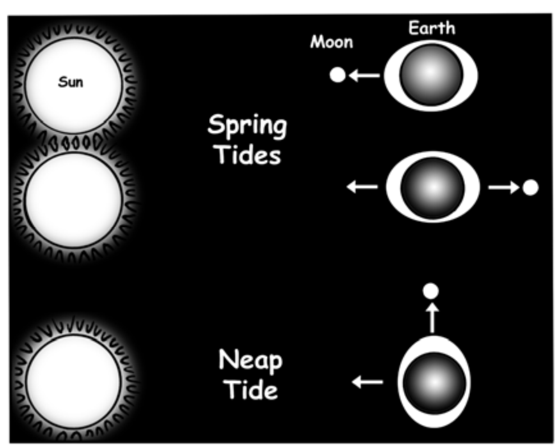


Figure 2: Illustration of how the relationship of the Sun and Moon affect Spring and Neap tides.

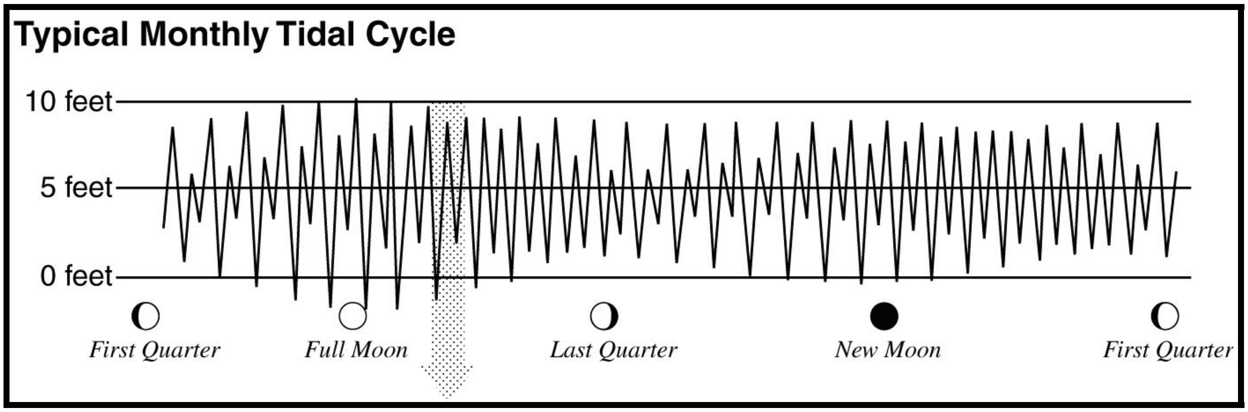


Figure 3: Monthly tidal cycles.

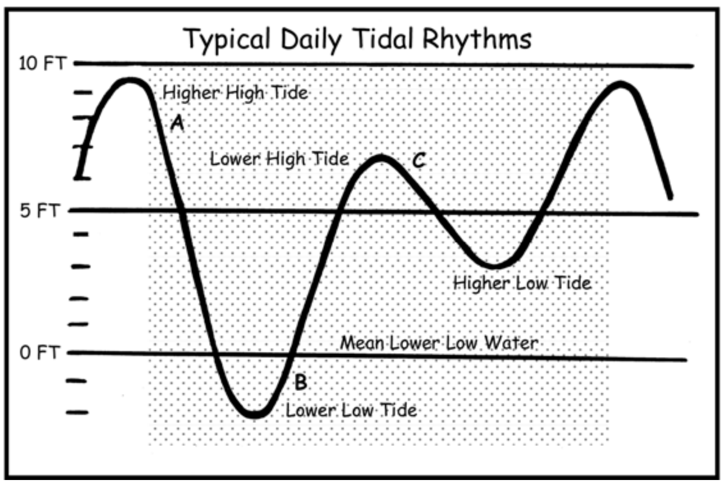


Figure 4: Typical daily tide cycle.

Each day along the Oregon coast, there are two high tides and two low tides of unequal height and duration (Figure 4). The outgoing (receding) tide is called an *ebb tide*. The incoming (rising) tide is called the *flood tide*. The *datum* or "zero mark" for measuring tidal elevations in our region is *mean lower low water* (MLLW), which is the average of the lower of the two daily low tides over many years. The average of the higher of the two unequal high tides is called *mean higher high water* (MHHW). *Mean high water* (MHW) is the average of all observed high tides; similarly, *mean low water* (MLW) is the average of all observed low tides. The *mean tidal range* is the difference in elevation between the average of all low tides and the average of all high tides. See sidebar on **Elevation reference systems ("datums")** for more information.

Tidal Terminology

Ebb tide is the outgoing (receding) tide.

Flood Tide is the incoming (rising) tide.

Slack tide when there is no tidal current.

Extreme High Tide (EHT)- The highest projected tide that can occur. It is the sum of the highest predicted tide and the highest storm surge.

Mean Low Water (MLW) - The average of all observed low tides.

Mean Higher High Water (MHHW) – The average height of the higher of the two daily high tides.

Mean High Water (MHW) – The average of all observed high tides, including both the higher high and lower high tides recorded each day.

Mean Low Water (MLW)- The average of all observed low tides, including both the lower low and the higher low tide recorded each day.

Mean lower low water (MLLW) is the average of the lowest of the two daily low tides the elevation is the "zero mark" for measuring tidal elevations.

Extreme Low Tide (ELT) - The lowest estimated tide that has ever occurred.

Land ownership in the estuary is partly determined by elevation of the land relative to the tides. At the time of statehood, the state of Oregon was granted all land below navigable waters and tidal waters. Typically, the state ownership boundary is set at MHW. Thus, most high salt marshes and tidal swamps (found between MHW and the upland) are privately owned. In addition, there are privately owned tidelands below MHW that were deeded during the mid- to late 1800s. Privately owned tidelands are still part of the estuary and subject to estuarine planning and regulation. Shalowitz and Reed (2000, 1962-64) provide further information on tidal datums and boundaries.

Elevation Reference systems ("datums")

Several different elevation reference systems are used to describe tides, water levels, and land surface elevations on the Oregon coast. Tidal elevations are measured relative to mean lower low water (MLLW); in this reference system, the MLLW datum is defined as 0 ft elevation, so that (for example) a "tidal elevation" of 8 ft means 8 ft above MLLW. Tidal elevations are established through longterm monitoring by NOAA's National Ocean Service (NOS).

Land elevations are referenced to fixed national survey datums ("geodetic datums" or "absolute elevations") such as the North American Vertical Datum of 1988 (NAVD88) and the older National Geodetic Vertical Datum of 1929 (NGVD29). Geodetic datums use a fixed zero point which does not change with location or time.

Tidal regimes vary with location depending on prevailing winds, currents, and other factors, so the absolute elevation of MLLW varies from place to place. In addition, changing sea levels and land levels (subsidence or uplift) alter the relationships between MLLW and the land surface. Thus, the relationship between tidal elevations (MLLW) and geodetic datums (NGVD29, NAVD88) varies from place to place and over time.

The U.S. Army Corps of Engineers Coastal Geology manual (U.S. Army Corps of Engineers 1995) states that "On project maps and documentation, all tidal datums must be clearly related to the fixed national survey datums." You may need expert assistance to establish these relationships; common methods include combinations of traditional survey methods, Global Positioning System (GPS) data, and calibration to existing USGS benchmarks.

Further information can be found at:

U.S. Army Corps of Engineers, New Orleans District Survey Section, Frequently Asked Questions page, http://www.mvn.usace.army.mil/ed/edss/FAQprint.asp

U.S. Army Corps of Engineers Engineering Manuals, Engineering and Design - Coastal Geology http://www.usace.army.mil/publications/eng-manuals/em1110-2-1810/toc.htm

NOAA Answers page (search for "geodetic benchmarks"): http://findanswers.noaa.gov/noaa.answers

E. Salinity zones

Differences in salinity have a major influence on the biology of estuaries. Estuaries are divided into three salinity zones. The *marine salinity zone* is located just inside the mouth of the estuary and has high salinities (30 to 18 parts per thousand or ppt). Bottom sediments in this zone are mainly fine sands of marine origin. The *mixing zone* is located farther up the estuary (Figure 5). Salinities in this zone range from 18 to 5 ppt, and bottom sediments are a mixture of fine sands of marine origin and riverine sediments from the watershed. The *riverine* or *freshwater tidal zone* extends from the mixing zone upriver to the head of tide. Salinity ranges from 5 ppt to fresh (0 ppt). Bottom sediments are fine sand, silt, clays, and organic matter derived mainly from the watershed. Other salinity classifications are described in the **glossary**.

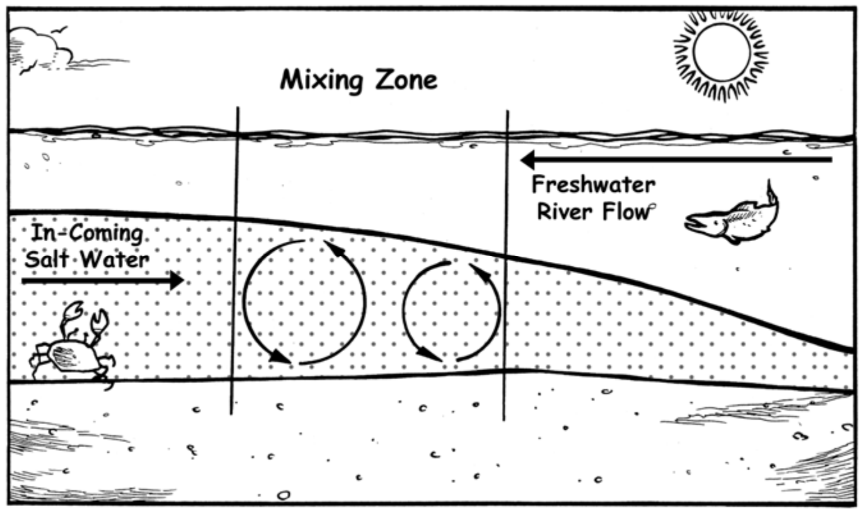


Figure 5: Illustration of the estuary mixing zone (based on Cortright et al. 1987).

F. Estuarine habitats

Estuarine habitats are classified by degree of tidal influence, predominant plant communities, and substrates. Figure 6 shows where different estuarine habitat types might be found at the mouth of a typical Oregon estuary. Although we may "deconstruct" estuaries into various habitat types, estuaries function as a whole. If any part of an estuarine habitat is lost or degraded, the whole ecosystem is degraded.

Subtidal estuarine habitats include *channel bottoms, slope bottoms,* and the *open water* above them. Salmon and other fish migrate and forage here, and many other animals -- both predators and prey -- are drawn to the productive areas where salt and freshwater mix. The method described in this publication does not assess subtidal habitats, but these habitats are closely tied to the higher intertidal wetlands assessed in this method.

Between the extreme low-water mark (about 3 feet below MLLW) and the mean tide level (about 4 to 5 feet above MLLW) are *tidal flats*. These areas can be sandy and firm, or silty, muddy and soft; they are inundated by the tides twice a day. Muddy tidal flats are rich with burrowing clams, worms, shrimp, amphipods, and other animals that feed on detritus and themselves become prey for fish and birds. Shorebirds, wading birds, ducks, geese, and many other birds rest and forage on the tidal flats. Commercial oyster racks are typically placed over mud flats.

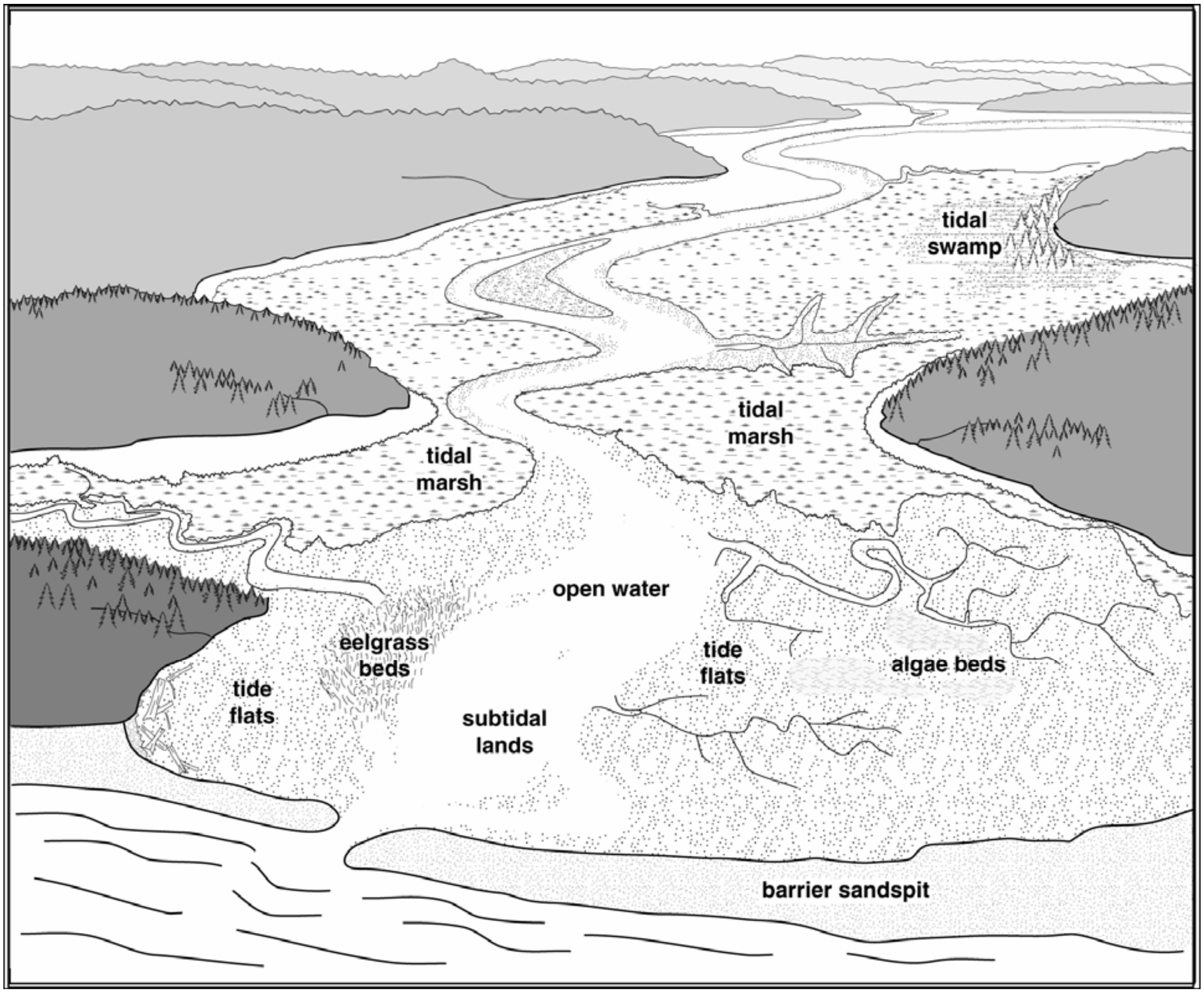


Figure 6: Typical estuary habitat types (from Good 1999).

Tidal flat habitats include *eelgrass beds* – highly productive underwater "meadows" that provide spawning substrate for herring; food for migrating Black Brant geese; and hiding places for young salmon, crab, and many other species. *Algal beds* are another productive tidal flat habitat, often occupied by sea lettuce (*Ulva*) and the hollow green strands of *Enteromorpha.*

At about the midtide level (4 to 5 feet above MLLW), there is a distinct transition from soft-bottom, algae, and eelgrass-dominated tidal flats to higher ground with more dense plant life – the *tidal marshes* and *tidal swamps.* **These are the tidal wetland types assessed in this module.** They are periodically inundated by tidal waters, typically daily (in the case of low marsh) or once or twice a month during spring tides, but at least annually. Tidal wetlands include emergent, scrub-shrub, and forested wetland types.

Emergent tidal wetlands are also known as tidal marsh, salt marsh, intertidal marsh, or brackish marsh. There are two main categories of tidal marsh: low and high marsh. *Low marsh* is found where the tides predictably flood the ground twice a day. Plant life here is tolerant of high salinity and dessication; typical plants include succulents like pickleweed and fleshy jaumea, and grasses and sedges like saltgrass and Lyngbye's sedge. At about the mean high water line, a sharp elevation break marks the transition to *high marsh*. Oregon's high marsh is a distinctive "tidal prairie," dominated by tufted hairgrass and other grasses, with a wide variety of other plants forming a diverse community. Moving upslope or upstream into lower salinity zones, the high marsh mix contains more and more broadleaved plants like asters, yarrow, and Pacific silverweed.

Scrub-shrub and forested tidal wetlands are also known as *tidal swamps*. These wetlands are found high in the estuary, often many miles upriver from the ocean. Tidal swamps are defined by the dominance of woody plants such as Sitka spruce, black twinberry, Pacific crabapple, and willows (Figure 7). Many tidal swamps are *freshwater tidal* wetlands (classified in the NWI as *tidally-influenced palustrine* wetlands), with tidal fluctuation in water levels but little or no measurable salinity. These wetlands may have plant communities dominated by freshwater wetland plants like slough sedge and skunk cabbage. The tidal flooding of marshes and swamps in the upper reaches of an estuary is due in part to the "holdup" effect of the incoming tide on river flow, so these wetlands are inundated more often in the winter when river flow is high.

Tidal marshes and swamps usually have highly branched, sinuous, deep, steep-sided tidal creeks. These creeks serve as conduits for exchange of water, nutrients, and detritus, as well as low-tide refugia for small fish such as juvenile salmon. At high tide, these fish can forage in channels and across the wetland surface, feeding on estuarine invertebrates, aquatic insects, and terrestrial insects that fall into the water from emergent vegetation or drift in from nearby riparian areas.

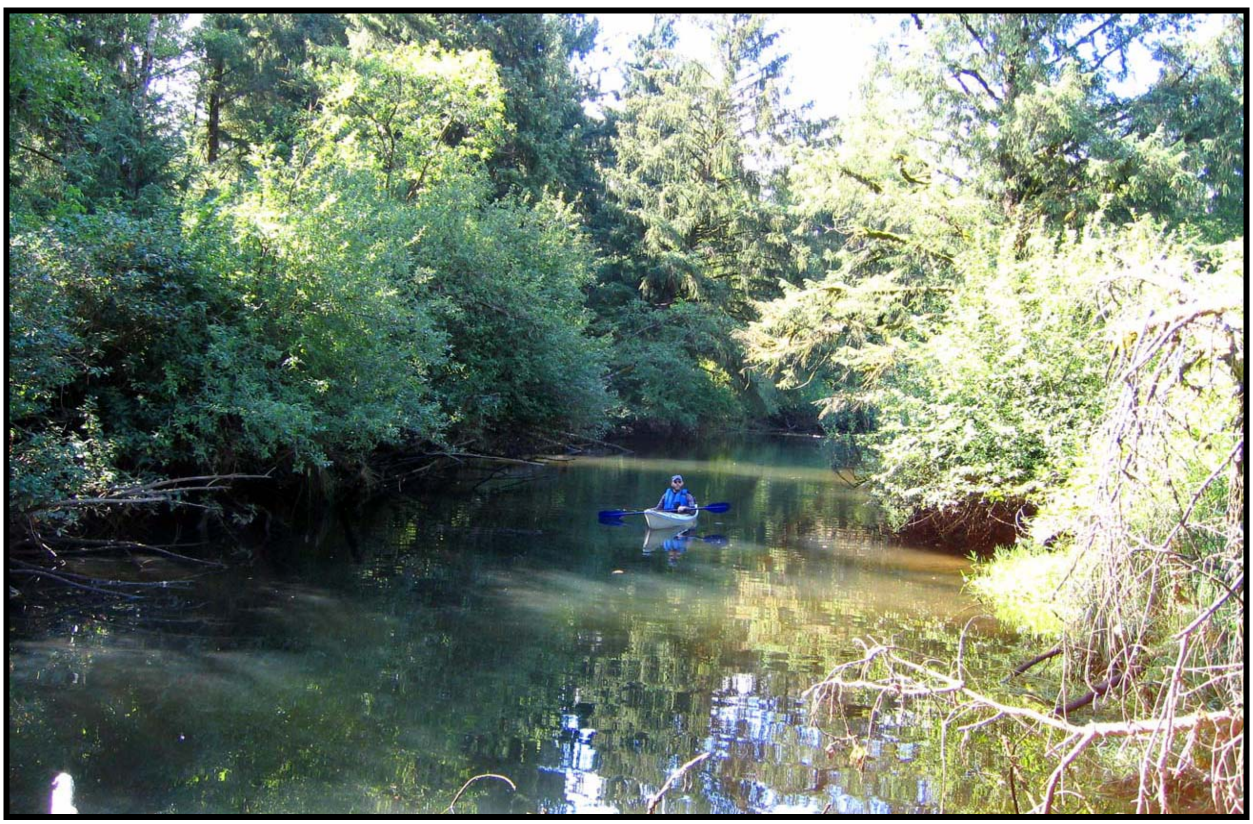


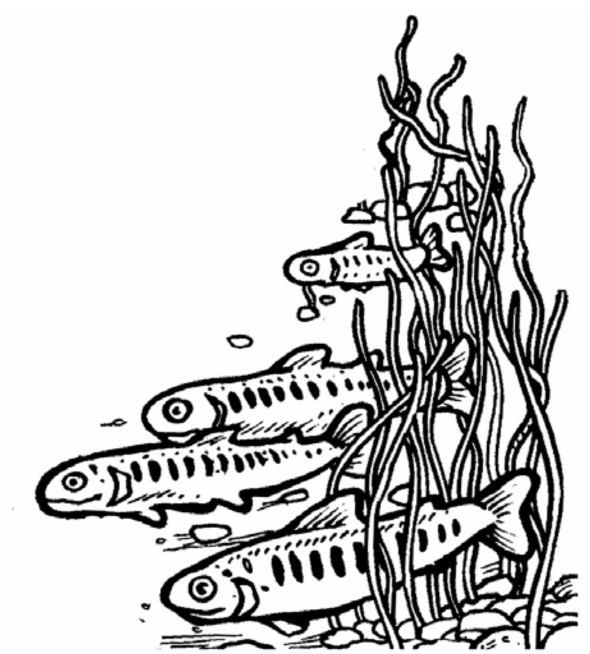
Figure 7. Large tidal channel in an Oregon tidal swamp, north coast estuary, near high tide. Photo: L. Brophy.

G. Salmon in estuaries

Recovery of salmon and steelhead stocks in the Pacific Northwest is a major environmental issue. The Oregon Plan for Salmon and Watersheds is a strategy for that recovery. Most recovery efforts have focused on improving freshwater stream and riparian habitat, but new information is bringing increased attention to the role of the estuary. Studies at South Slough National Estuarine Research Reserve, the Salmon River estuary, and other locations in the state (Bottom et al. 2004, Miller and Sadro 2003, Gray et al. 2002) indicate that estuaries play a very important role in salmon survival, diversity, and productivity. Recognition of the role of estuaries is overdue, because migrating juvenile salmon require a continuum of habitats from freshwater spawning grounds to the ocean. Certain estuarine habitats, such as the brackish-freshwater interface, may be particularly important to salmon and may deserve emphasis in restoration planning (Simenstad and Bottom 2004).

Estuaries are important for adult salmon, providing the necessary transition and holding areas for the fish before they begin their upstream migration. For juvenile salmon, estuaries provide a food-rich environment that promotes rapid growth and increased chances for survival, refuge from predators in narrow, winding channels with overhanging vegetation, and brackish salinities, allowing salmon to make the physiological transition between fresh and salt-water environments

Almost all juvenile salmon migrate into estuarine habitats between mid-winter and late summer. The juveniles rear in the estuary for varying lengths of time (depending on the estuary and the species) before continuing their migration to the ocean. Some salmon stocks move through to the ocean in just a few days, while others forage in shallow embayments and backwater sloughs for months, and still others reverse their downstream migration and re-enter freshwater streams for a time. The rich foraging opportunities in estuary habitats promote rapid growth of juvenile salmon. Research has shown that rapid estuarine growth and the resulting larger size of juvenile salmon when they enter the ocean result in increased ocean survival rates (Reimers 1973; Solazzi et al. 1991).



III. ESTUARY ASSESSMENT

A. Concepts and approach

This assessment is designed to comprehensively identify, characterize, and prioritize tidal wetlands within individual Oregon estuaries south of the Columbia. The method is intended for use within a single estuary, not for prioritizing wetlands across different estuaries. Tidal wetlands are defined as those wetlands that are periodically flooded by tidal waters (see **Glossary**). This assessment excludes tidal flats, eelgrass beds, and algal beds. Although tidal flats are biologically important, they are fundamentally different in their land use history and management, and cannot be addressed using the techniques in this module.

This assessment uses existing data and generates new data to locate current and former tidal wetlands in the estuary. No single existing data source provides a comprehensive inventory of current and former tidal wetlands, so a combination of resources will allow you to identify the historic extent of tidal wetlands (defined in **Critical questions** below). Defining the limits of tidal influence in the upper estuary is particularly challenging. However, the biological benefits of tackling this challenge will be particularly great, in part because this area is considered particularly important to juvenile salmon (Simenstad and Bottom, 2004).

After you have identified the historic extent of tidal wetlands, the next step is to assess alterations to these areas. Your assessment of alterations will allow you to define analysis units called "sites," based on ecological factors and action planning needs. The final step, **Site Prioritization**, ranks these sites for restoration and conservation actions.

B. Critical questions

1. What was the historic extent of tidal wetlands within the estuary?

For the purposes of this assessment, "historic" means prior to European settlement. Determination of the historic extent of tidal wetlands is critical for four purposes: 1) To identify and characterize tidal wetlands that have not yet been identified in any existing study; 2) To determine what proportion of pre-settlement tidal wetlands have been lost or converted to other wetland types; 3) To calculate the relative loss of different types of tidal wetlands; and 4) To find appropriate locations for restoration of each of the tidal wetland types.

A variety of information sources will contribute to your map of the historic extent of estuarine wetlands. Your starting point will be a map of tidal and potentially tidal wetland sites (Scranton 2004) developed for Volume 3 of the Hydrogeomorphic Guidebook for Tidal Wetlands of the Oregon Coast (Adamus 2005b). Additional resources will help you refine this map, including National Wetlands Inventory mapping, Oregon Estuary Plan Book habitat maps, historic vegetation mapping, aerial photographs, field observations and conversations with local landowners and residents.

Even though the resources used in this assessment originated at a variety of scales with varied mapping techniques, and had varied goals, they can be combined to evaluate historic extent because of the distinct hydrology and geomorphology of tidal wetlands. Tidal flows create distinct channel morphology, plant communities, soils, and other landscape forms and features. In many cases, such indicators of tidal influence remain evident long after a site is diked or otherwise altered, making it possible to map current and former tidal wetlands.

2. What alterations have occurred that reduce tidal wetland functions?

This question is important because restoration involves removal or modification of alterations that reduce estuary functions. In addition, each alteration is a potential restoration opportunity, so your assessment of alterations will help you build a restoration action plan.

Your first step in assessing alterations will be examination of existing data such as the Oregon Estuary Plan Book and the National Wetlands Inventory. However, the core of your assessment of alterations will be new data you generate through aerial photograph analysis, field work, and local knowledge. Your goal will be to identify alterations to tidal wetlands, particularly those that have restricted tidal flow.

3. What restoration and conservation opportunities exist that could help restore impacted tidal wetland functions?

Restoration has been defined as the return of an area to its pre-disturbance conditions (National Research Council 1992). Thus, restoration often consists of identifying and removing disturbances (alterations). Step 2 will identify alterations, which represent potential restoration opportunities. Restoration opportunities will range from more intensive actions (like dike removal, meander restoration, and ditch filling) to less-intensive actions (e.g. grazing reductions, riparian fencing and plantings).

Theoretically, restoration opportunities exist wherever there have been alterations to the estuary. Practically speaking, opportunities actually exist only when a landowner is willing and interested. Economic considerations are often central to these restoration decisions. Economic analysis is beyond the scope of this assessment, but suggestions are found in Appendix E4, **Further Analyses**.

In this module, the term "conservation" is used to refer to any voluntary action that protects, preserves and manages existing resources. Examples include conservation easements and land acquisition for conservation purposes. Identification of conservation opportunities will flow naturally from Steps 1 and 2. By identifying the historic extent of tidal wetlands and then evaluating alterations, your analysis will locate those tidal wetlands that remain relatively unaltered. These wetlands offer conservation opportunities.

No organization has unlimited funds to accomplish restoration and conservation goals, so prioritization of opportunities is needed. Prioritization is the final step of this module, highlighting those opportunities that offer high potential for biological benefits. The prioritization focuses on biology, but it also includes supplementary analyses of non-biological factors that affect restoration decision-making, such as number of landowners, land ownership type, and regulatory context.

C. Materials needed

The following materials are needed for the estuary assessment. You may use either a GIS (Geographic Information System) for your analysis, or paper maps and overlays. Sources for both types of data are listed below; materials are listed in the order in which they are used.

A good starting point for much of this information is the Oregon Coastal Atlas website (http://www.coastalatlas.net). Other sources are listed below.

Existing studies specific to your estuary. These documents describe resources in a specific estuary. Examples include Benner (1992, Coquille); Coulton et al. (1996, Tillamook); Simenstad et al. (1999, Tillamook); Brophy (2002, Nestucca and Siletz); Brophy (2001, Siletz); and the Oregon Estuary Inventory series (ODFW 1979). These documents are available at Oregon State University system libraries (http://oasis.orst.edu).

Existing tidal wetland prioritizations for Oregon. Comprehensive prioritizations following methods similar to those in this module have been completed for the Nehalem, Yaquina, Alsea, Siuslaw, Umpqua, Smith, Sixes and Elk River estuaries (Brophy 2005; Brophy 2003a; Brophy 1999; Brophy and So 2005a, b, c). Reading these prioritizations will help you conduct estuary assessments in other estuaries. Most of these reports are available at the Green Point Consulting website, http://www.greenpointconsulting.com/reports.html. Scranton (2004), Simenstad and Feist (1996) and Lebovitz (1992) characterize potential tidal wetland restoration and conservation sites in multiple estuaries. These documents are available at Oregon State University system libraries (http://oasis.orst.edu).

USGS topographic maps (7.5 minute maps, 1:24,000 scale). Use the USGS maps you have gathered for other portions of the assessment. For this module, you will need USGS maps to cover all lowlands (up to about the 40' contour) adjacent to tidal water bodies, from the ocean up to head of tide (see previous paragraph). For tidal streams where DSL does not list head of tide, acquire USGS maps up to where the 40' contour crosses the stream. Obtain USGS topographic maps online from the Oregon Coastal Atlas (http://www.coastalatlas.net), from the USGS Map Store (call 1-888-ASK-USGS), or from local bookstores or map suppliers.

Head of tide for the mainstem river and for all tributaries. "Head of tide" is the upstream limit of tidal influence in a river channel or other waterway. A list of heads of tide is available on the Oregon Department of State Lands website, (http://egov.oregon.gov/DSL/NAV/tidally.shtml). A digital version can be obtained from the Oregon Coastal Atlas (http://www.coastalatlas.net). Head of tide is not shown for all tributaries; local knowledge will help you determine head of tide for streams missing from the DSL database.

Tidal wetlands map (Scranton 2004) developed for Volume 3 of the Hydrogeomorphic Guidebook for Tidal Wetlands of the Oregon Coast (Adamus 2005b). The Guidebook is a functional assessment method developed for use in Oregon tidal wetlands (see Monitoring section for details). The tidal wetland map (called the "HGM map" in this module) will be your base map for this assessment. The HGM map shows tidal wetlands and potentially tidal areas; it requires field verification (which this method provides). You can download a GIS version of this mapping from the Oregon Coastal Atlas. Search for "Scranton" on the GIS search page, or download directly at http://www.coastalatlas.net/download/shapes/tidal_marsh.zip). For printable PDF maps of individual estuaries, email the Oregon Coastal Atlas project (CoastalAtlas@lists.oregonstate.edu).

The Oregon Estuary Plan Book. Hard copies of this report can be found in libraries. GIS data layers are available from the Oregon Coastal Atlas, http://www.coastalatlas.net.

National Wetlands Inventory (NWI) maps. You will need NWI maps to cover the entire historic extent of your estuary. See the *Riparian/Wetlands Assessment* component of the Watershed Assessment Manual for information on obtaining NWI maps. If you have access to GIS, you can obtain digital NWI maps free online at the NWI Wetlands Digital Data website, http://wetlandsfws.er.usgs.gov/NWI/download.html. Availability of digital NWI data is changing rapidly, so check frequently for updates. You can also get paper copies of NWI maps from the Oregon Department of State Lands; use the order form at http://www.oregon.gov/DSL/WETLAND/docs/nwi_map_order.pdf, or call (503)378-3805.

Local Wetlands Inventories reports and maps (LWIs) within your study area (if any). LWIs are more accurate and higher-resolution than NWI maps. To determine whether Local Wetlands Inventories have been conducted in your study area, and to obtain the reports, contact your City Planning department, check the Oregon Department of State Lands LWI web page at http://www.oregon.gov/DSL/WETLAND/lwi.shtml, or contact Heather Howard at the Oregon Department of State Lands, 503-378-3805 ext. 235.

Oregon Natural Heritage Information Center historic vegetation mapping for the Oregon Coast at a scale of 1:24k (Hawes et al. 2002). This is not available as paper mapping, but a GIS shapefile or coverage can be obtained from John Christy at the Oregon Natural Heritage Information Center, 503-731-3070 ext. 108. Be sure to ask for the 1:24,000 scale mapping of the coast, not the 1:100,000 statewide mapping.

The Natural Resource Conservation Service (NRCS) soil survey for your area. Paper copies of soil surveys can be obtained from your local Soil and Water Conservation District (SWCD), or your local NRCS service center. Find your area service center in your phone book, online at the USDA Service Center Locator (http://offices.sc.egov.usda.gov/locator/app), or by calling Gail Culver at the state NRCS office, 503-414-3012. Obtain GIS soils data from the NRCS Oregon Soil Survey Data website, http://www.or.nrcs.usda.gov/pnw_soil/or_data.html.

Historic and current aerial photographs of your estuary *[see sidebar on aerial photo sources]*. Contact prints are recommended for the aerial photo interpretation tasks in this assessment. Photos taken at low tide provide the most useful information on site features; for example, they show tidal channels through mudflats that are not visible at high tide.

- Obtain the largest-scale current aerial photographs you can find for your study area. A contact print scale of 1:12,000 (1"=1000'), such as the BLM's cyclic aerial photography, is good. Contact prints at 1:24,000 (1"=2400'), such as the 2001 Army Corps coastal flight, are less useful. Talk with others about your quest for aerial photographs; federal and state agencies may have aerial photography that is well-suited for your use.

- Aerial photograph contact prints are most useful as stereo pairs, viewed with a magnifying stereoscope. The topographic relief visible in stereo view will help you interpret water flow patterns and see alterations like dikes and fill.

- If you are using a GIS, digital orthophotos (often called DOQs or "digital orthoquads") are very important to your assessment. You can use DOQs to evaluate general levels of alteration, and to match locations in the GIS and with your aerial photo prints.

Laminated aerial photographs. Make a set of copies of your most recent, largest-scale aerial photographs and laminate them for use in the field. You may want to enlarge the photos so you have more room for annotations.

Waterproof fine-point markers for marking on aerial photograph laminates. "Lumocolor" mylar markers work best; extra fine point "Sharpie" markers are also suitable.

Tide tables for your local area.

Global positioning system (GPS) for recording locations of field observations.

Mapping of streams, rivers and other water bodies (hydrography) at 1:24k scale or better (from other modules of the watershed assessment). Use the most detailed mapping available. These data will help you understand water flow patterns within your estuary.

Field observation and interviews with local landowners and other knowledgeable about local conditions and land use history. Detailed instructions below provide specifics on information needed.

Sources for Aerial Photographs

Historic aerial photos. The University of Oregon Map and Aerial Photography Library maintains a collection of historic aerial photographs. Details can be found at the Library's website, http://libweb.uoregon.edu/map/orephoto/index.html. However, not all photos are described on the web page, so it's best to contact the map library at (541)346-4565 or map@uoregon.edu.

U.S. Army Corps of Engineers aerial photography. Information can be found at the ACE Portland district's aerial photography web page, https://www.nwp.usace.army.mil/EC/ap.asp; or contact Chris Edwards, Portland District, U.S. Army Corps of Engineers, (503) 808-4820.

BLM aerial photography. BLM imagery is available for much of Oregon's central and south coast. Recent photos have been flown at a scale of 1:12,000 (1"=1000') in true color stereo pairs. Information is available at the BLM Aerial Photography Reproduction and Archive web page (http://www.blm.gov/nstc/aerial/index.html), or contact Connie Slusser, BLM National Science and Technology Center, 303-236-7991, constance_slusser@blm.gov.

Digital orthophotos. Black and white digital orthophotos, which can be used in a GIS, are available at the Oregon Coastal Atlas, http://www.coastalatlas.net. New, higher-resolution digital orthophotos were acquired in 2005; they will be made available online at the Oregon Explorer website (http://oregonexplorer.info/). See the Oregon Geospatial Enterprise Office 2005 orthoimagery update web page, http://www.oregon.gov/DAS/EISPD/GEO/coordination/ortho_2005.shtml, for details.

D. Necessary skills

This module assumes the following skills:

- Ability to use and understand the HGM (hydrogeomorphic) tidal wetlands mapping. Basic information on this resource is found in this module and in Appendix E6, but additional knowledge would be useful.

- Ability to use and understand the following maps: NRCS soil survey maps, USGS topographic maps, and National Wetlands Inventory maps (see the **Riparian/Wetlands Assessment** module for more information).

- Ability to interpret aerial photographs, both prints and digital versions. Skill with a stereoscope (and access to a mirror stereoscope, preferably a magnifying scope) is especially useful.

- Ability to use a dot grid to calculate area of sites (not needed if using GIS).

- GIS skills and equipment are desirable but not assumed.

E. Final Products

Your assessment will produce the following products:

Map E1:	Historic tidal wetlands
Map E2:	Map of tidal wetland restoration and conservation sites
Map E3:	Tidal wetland prioritization
Forms E1-A, E1-B:	Indicators of tidal influence – Parts 1 and 2
Form E2:	Field observations: Hydrology
Form E3:	Field observations: Vegetation
Forms E4-A, E4-B:	Alterations to tidal wetlands – Parts 1 and 2
Form E5:	Conservation sites
Form E6:	Restoration sites
Form E7:	Landowner information
Form E8:	Prioritization scoring
Form E9:	Tidal channel condition scoring

F. Assessment method

Figure 8 shows the key steps and products of the assessment process. The process starts by acquiring the tidal wetland map (called the "HGM map" in this module) from the Hydrogeomorphic Assessment Guidebook for Tidal Wetlands of the Oregon Coast (http://www.coastatlas.net) This is the base map needed to start this assessment. The HGM map shows tidal wetlands and potentially tidal areas; it requires field verification (which this method provides).

Step 1 of your assessment is determination of the historic extent of tidal wetlands in the estuary. The first task is to locate areas that have already been mapped as tidal wetlands in existing resources starting with the HGM map and other resources like the NWI. Next, aerial photos, fieldwork, and local knowledge will help you determine the likelihood of tidal influence in areas that have not previously been mapped as tidal wetlands, producing a map of historic tidal wetland extent (Map E1).

Step 2 identifies alterations to the historic estuary. Your assessment of historic extent (Step 1) and alterations (Step 2) will produce a map showing both altered and relatively unaltered tidal wetlands (Map E2).

Step 3 involves grouping and subdividing the areas in Map E2 into units of analysis called "sites" that will be prioritized for conservation and restoration actions in Part IV of this module.

IMPORTANT: *In practice, steps 1-3 are not conducted sequentially, but iteratively. For efficiency, observe indicators of tidal influence and alterations, and use your observations to define analysis units. The recommended procedure is:* **First, read the instructions for Steps 1 through 3. Second, complete Steps 1-3 in a portion of your assessment area that contains both altered and relatively unaltered wetlands. Third, proceed to the next subarea using your experience from the first area to guide you. As you become more knowledgeable, you may wish to revise site definition and characterizations for areas you worked on first.**

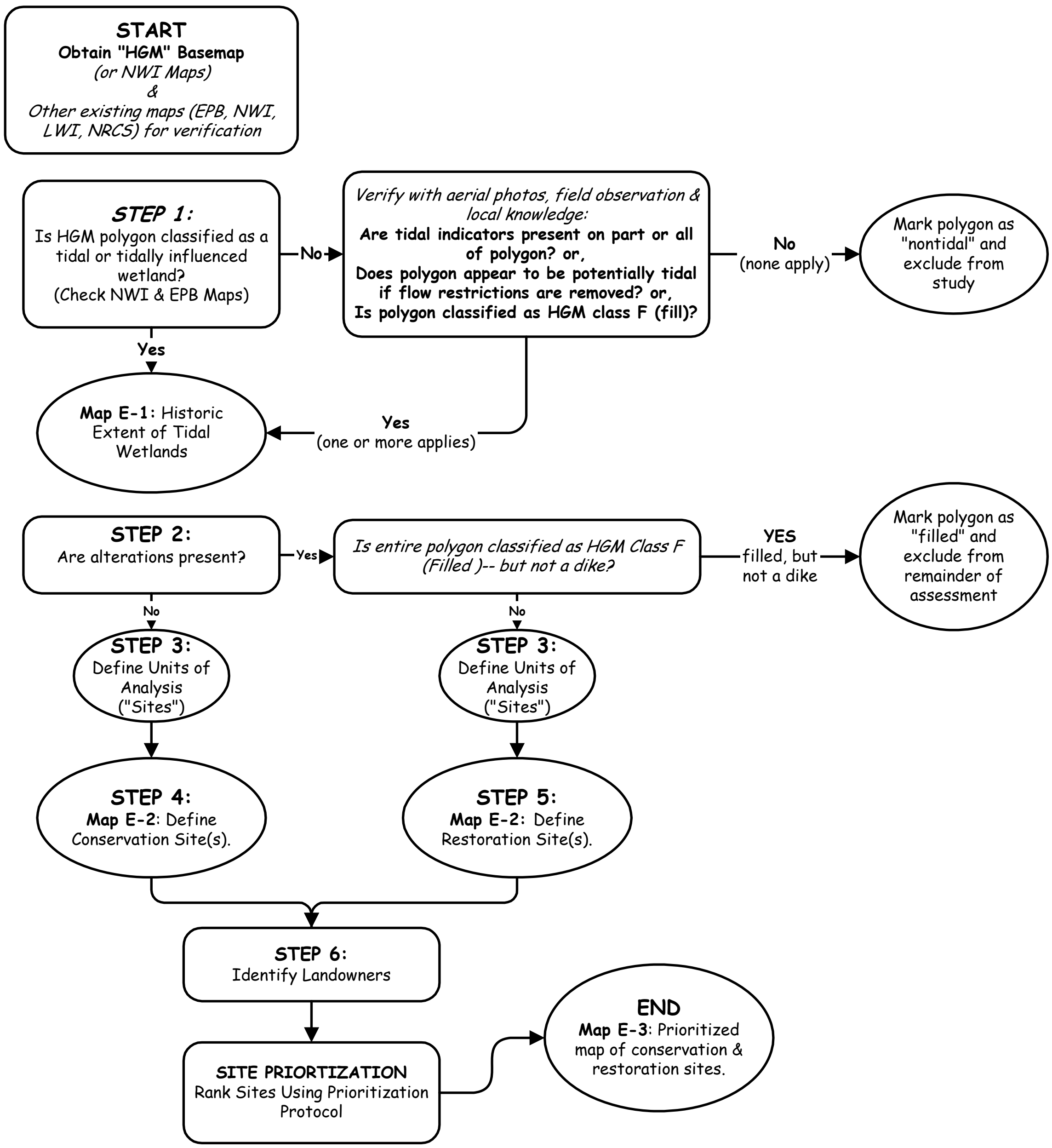


Figure 8: Assessment Process Flow Chart.

STEP 1: IDENTIFY THE HISTORIC EXTENT OF TIDAL WETLANDS

Assessing the original extent of the estuary (for this analysis, defined as current and former tidal wetlands) is a challenging task. Upper tidal areas – the brackish and freshwater tidal wetlands – have been little studied in Oregon. Many of these upper tidal wetlands have been converted to agriculture and are no longer easily recognizable as former tidal wetlands. On the downstream end of the estuary, coastal development has obscured many of the landforms and features that could otherwise have been used to identify the original estuarine habitats.

This step will identify the "pre-settlement" extent of the estuary, producing a map of historic tidal wetland areas. Your starting point will be a map of tidal and potentially tidal wetland areas (Scranton 2004) developed for Volume 3 of the Hydrogeomorphic Guidebook for Tidal Wetlands of the Oregon Coast (Adamus 2005b). The Scranton map is referred to in this module as the "HGM map." The HGM map shows tidal wetlands and potentially tidal areas; it requires field verification (Adamus 2005b), which this step provides. Additional resources (such as the Oregon Estuary Plan Book, wetland inventory maps, historic vegetation data, aerial photographs, and local knowledge) will allow you to refine the HGM map by analyzing the likelihood of tidal influence in each area. You will use forms E1-A and E1-B to record and summarize your data.

GIS tip: *When entering data during this part of the assessment you can use paper data sheets, an electronic spreadsheet, or a GIS (Geographic Information System). If you use GIS, look for the GIS field names in each step where you enter data. Suggested GIS field names are shown in the blank forms at the end of this module. GIS data may be coverages, shapefiles, or geodatabases. The term 'shapefile' and 'layer' will be used to refer to all GIS data sources.*

Orientation

Existing studies

Before you begin your analysis, review any existing reports that describe your estuary's resources (see **Materials needed** above). These will provide an overview of your study area, and may provide specific details that will improve the accuracy of this assessment.

USGS topographic maps

USGS topographic maps will provide orientation and landscape perspective for your mapping work. Assemble your USGS maps in order from downstream to upstream along the mainstem river and tributaries. You may find it easiest to tape together selected USGS topographic maps to provide the "big picture" while keeping map size manageable.

Head of tide

Referring to the DSL head of tide data and your USGS topographic map, mark heads of tide on your HGM base map. Mark head of tide for the mainstem river and for all tributary streams where this information is available. Where head of tide is given as a section (e.g. T21S R11W Sec. 3) rather than a river mile, mark head of tide at the upstream end of that section, and ask local residents to help you improve your accuracy. Mark the head of tide as a thick black line straight across the river or stream.

HGM map preparation

The HGM map (Scranton 2004) will serve as your base layer for this assessment, because it provides the most complete mapping available of existing and potential tidal wetlands. The HGM map was developed from a variety of sources. Note that the HGM map includes diked and otherwise altered areas, so some of the HGM mapped areas are no longer tidal, and some may no longer be wetlands.

To keep the steps in this assessment clear, the HGM mapped areas will be referred to as the "HGM polygons" in this module. **However, it is important to remember that this refers to actual land areas, not abstractions.** Your analysis will characterize the "HGM polygons" (either individually or as groups), then lump and split them as needed to form appropriate analysis units ("sites") for your prioritization.

IMPORTANT: If your study area contains many HGM polygons (e.g., over 100) you can group HGM polygons that share key characteristics (particularly level of alteration) into analysis units called "sites." You can then characterize these sites rather than individual HGM polygons. (However, if the number of HGM polygons in your study area is small -- e.g., under 100 -- you should characterize each polygon separately.)

In reality, the process of characterizing and grouping HGM polygons is iterative. For example, you need to be able to recognize alterations in order to group polygons for analysis. Therefore, the recommended procedure is to carefully read Steps 1-3, then <u>complete all three steps for a small portion of your study area</u> that contains both altered and relatively unaltered wetlands. Next, proceed to another subarea, using your experience from the first subarea to guide you. As you become more knowledgeable, you may wish to revise site definition and characterizations for areas you worked on first.

In Steps 1 and 2 of this module, the term "HGM polygon" can refer to either a single polygon or a group of polygons ("site").

The HGM mapping will be most useful to you as a GIS layer or a 1:24,000 mylar overlay, so that you can view the USGS topographic maps and other data "beneath" the HGM mapping. Display the HGM polygons according to the attribute "HGM class." The classification scheme is shown in Table 1 below.

Table 1. HGM base map classification (Scranton 2004). Classes assessed in this module are in bold.

Class	Class name	Description
MSL	**Marine-sourced low marsh**	Salt marsh or brackish marsh generally inundated daily. In the HGM guidebook, MSL is equivalent to NWI class E2EMN and EPB class 2.5.11.
MSH	**Marine-sourced high marsh**	Salt marsh or brackish marsh inundated less than once per day (but usually at least once per month). In the HGM guidebook, MSH is equivalent to the NWI class E2EMP and EPB class 2.5.12.
RS	**River-sourced tidal wetland**	Marshes and swamps along river channels that are flooded by tides at least once annually and receive little or no marine water.
PF	**Potential tidal forested wetland**	Forested lands in the upper estuary likely to receive tide-related inundation at least once annually.
RCA	**Restoration consideration area**	Hydrologically altered areas that may have geotechnical potential for restoration of tidal circulation; also, areas where tidal status could not be determined during the course of Scranton's thesis (Scranton 2004).
F	**Fill (filled former tidal wetland)**	Areas filled and/or compacted for human use.
W	Open water	Water and tidal channels
NT	Nontidal (palustrine) wetland	Non-tidal wetlands
UN	Unconsolidated sediments	Gravel bars, beaches or dunes
UP	Not wetland	Uplands

For further descriptions of these classes, see Appendix E2. This assessment addresses only those HGM polygons classified as MSL, MSH, RS, PF, RCA, and Fill. Therefore, your first step is to delete all HGM polygons that have other classifications.

Working on your HGM overlay, delete (cross out) all HGM polygons classified as Nontidal wetland ("Palustrine"), Unconsolidated, Water, and Upland. Retain all HGM polygons classified as Marine-sourced high tidal wetland ("MSH"), Marine-sourced low tidal wetland ("MSL"), River-sourced tidal wetland ("RS"), Potential forested tidal wetland ("PF"), Restoration Consideration Area ("RCA"), and Fill.

To help you track data about each HGM polygon, mark each HGM polygon with its unique identifying code from the HGM database, written as "HGM-[id code]" (for example, "HGM-354" for HGM polygon #354). (GIS users: This is the field "Object_ID" in the HGM attribute table.) As you characterize the polygons, you will be recording these ID codes in Column 1 of Form E1-A and Column 12 of E1-B. If you wish, you may also define a project ID code for each polygon or group of polygons (Column 2 of Form E1-A). An example of a project-specific ID would be a site number (see Step 3 below).

Note: In some cases, you may find that only a portion of an HGM polygon shows tidal indicators; in this case, simply assign the indicator to the entire HGM polygon. In later steps, you will subdivide or group the HGM polygons into analysis units that will allow more detailed characterization.

> ***GIS tip**: Create a new shapefile named "MapE1" by making an exact copy of the HGM layer. This is your base layer for this module. Delete all HGM polygons classified as Nontidal wetland ("Palustrine"), Unconsolidated, Water, and Upland. Retain all HGM polygons classified as Marine-sourced high tidal wetland ("MSH"), Marine-sourced low tidal wetland ("MSL"), River-sourced tidal wetland ("RS"), Potential forested tidal wetland ("PF"), Restoration consideration area ("RCA"), and Fill ("F").*

Identify "likely tidal" areas

HGM base layer

Enter the HGM class for each polygon in Column 5 of Form E1-A. Polygons classified as MSH and MSL in the HGM base layer can be assumed to be tidal wetlands. For these polygons, enter "Y" in Column 6 of Form E1-A. For all other HGM classes, enter "N" in Column 6. (Entering "N" in Column 6 does not indicate the area is nontidal -- just that further data are needed to determine its tidal status.)

Oregon Estuary Plan Book

Many of the HGM polygons are shown in Estuary Plan Book (EPB) habitat maps, particularly in the lower estuary. EPB habitat type codes are explained in Appendix E2. If any part of an HGM polygon is shown in the Estuary Plan Book habitat map, enter "Y" in Column 7 of Form E1-A, and record the EPB habitat type code(s) in Column 8. If an HGM polygon is not shown on the EPB map, enter "N" in Column 7 of Form E1-A.

Examples of EPB habitat codes are "2.5.11" for low marsh, "2.5.12" for high marsh, and "2.5 D" for diked tidal marsh. Figure 9 shows an example of EPB habitat mapping; Appendix E2 contains a key to EPB habitat codes.

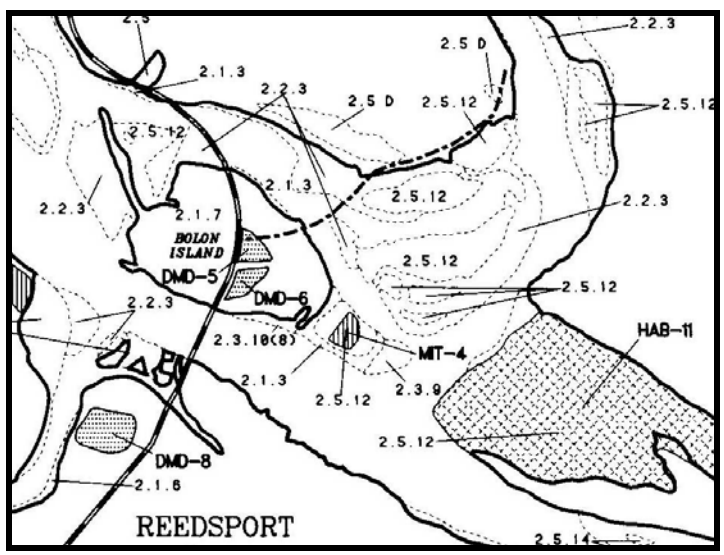


Figure 9. Example of Estuary Plan Book habitat mapping. See Appendix E7 for codes.

GIS tip: In the attribute table of your "MapE1" shapefile, create new fields to match those in Form E1-A and E1-B. Suggested field names of 8 characters or less are shown on the forms. For any HGM polygons shown in the EPB habitat maps, enter "Y" and the EPB habitat codes in the field "EPB_CD." Enter "N" if the polygon is not shown on the EPB map. You may find that the EPB layer does not register (line up) with other layers; if so, use your judgment in interpreting which EPB polygons correspond to your HGM polygons.

National Wetlands Inventory (NWI)

Most of the HGM polygons are shown on National Wetlands Inventory maps (example, Figure 10). This step analyzes NWI maps for areas that are defined as tidal in the NWI; your results will be recorded in Form E1-A.

Most tidal wetlands are classified in the NWI as Estuarine Intertidal (code "E2"). Thus, any area on the NWI map that is marked with a code beginning with "E2" is very likely a tidal wetland. The next two letters in the code indicate the type of vegetation. "EM" indicates emergent vegetation (nonwoody plants like grasses, sedges and bulrushes). "SS" indicates woody shrubs under 6m tall, like willows. "FO" indicates forested wetland. A single, final capital letter after the vegetation class indicates the water (flooding) regime. "N" indicates regularly flooded, and P=irregularly flooded. Examples of full codes include:

E2EMN = Estuarine intertidal emergent wetland, regularly flooded

E2SSP = Estuarine intertidal scrub-shrub wetland, irregularly flooded

Freshwater wetlands with tidal influence ("freshwater tidal" wetlands) fall into the Palustrine category in the NWI mapping. These have codes beginning with "P". Subsequent code letters may be "EM", "SS" or "FO" as for the estuarine system. A final capital letter indicates the tidal flooding regime: S=temporarily flooded (tidal), R=seasonally flooded (tidal), and T=semipermanently flooded (tidal), and V=permanently flooded (tidal). Other final capital letters (such as A, B, C, D, W, Z) are used for nontidal freshwater wetlands (see next paragraph).

Many diked or otherwise altered former tidal wetlands are shown in the NWI as palustrine (freshwater) wetlands with codes beginning with "P" but lacking the tidal water regime codes. The second and third letters of these codes are "EM", "SS" and "FO" as described above. The fourth letter indicates the nontidal water regime; common codes are "C" for seasonally flooded and "A" for temporarily flooded. Some of the altered, former tidal wetlands have "modifiers" at the end of the NWI code indicating the alterations that removed them from tidal status, but some do not. Modifiers indicating alterations include:

d = partially drained/ditched

f = farmed

h = diked/impounded

s = spoil (i.e., fill material in the wetland resulting from excavation elsewhere)

x = excavated

If a modifier is present, it is entered in lower case after the water regime classification. For example, "PEMCh" indicates a diked palustrine emergent seasonally flooded wetland, and "PFOCd" indicates a ditched forested wetland. The modifier "b" indicates beaver-dammed, a common phenomenon in the transition zone from tidal to nontidal wetlands.

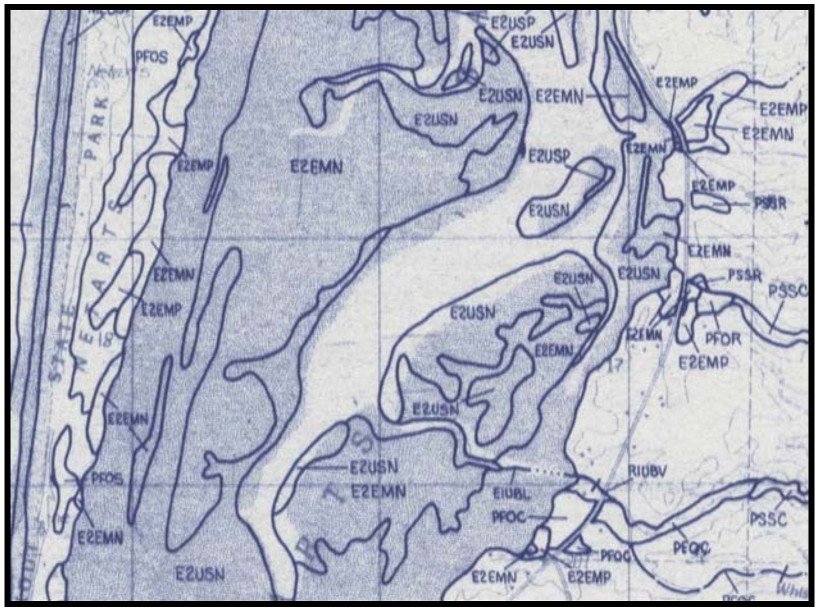


Figure 10. Example of National Wetland Inventory (NWI) mapping. See Appendix E7 for codes.

An example of an NWI map is provided in Figure 10. Appendix E2 includes a key to NWI codes. For more detailed descriptions of the NWI mapping program, visit the NWI web page at http://www.nwi.fws.gov/.

In Form E1-A, record all of the underlying NWI classifications for each HGM polygon in Column 9, including any modifiers. Some HGM polygons may be classified as upland on the NWI map; if so, enter "U" in Column 9. **If the NWI contains polygons that are missing from the HGM base layer which you feel should be included in your map, this is the time to add them. Assess these polygons just as you do the HGM polygons from this point on.**

GIS tip: *Enter the NWI codes for each polygon in the field "NWI_CD."Add to your layer any NWI polygons that you think may possibly be tidal wetlands, but which are missing from the HGM base map, and analyze them following the same methods from this point on.*

If any of the underlying NWI codes for a polygon indicate tidal influence (code begins with E, or code contains a tidal water regime modifier code of R, S, T, or V) enter "Y" in Column 10 of Form E1-A. If any of the underlying NWI codes have the modifier "h," indicating diking, enter "Y" in Column 10 of Form E1-A. (The "diked" modifier indicates the area may have been tidally influenced in the past. Obviously, not all NWI diked wetlands are former tidal wetlands, but within the HGM mapping area, this is a fairly reliable indicator of former tidal status.) If none of the above apply, enter "N" in Col. 10.

GIS tip: *If any of the NWI codes indicate tidal influence or diking, enter "Y" in the field "NWI_TID;" otherwise, enter "N."*

Local Wetlands Inventory (if any)

If a Local Wetlands Inventory (LWI) has been conducted for part of your study area, obtain a copy. LWIs use the same classification system as the National Wetlands Inventory (NWI), but the accuracy is higher. Follow the NWI analysis procedures described in the previous section, but use the LWI instead of the NWI. Record your results in Columns 9 and 10 of Form E1-A, noting the data source as "LWI."

Summarize "likely tidal" areas from HGM, EPB and NWI

The HGM polygons for which you have just entered 'Y" in Column 6, 7, or 10 of Form E1-A are those mapped as tidal wetlands in the HGM, EPB and NWI maps, or shown as diked wetlands in the NWI. These wetlands are very likely to have been part of the historic extent of tidal wetlands in your study area. Give these polygons a "tidal score" of 10 in Column 22 of Form E1-B, and record their tidal status as "Y" in Column 23. These polygons will definitely be shown on your product from this step (see **Map E1, Historic extent of tidal wetlands** below).

For these "likely tidal" polygons, you have only one remaining analysis within the "historic extent" section of this assessment – determination of **Historic vegetation type** (next step). After that, you can skip the rest of Step 1 and move directly to Step 2 (**Assess alterations to tidal wetlands**). For polygons marked "N" in Column 6, 7, and 10 of Form E1-A, you need to continue with the rest of Step 1 to determine the likelihood that the polygon is or was once a tidal wetland.

Analyze other tidal status indicators

The rest of this section focuses on using other data sources to determine tidal status. Please note that analyses 2 through 4 **(Soil survey mapping, historic and current aerial photo interpretation, and field observation/local knowledge**) are not required for polygons marked "Y" in either Columns 6, 7, or 10 of Form E1-A. However, conducting these analyses for all polygons will increase your understanding of the estuary.

1- Historic vegetation type

This step uses historic vegetation maps to help you locate tidal wetland areas and determine their former vegetation type. You will need this information to conduct your prioritization (Step 3 of this assessment), even if you have already determined that certain polygons are current or former tidal wetlands. So, don't skip this step even if you marked "Y" in Column 6, 7, or 10 of Form E1-A.

Historic vegetation mapping (Hawes et al. 2002) from the Oregon Natural Heritage Information Center (ORNHIC) identifies areas that were historically tidal marsh and tidal swamp. Tidal swamp (forested or scrub-shrub tidal wetland) is a type that was once common in Oregon's upper estuaries, but is now almost completely converted to other uses, so it is of special interest for this assessment.

Using the ORNHIC historic vegetation map, check each HGM polygon for areas mapped as "tidal marsh." This vegetation type is abbreviated "WSM" in the field "VEG_ABB" in the ORNHIC layer; the description "tidal marsh" is found in the field VEG_TEXT. (This is the only vegetation type found in the ORNHIC map that is explicitly tidal.) If there is any area of ORNHIC historic tidal marsh within the HGM polygon, enter "Y" in Column 11 of Form E1-A (GIS field

ONHP_TID). These areas are very likely to have once been tidal wetlands, so assign these polygons a score of 10 in Column 22 of Form E1-B if you have not already done so in earlier steps. (Note that many areas that were once tidal marsh are not specifically classified as tidal marsh in the ORNHIC mapping, but instead are coded as "wet prairie," "wet meadow," etc. These will be identified in other steps.)

Next, check each HGM polygon for areas classified by ORNHIC as swamp (forested or scrub-shrub wetland). ORNHIC abbreviations for swamps are shown in Table 2 below. (Swamp types found on the Oregon coast, but not intersecting with the HGM base layer, were omitted.) Enter "Y" in Column 13 of Form E1-B (GIS field ONHP_SMP) if a polygon contains any of these vegetation types. Note that not all areas mapped as swamp were tidally influenced; your other information sources will help you eliminate nontidal swamps from your map.

Table 2. List of forested and scrub-shrub wetland types contained in the ORNHIC historic vegetation layer.

Description (ORNHIC field VEG_TEXT)	**Abbreviation** (ORNHIC field VEG_ABB)
Ash-alder-willow swamp	FALW
Red alder swamp	FL
Sitka spruce swamp	FSL
Crabapple swamp	HC
Brush fields or thickets on bottoms or wet terraces	HD
Shrub swamp, composition unknown	HSS
Willow swamp	HW
Sitka spruce swamp with scattered spruce and dense shrub understory	OFSL
Mixture of shore pine swamp and undifferentiated "marsh"	WSP
"Swamp," composition unknown	WSU

If you entered "Y" in Column 13 but Columns 6, 7 and 10 of Form E1-A are empty or marked "N", also mark "Y" in Column 3 (field check needed – GIS field FLDCK_RQ). Because some historic swamp sites in the upper estuary may have been nontidal, fieldwork is needed for these areas.

2- Soil survey mapping

[You may skip this step for polygons marked "Y" in Column 6, 7, 10 or 11 of Form E1-A.]

Soil survey maps can provide important clues to additional areas of current or former tidal influence. Although tidal influence is not explicitly marked on soil survey maps, historic tidal influence is evident in soil characteristics.

High likelihood of tidal influence: Soils in the following series are likely to have been formed under tidal influence, and are generally located at elevations where tidal influence may be present or restorable (Thor Thorson, NRCS, and Herb Huddleston, OSU, personal communication). This list covers the entire Oregon coast, so not all of these soils will be found in your study area:

- Bragton
- Chetco
- Coquille and variants
- Fluvaquents-histosols complex (also found in nontidal areas)
- Brallier and variants
- Clatsop
- Coquille-Clatsop complex
- Langlois

If any of your HGM polygons contain any of the above soil types, enter "Y" and list the tidally influenced soil types in Column 14 of Form E1-B (GIS field SOIL_TID). Otherwise, enter "N" in this column.

3- Historic and current aerial photograph interpretation

[You may skip this step for polygons marked "Y" in Column 6, 7, 10 or 11 of Form E1-A.]

Starting with the earliest historic aerial photographs you can obtain, and continuing through the most recent available aerials, check each HGM polygon for indicators of tidal influence.

As you find indicators of tidal influence in aerial photos, you will be marking their locations on your laminated aerial photographs (or digitizing them in your GIS), and recording them in Form E1-B. The indicators are described below.

First, train yourself by examining areas that are currently identified as tidal wetlands in the EPB and NWI mapping. Look for the sinuous, winding channels typical of Oregon tidal wetlands (Figure 11). Active channels are well-defined, whereas old remnant channels look somewhat "blurry" on

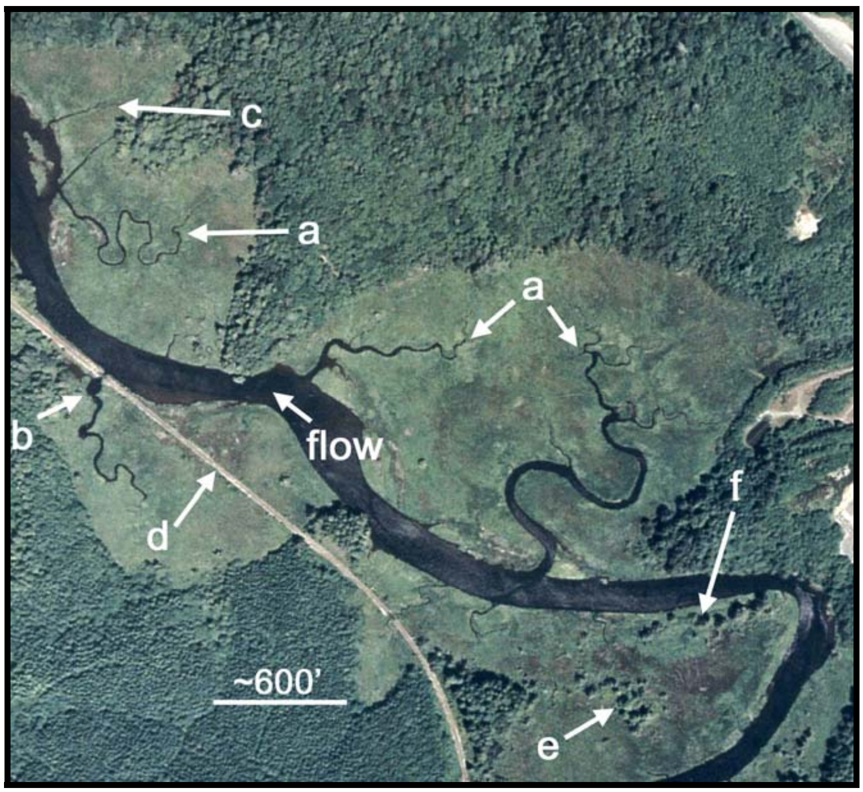


Figure 11. Undiked tidal marsh in an Oregon south coast estuary, showing channel features and small area of tidal swamp.

Labeled features: a = typical meandering tidal channels, b = turbulence pool caused by tidal flow restriction at railroad crossing; c = minor ditching in relatively undisturbed marsh; d = railroad embankment which alters diffuse surface flow; e = small area of tidal swamp; f = Sitka spruce and shrubs on natural levee.

aerial photos. Examine your hydrography layer (streams mapping) to see where streams flow into the estuary. One type of channel that is a particularly good indicator of tidal influence is the "blind channel." Blind channels are winding tidal channels that do not connect to a freshwater drainage, and are formed by tidal action alone. They are often seen in fringing wetlands along bay margins and stream banks.

If you can't see well-defined, meandering tidal channels in the earliest historic aerial photographs check subsequent photos. If you see active tidal channels in any year's photo, enter "Y" in Column 15 of Form E1-B, and record the year of the photo in which you saw the channels. If you do not see meandering tidal channels in any year's photos, enter "N" in this column. If you are uncertain, mark "Q" in Column 15, and also mark "Y" in Column 3 of Form E1-A ("Field check required," GIS field FLDCK_RQ).

In HGM polygons that have been diked, ditched, culverted, farmed or grazed, you may see shadowy "remnant channels" (Figures 12 & 13) with a sinuous form similar to undisturbed tidal channels in natural tidal marsh. Remnant tidal channels are found where active tidal channels once flowed, and they can remain visible on the landscape for many decades after diking and

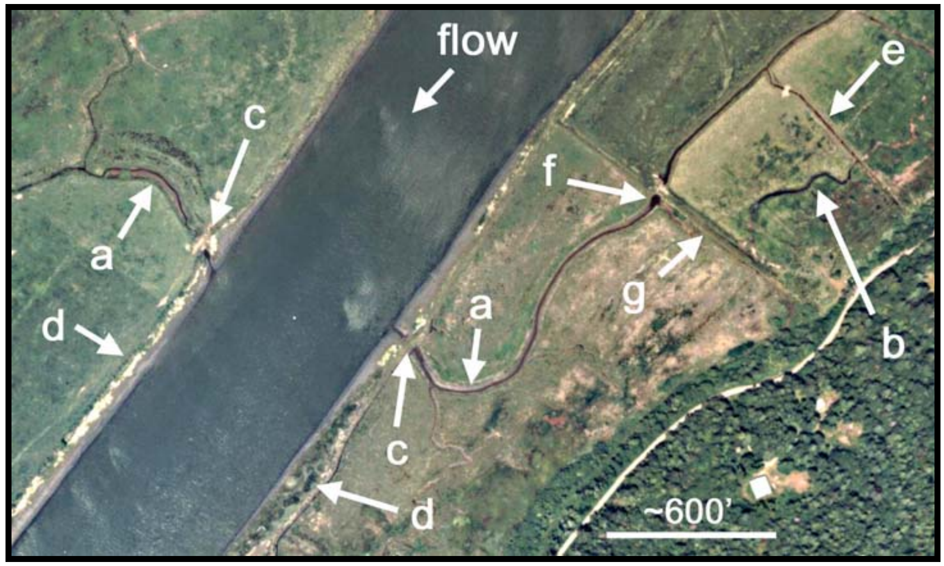


Figure 12. Diked former tidal marsh in an Oregon south coast estuary, showing alterations.

Labeled features: a = Dredged natural meanders with sidecast berms; b = remnant meander (altered through grazing/tillage, but still actively carrying flow); c = channel which "disappears" under dike, indicating likely tidegate or restrictive culvert location; d = perimeter dike; e = typical linear ditch; f = turbulence pool caused by restrictive culvert at internal berm; g = internal berm (cross-dike) which also serves as farm road, with parallel borrow ditch.

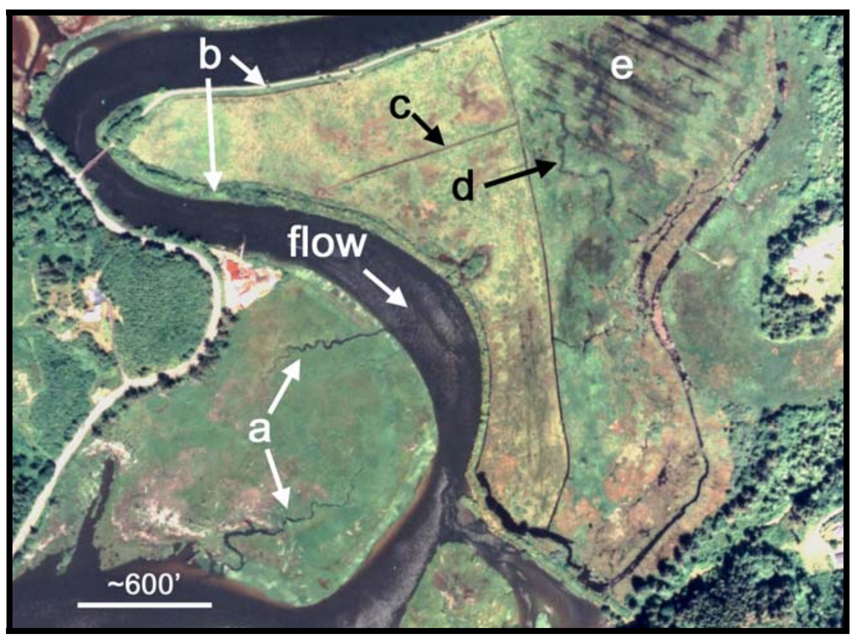


Figure 13. Undiked tidal marsh (marked "a") in an Oregon central coast estuary, and diked former tidal marsh on opposite bank (b, c, d, e).

Labeled features: a = typical meandering tidal channels in undiked marsh; b = dike with borrow ditch (upper portion of dike also serves as a local access road, and also acts as channel armor); c = typical linear ditch; d = remnant channel in ditched field; e = linear tillage/ditching pattern.

ditching. They can usually be distinguished from active tidal channels because they look blurry and diffuse, rather than contrasting sharply with the adjacent marsh. (Nontidal wetlands and riparian areas can have remnant channels, too, but other evidence will help eliminate these.) For each HGM polygon where you saw remnant channels, enter "Y" in Column 16 of Form E1-B (GIS field CHREM_YR), and record the year of the photo in which you saw the channels. If you did not see remnant channels in any of the photos, enter "N" in Column 16. If you are uncertain, mark "Q" in Column 16, and also mark "Y" in Column 3 of Form E1-A ("Field check required," GIS field FLDCK_RQ).

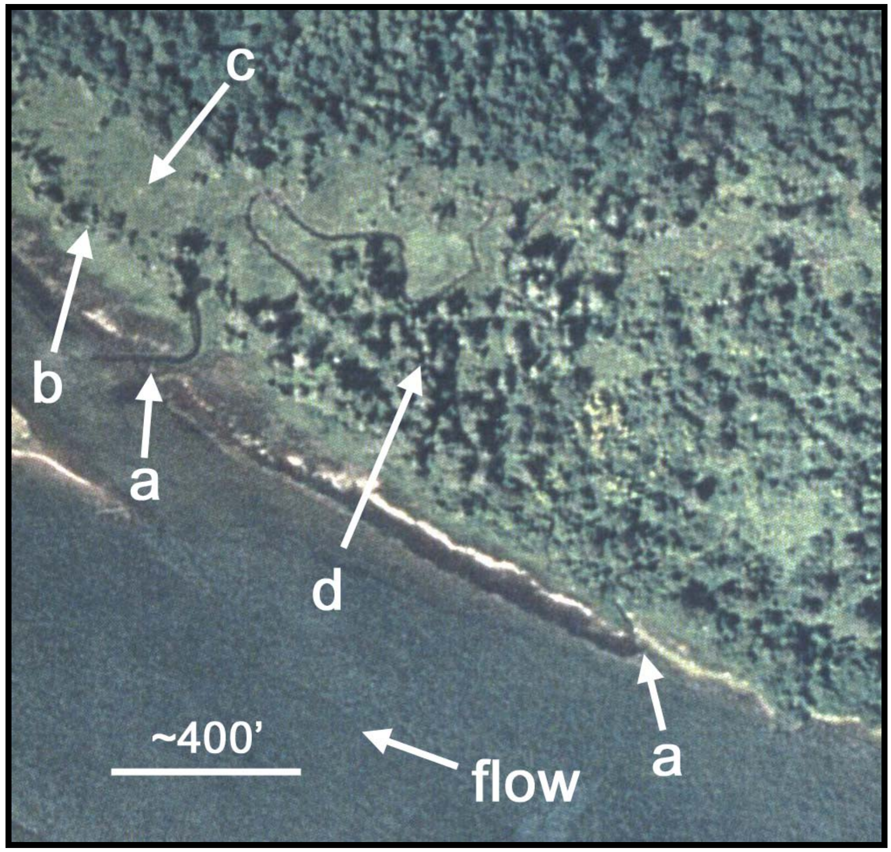


Figure 14. Undeveloped tidal wetlands in an Oregon south coast estuary, showing transition from tidal marsh to tidal swamp.

Habitats grade from tidal marsh with scattered spruce at left, up to tidal swamp dominated by Sitka spruce in center. Labeled features: a = tidal channel mouths; b = Sitka spruce and shrubs on natural levee; c = tidal marsh; d = tidal swamp (forested tidal wetland).

As described in **Estuary Basics**, some tidal wetlands are forested. These habitats are known as tidal swamp, and one easily identified plant that is often dominant in tidal swamp is Sitka spruce. If you are able to identify tree species in your historic aerial photographs, look for areas where Sitka spruce is the dominant tree. (You may need technical assistance to distinguish spruce from other conifers in aerial photos.) Scattered Sitka spruce are often found in the transition zone between tidal marsh and tidal swamp in the upper estuary (letter "e" on Figure 11; letter "d" on Figure 14). In Oregon's freshwater forested tidal wetlands, Sitka spruce is often the dominant tree (Figure 14). For each HGM polygon where you saw dominant Sitka spruce in an aerial photograph, enter "Y" and the year of the photo in Column 17 of Form E1-B. If you entered "Y" in Column 17 but entered "N" in Columns 6 through 16, you should also mark "Y" in Column 3 of Form E1-A (GIS field FLDCK_RQ) because dominance of Sitka spruce provides only secondary, supporting data for this study (that is, not all spruce forests are tidal swamps).

4- Field observation and local knowledge

[You may skip this step for polygons marked "Y" in Column 6, 7, 10 or 11 of Form E1-A.]

Freshwater and brackish tidal wetlands in the upper estuary have been little studied in Oregon. You may find that at this stage in the assessment, you have no evidence of tidal influence for many of the HGM polygons. Yet, despite the lack of tidal indicators in existing data sources and aerial photographs, many of these may be current or former tidal wetlands. It is important to retain these polygons in the mapping until you can conduct a field visit and/or obtain detailed information from the landowner or another person who has knowledge about the local area.

At this point in your assessment, HGM polygons which lack clear evidence of tidal influence should be marked "Y" in Column 3 of Form E1-A (GIS field FLDCK_RQ) to indicate that a field check is needed. HGM polygons without clear evidence of tidal influence are those that have "N" entries in Columns 6, 7, 10, 11, 13, 14, 15, 16 and 17 (or possibly "Y" in Column 17 but "N" in all other columns). If any of these polygons are not marked "Y" in Column 3 of Form E1-A, enter "Y" in that column now. In the next few paragraphs, these polygons will be referred to as "field-check polygons."

(a) Landowner contacts and other local knowledge

Before you begin your field work, you will need to contact landowners for the field-check polygons. If possible, obtain permission to walk on the site; this will allow you to get the most accurate information. ***Never visit a site without the landowner's permission.*** Whether or not you obtain access permission, talk with the landowner (or seek other local knowledge) to find out if the site experiences tidal flooding. If the landowner or other source confirms that the site is flooded by the tides, enter "Y" in Column 18 in Form E1-B (GIS field LOCAL_TID). If local knowledge fails to confirm tidal influence, leave Column 18 unmarked; you should check other indicators for these areas.

Note that altered sites may currently be nontidal even though they were formerly tidal. Possible reasons for loss of tidal flow will be assessed in Step 2: ***Assess alterations to the estuary****.*

(b) Prepare for field visits

After obtaining landowner permission for access, conduct field visits to the field-check polygons (which have the entry "Y" in Column 3 of Form E1-A), or observe these from nearby vantage points if you did not obtain access permission. Field trips give you a good opportunity to observe indicators of tidal influence, described in detail below. Bring your current aerial photo laminates and fine-point waterproof markers (see "Materials needed"). Be sure to bring a tide table and a watch so you can relate your observations to the tidal cycle. If possible, bring a GPS unit to record the locations of your observations.

(c) When and where to visit

For efficiency, combine this step with the field visits needed for the assessment's next step, "Assessing alterations," so complete as much of that section as possible before you go out in the field.

Be careful when walking on tidal wetlands, especially in the upper estuary. These wetlands often have a network of deep, steep-sided tidal channels that are hard to see – until you step in them! In fact, tidal channels in many upper estuary tidal wetlands are partly subterranean, so beware of deep holes that connect the subterranean channels to the surface at intervals. These holes may be hidden by vegetation, so use a tall walking stick to probe ahead of you in new areas.

With your aerial photo laminates, markers, the HGM overlays, and tide tables in hand, visit each field-check polygon and look for indicators of tidal influence. To observe tidal outflow points and channel morphology, the best time to visit is at low tide (preferably a minus tide). You'll want to check tidal channels on the site itself, as well as looking for evidence of tidal influence at the point where tidal flow enters (or would enter) the site (tidegated culverts or channel mouths). You can either walk around on the polygon in question, or observe it from a boat or nearby vantage point.

The upstream end of a culvert at the mouth of a tidal (or formerly tidal) channel is often inundated during the entire tide cycle. Therefore, you may need to use a boat to observe the downstream end of the culvert from the adjacent tidal river or stream. Many culverts and tide gates can be viewed only at very low tides (zero or minus tides). Thick vegetation often grows over natural levees and dikes at these outflow points. Use your aerial photographs to try to locate their positions and investigate closely at these locations. Visiting at low tide will help, since you may be able to hear water flowing out from culverts and tide gates at low tide.

For observation of tidal inundation, the best time to visit is on a higher high tide during the time of the month when tides are highest ("spring tide" – see **Glossary**). You may need to visit upper estuary sites during winter, when river flows and tidal ranges are higher. To document tidal fluctuation in channels and tidal inundation, visit sites at **both** low and high tide on the same day, or install a water level recording device. If channels on a site are formerly tidal, but tidal flow has been cut off or restricted, you need to observe tidal fluctuation just outside the site and correlate this to elevations on the site (see **Tidal channel mouths** – **culverted or tidegated sites** below).

(d) Tidal inundation

Most authorities use frequency of inundation by tidal waters as a defining characteristic of tidal wetlands (see **Glossary**). Check for tidal inundation at each HGM polygon where you have entered "Y" in Column 3 of Form E1-A ("Field check required"). Visit at the peak of a higher high tide during a new moon or full moon period ("spring tide"), and mark the high water level with a sturdy stake or other fixed reference point. Then observe the water level again at low tide **on the same day** and compare to your high tide reference mark. Repeated visits will help confirm your observations.

Be aware that many upper estuary sites experience tidal flooding only during high river flows in winter, so it is best to visit these sites in winter. Higher high tides often occur at night during winter; walking on tidal wetlands at night can be hazardous, so you may want to construct a homemade "crest gauge" to record the highest night-time tide, and compare the maximum water level to the elevation of the site the next day. Pritchard (1995) provides instructions on how to build a simple crest gauge.

If the area you visited is inundated at high tide, but not at low tide, mark "Y" in Column 19, Form E1-B and record the details in Form E2. For any polygon where you observe tidal inundation, you can skip the rest of this section, because you have confirmed that the site is tidally influenced. Your results will be summarized in Step 4, **Summarize tidal indicators**.

If you do not observe tidal inundation, go on to the next two steps (**Tidal channels**). Since the frequency of tidal inundation may be low for some sites in the upper estuary, these next steps describe how to evaluate tidal fluctuation in interior channels. This will allow you to make a preliminary determination of tidal influence even if you do not observe surface inundation.

(e) Tidal channels – non-diked, non-ditched sites

*[You may skip this step if you confirmed that the site has **Tidal inundation**, above.]*

If you did not observe tidal inundation, you should check for tidal fluctuation in channels on the polygon. Try to obtain landowner permission to walk onsite, because many characteristics can only be observed from close-up. If the polygon is undiked and its outflow is not culverted or ditched (see Step 2, **Assessing alterations**), look for deep, steep-sided channels in the interior of the polygon which are nearly empty at low tide. At low tide, these channel banks will often be wetted well above the water level or even to the top of bank, due to fine-textured soils that retain water after the tide drops (Figure 15).

Observe water levels in these channels at different tide stages on the same day to verify that they are tidally influenced (flow will reverse and enter the site during the flood tide). Record your observations in Columns 1-9 of Form E2, making sure to note the specific time and date of each measurement or observation. Mark the locations of your observations on your aerial photo laminates, using codes specific to each observation and record GPS coordinates. If your field work provides evidence of tidal fluctuation in water levels within any interior channel in an HGM polygon, enter "Y" in Column 9 of Form E2 and in Column 20 in Form E1-B (GIS field FLD_TIDCH) for that polygon.

Photo: L. Brophy

Figure 15. Small tidal channel in tidal swamp, mid-coast Oregon estuary. Channel is nearly empty at low tide, but banks are wetted to top from recent high tide. Note shading of channel by vegetation.

(f) Tidal channels – diked/ditched/culverted sites

*[You may skip this step if you confirmed that the site has **Tidal inundation**, above.]*

If the polygon you are visiting is diked, ditched, culverted, or otherwise altered, you may not see tidal inundation or the deep, steep-sided tidal channels that are typical of less-disturbed tidal wetlands. Look for "muted" tidal influence in interior channels (often ditches) on the site; “muted” tidal influence means that alterations such as diking have reduced the amount of tidal exchange but not completely eliminated it. The best way to determine whether a channel is tidally influenced is to use a simple staff gauge. Firmly anchor a tall stick in the bottom or side of the channel. Use a stick tall enough to extend above the top of bank, and place it so it is in the water at the time of your visit. Time your visit for the lower low tide during a full moon or new moon tide series. Mark the current water level with waterproof marker or firmly tied flagging. Referring to your tide chart, return at high tide (**on the same day**) and see if the water level has responded to the tidal fluctuation. Record the direction of flow at each visit. Use several different staff gauge locations, some near the tidal water body and some further away. Detailed information on how to monitor tidal levels can be found in Carlisle et al. (2002).

Be aware that many upper estuary sites experience tidal flooding only during high river flows in winter, so it is best to visit these sites in winter. Higher high tides often occur at night during winter, but walking on tidal wetlands at night can be hazardous. Therefore, you may want to construct a homemade “crest gauge” to record the highest nighttime tide, and compare the maximum level to the low tide level the next morning. Pritchard (1995) provides instructions on how to build a simple crest gauge.

If you observe tidal fluctuation in internal channels within a polygon, record your observations in Form E2; mark the locations of the tidal channels on your aerial photo laminates; record GPS coordinates; and enter “Y” in Column 20 of Form E1-B (GIS field FLD_TIDCH). If you do not see tidal fluctuation in the polygon’s interior channels, check water levels and flow patterns outside the channel mouth, on the banks of the adjacent tidal water body (next section.)

(g) Tidal channel mouths – culverted or tidegated sites

[You may skip this step if you confirmed that the site has ***Tidal inundation****, above.]*

If one or more of the HGM polygon’s drainages are tidegated or highly restricted (outflow has a small, restrictive culvert), you need to check for tidal influence both inside **and outside** the restriction (in the adjacent tidal water body). Within channels behind (upslope of) a restriction, you may not be able to observe tidal influence because the restriction may block tidal entry. However, these channels may have been tidally influenced before the restriction existed.

Low tide observations: Visit each restrictive channel mouth at low tide, preferably on a spring tide (maximum tide of the month) to see how water flows out. If water is impounded behind the restriction (culvert/tide gate), you may see a vortex or whirlpool on the upslope side due to the water level difference as the tide drops outside. At this time, outflow will often form a high-velocity “jet’ as it exits the restriction. Watch the culvert as the tide reverses and begins to rise. If outflow slows and reverses as the tide rises, the channel is definitely tidally influenced.

High tide observations: Check each channel mouth again near high tide on the same day, to observe differences. If freshwater flow is impounded behind the restrictive culvert/tide gate (often true in winter), the water levels inside and outside the site may be “balanced” at high tide, and water on both sides of the restriction may appear calm. Alternatively, you may see some inflow through the culvert or leaky tide gate (reversal on flood tide). The outer end of the restrictive culvert/tide gate itself may be inundated at high tide but not at low tide, suggesting that the channels inside could be tidally influenced if the restriction were removed. As described above, **be aware that many**

upper estuary sites experience tidal flooding only during high river flows in winter, so it is best to visit these sites in winter. Also see information in (e) and (f) above about nighttime high tides in winter and constructing a homemade crest gauge to track those high tides.

Summary: If you see tide cycle flow changes (direction changes or whirlpool formation) inside and outside the wetland at low and high tide, or if a high tide inundates the restriction but it is exposed at low tide, the channels behind the restriction are probably tidal. Enter your observations in Form E2; mark the location of your observations on your aerial photo laminates, and record GPS coordinates. Enter "Y" in Column 20 of Form E1-B (GIS field FLD_TIDCH). If you see no tidal cycle flow changes at the restriction even during high winter flows, or if the restrictive culvert is perched far above the highest tide level outside, the channels behind the restriction are probably not tidally influenced. Enter your observations in Form E2, mark their location on your laminates, record GPS data, and enter "N" in Column 20 of Form E1-B.

Large polygons might have tidal influence at their lowest edge but not on upper portions of the polygon. Such a situation need not be evaluated during this assessment; your analysis of tidal influence at the polygon's lower edge is adequate.

Special situation: Offsite tidal restrictions affecting multiple HGM polygons. A single restriction (river mouth tide gate, restrictive culvert on a large formerly tidal channel, etc.) may affect many HGM polygons upstream. For example, tide gates located at mouths of tributaries can restrict or eliminate tidal flow to an entire tributary system (Figures 16 & 17). Another example is a restriction at the mouth of a

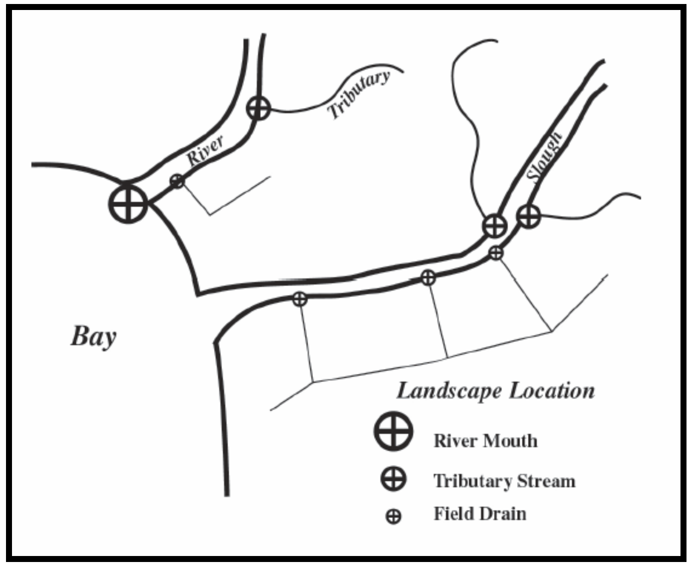


Figure 16. Landscape positions of tidegates (from Giannico and Souder 2005). Common tidegate locations are pictured: River mouths, tributary streams, and field drainage ditches.

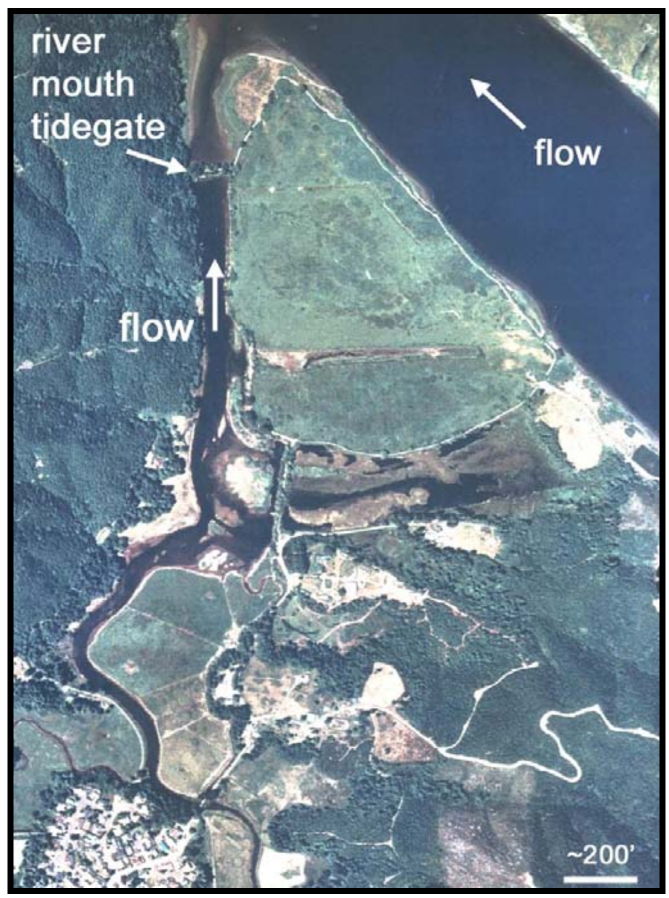


Figure 17. "River mouth" tidegate on a major tributary in an Oregon estuary.

The entire stream system upstream of the tidegate (in center and bottom of photo) is affected by the tidegate and has no tidal exchange.

major tidal channel in a large agricultural area (Figure 18). Because such offsite restrictions eliminate or greatly reduce tidal fluctuation in channels of all the polygons behind them, you cannot use the methods described above to determine tidal influence for those polygons. For all HGM polygons affected by an offsite restriction, mark the location of the offsite restriction on your aerial photograph, enter "Q" for "questionable" in Columns 19 and 20 of Form E1-B, and use other indicators. You may need expert assistance to determine the historic tidal status of these polygons. Local measurements and models of tidal range and river flows, along with elevation surveys of areas behind offsite restrictions, can help determine the historic and current status (tidal vs. nontidal) of such areas.

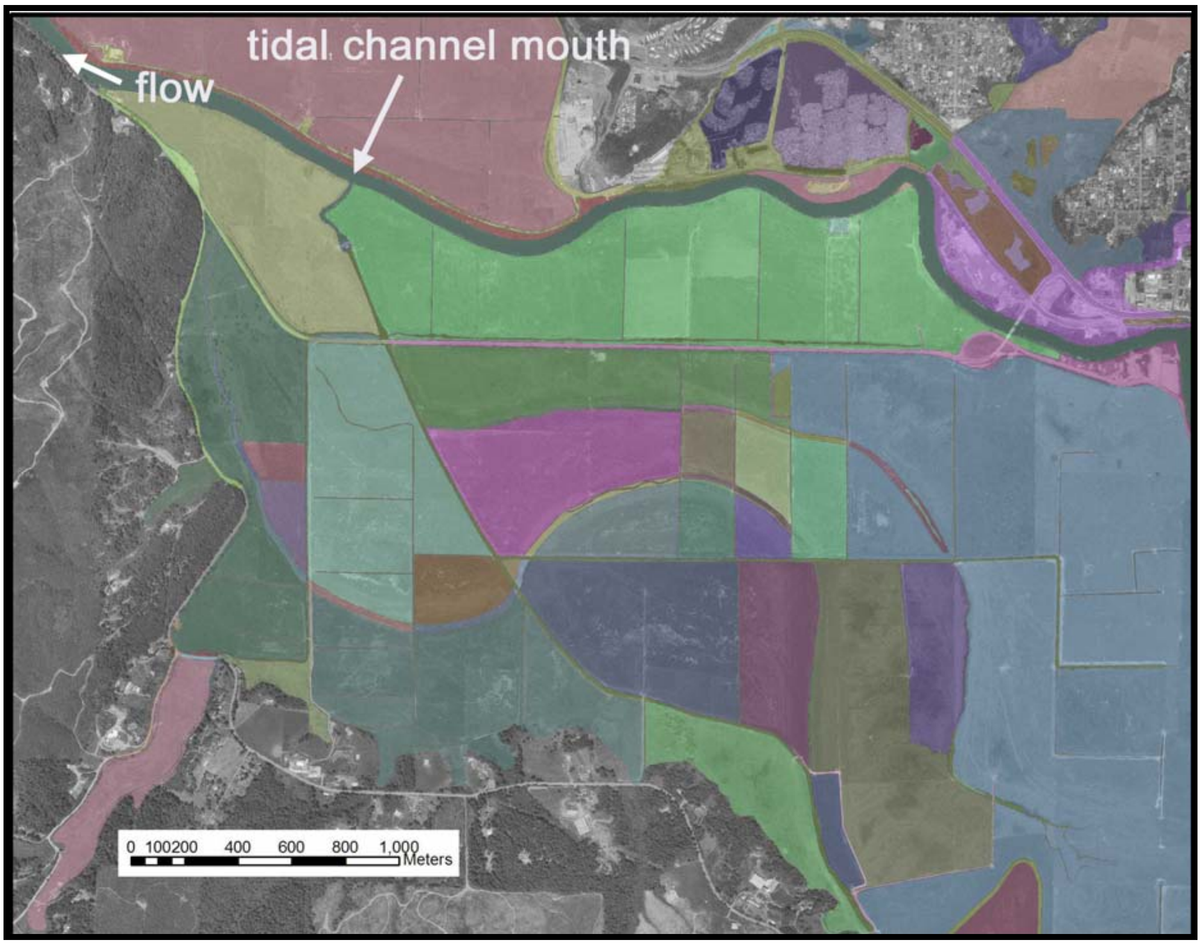


Figure 18. Large agricultural area on floodplain, Oregon south coast estuary. The area depicted is near head of tide, above River Mile 20.

Most of the fields in this image appear to drain through a single major ditched channel, with its outlet in the tidal section of the river system ("tidal channel mouth"). The extent of former tidal influence can be difficult to determine in situations like this. Similarly, it is difficult to determine what areas might have enough tidal influence to restore to tidal wetland if restrictions were removed. Note that some of the HGM polygons are located more than 3 km upstream of the marked tidal channel mouth.

Individual HGM polygons are colored separately. Colors are not significant, but are used simply to illustrate the number and arrangement of separate HGM polygons in this area.

(h) Vegetation

*[You may skip this step if you confirmed that the site has **Tidal inundation**, above.]*

Presence of brackish-tolerant plants is a strong indicator of tidal influence. To determine if this indicator is present, obtain assistance from a botanist. See Appendix E3 for a list of species that are tolerant of indicate brackish water and can indicate tidal influence: examples include Lyngbye's sedge, saltgrass, pickleweed, fleshy jaumea, tufted hairgrass, and Baltic rush. In the upper estuary (particularly the freshwater tidal zone), these species may be absent, or present only on the banks of tidal channels or within the channels. Certain plant species can indicate brackish water in tidal channels, even if the marsh surface has freshwater wetland vegetation; examples include Lilaeopsis, Lyngbye's sedge, saltgrass, brass buttons, and widgeongrass.

Many tidal wetland plants die back in the fall, so you should check vegetation during the summer (May - August). Record your observations in Form E3. If you observe brackish-tolerant vegetation, mark the area on your aerial photo laminates with the code "BV," and enter "Y" in Column 21 of Form E1-B (GIS field FLD_BRKV) for each HGM polygon where you observed brackish-tolerant vegetation.

5- Summarize tidal indicators

Review your entries in Columns 5-21 of Forms E1-A and E1-B. If Column 6, 7, 10, 11 or 19 is marked "Y," enter "10" in Column 22 ("Tidal score," GIS field TID_SUM). Otherwise, add up the number of "Y" or "Q" entries in Columns 13-21 and write the result in Column 22 of Form E1-B. The higher the score, the more likely the polygon is a current or former tidal wetland. Fill in Column 23 as follows: if Column 22 totals 3 or more, enter "Y" in Column 23 to indicate that the polygon is likely tidal or formerly tidal. If Column 22 totals 1 or 2, enter "Q" in Column 23 to indicate areas of questionable tidal status. If Column 22 totals 0, enter "N" in Column 23 to indicate likely nontidal status.

Enter "Y" in Column 4 of Form E1-A for all polygons that you have field-checked. For polygons with Column 22 scores of 1 or 2, conduct further field checks as described in the **Field observation and local knowledge** section above. However, determining current or former tidal influence for some polygons may require investigations beyond the scope of this assessment. Such investigations often include measurements of local tidal range, detailed elevation surveys, and measurements of channel morphology. Expert assistance is recommended for such studies.

Map E1, Historic Extent of Tidal Wetlands

In the first step of this assessment of historic extent, you deleted those HGM polygons that were classified as nontidal, water, unconsolidated, and upland. Now, you can delete those HGM polygons for which there is little or no evidence of historic or current tidal influence.

On your HGM overlay, delete (cross out) the polygons for which Column 23 in Form E1-B is marked "N" for "Nontidal." In this step, you are only deleting those polygons which evidence suggests ***were never tidal***. Do not eliminate polygons which are currently nontidal (due to diking, tidegating, fill etc.) but were probably once tidal; these are an important part of your analysis of the historic extent of tidal wetlands.

All of the remaining polygons -- coded "Y" or "Q" in Column 23 of Form E1-B -- make up **Map E1, Historic extent of tidal wetlands.** In Step 2, you will examine these areas for alterations.

Update the HGM base layer for other users

During your analysis of the historic extent of tidal wetlands, you may have identified areas that are shown in the HGM tidal wetlands map, but which are actually neither tidal wetlands nor former tidal wetlands. These are the polygons for which you entered "N" in Column 23 of Form E1-B. You can help improve the accuracy of the HGM map for future users by sharing your results. Contact the Oregon Ocean and Coastal Management Program (Tanya Haddad, 503-731-4065, ext. 30) to share your results.

STEP 2: ASSESS ALTERATIONS TO TIDAL WETLANDS

You have now developed a map showing the historic extent of tidal wetlands in your study area (Map E1). The next step -- assessment of alterations to tidal wetlands -- will provide you with the "big picture" of estuarine conditions, and allow you to develop restoration strategies. As you assess alterations, it is important to remember that no tidal wetland is completely unaltered. Tidal wetlands exist in a highly altered context of coastal and inland development. Even undiked, unditched tidal wetlands are affected by basin-wide changes in hydrology, sediment transport, and water quality caused by human land uses. In addition, this assessment does not evaluate all possible alterations to tidal wetlands; it focuses on those alteration types that have had the most widespread impacts on tidal wetlands within the scope of this module (i.e., south of the Columbia River). Despite these limitations, your assessment of alterations is a vital step in understanding the estuary.

This step provides instructions on how to assess alterations to the areas shown on Map E1, *Historic extent of tidal wetlands*. The areas shown on Map E1 will be referred to in this section as the "Map E1 polygons."

Steps in this section include 1) locating mapped alterations by examining the HGM base map, USGS maps, NRCS soil survey maps, Estuary Plan Book, and National/Local Wetlands Inventory; 2) verifying mapped alterations and locate additional alterations by examining aerial photographs, conducting field visits, and gathering local knowledge; 3) marking the identified alterations on your current aerial photo laminates (or digitizing them into your GIS) and recording them in Form E4-A and E4-B.

It is important to remember that the majority of tidal wetland alterations are currently unmapped. Your interpretation of aerial photographs, combined with site visits, will provide a great deal of new information that you can use immediately in watershed action planning. Because individual data sources may be inaccurate and interpretation may be difficult, consult several data sources and list all data sources on Forms E4-A and E4-B. The more data sources indicate a particular alteration, the higher the confidence level for that alteration.

Step 3 provides guidance on defining the individual restoration and conservation sites that will be your units of analysis for the remainder of this assessment module. These sites will be prioritized in Part III of this module.

As explained above, this assessment excludes filled areas that have been converted to developed uses; such areas will be identified and deleted from the map in this section.

Note: In some cases, only a portion of an HGM polygon shows alterations. In this case, simply record that alteration for the entire HGM polygon. In future steps, HGM polygons will be subdivided or grouped into analysis units that will allow more detailed characterization.

> ***GIS tip:*** *The "MapE1" shapefile attribute table will store your data on alterations. Each type of alteration will be recorded in one or more data columns in the attribute table. Suggested GIS field names are shown in Forms E4-A and E4-B. Detailed instructions are provided below.*

Site-specific alterations

The purpose of this section is to locate the following types of alterations within your Map E1 polygons:

- Dikes
- Ditches
- Restrictive culverts and tide gates
- Road and railroad embankments, bridges, and other structures crossing tidal wetlands
- Earthen dams and other channel blockages
- Channel armor/riprap
- Dredged material disposal/ditching sidecast
- Logging and driftwood removal
- Grazing
- Invasive species
- Fill

Existing data sources, and new data that you gain from aerial photos and field investigation, will help you locate these alterations. If you are working with paper maps, you will need to mark these alterations on your aerial photo laminates, so have ready at least 6 distinctive marker colors, symbols, or patterns for the most common alteration types (dikes, ditches, roads, filled areas, excavated areas, and culverts/tide gates). Less common alterations can be annotated with your choice of text or additional symbols.

How alterations affect tidal wetland functions

This section provides only a brief introduction to the impacts of alterations on tidal wetland functions. Further discussion is found in **Site prioritization: Tidal channel condition** and **Linking restoration to tidal wetland functions** below; and in Appendices E3 and E4 (**Restoration principles** and **Restoration approaches**). Adamus (2005a) contains detailed discussions of the relationships between site characteristics (including alterations) and wetland functions.

The first four of the alterations listed above (***dikes, culverts/tide gates, roads/railroads***, and ***dams***) have the broadest impacts. By restricting tidal flow, these alterations reduce or greatly alter nearly all tidal wetland functions, and in some cases completely eliminate those functions. ***Ditches*** change tidal flow patterns 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 wetland, reducing duration of inundation and diminishing wetland area. ***Tillage*** and ***grazing*** compact soils, contribute to erosion of channel banks, and reduce vegetation diversity and wildlife habitat. ***Channel armor*** and ***riprap*** cause erosion in adjacent areas, reduce vegetation diversity and channel shading, and reduce salmonid habitat functions. ***Impoundments***, ***excavation***, and ***dredged material disposal*** change wetland surface elevations, 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 salmon habitat functions of formerly shaded tidal channels. ***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 and waterfowl habitat functions.

HGM base layer

This assessment method excludes former tidal wetlands that have been filled and committed to developed uses, like roads, homesites and urban areas. These areas are classified as HGM Class F ("Fill") in Map E1. However, not all HGM Class F areas are converted to developed uses, so not all Class F areas will be excluded from the assessment. Specifically, Class F polygons that are dikes should be retained in the assessment, because dikes are important to restoration planning and design.

To locate dikes, look at the shape and location of the HGM Class F areas in Map E1. Fill polygons that form narrow bands along riverbanks may be dikes (Figure 19). Consult your aerial photographs and ask local residents if these are dikes. *Dike polygons will be retained in your maps of historic estuary extent and potential restoration sites.* However, if homes and other permanent structures are located on the dike, the dike polygons will be deleted from your analysis in later steps of the assessment.

For each Map E1 polygon that is classified as "Fill" and has been converted to developed uses (*but is not simply a dike*), enter "Y" in Column 2 of Form E4-A (GIS field FILLDEV_YN) and indicate your information source (HGM) in Column 3.

On your base layer of tidal wetlands (Map E1), you may see long, thin areas that are categorized as HGM class "Fill" (Figure 19). These may be dikes, or road or railroad embankments. Roads can act as dikes by blocking tidal flow to a former tidal wetland. If you see a road or dike on the HGM base layer that restricts tidal flow to part or all of an HGM polygon, enter "Y" in Column 4 of Form E4-A (GIS field DIKE_YN) for the affected Map E-1 polygons, and show the data source ("HGM") in the adjacent column. Mark the locations of the dikes on your laminated current aerial photographs, using a consistent color.

Some linear areas classified as "Fill" in the HGM base layer may be natural levees. Natural levees are high areas along riverbanks resulting from sediment deposition during flood flows (see **Dikes** below for details); they are most prominent in upper estuaries. If you are uncertain whether the linear HGM fill you see is a dike or a natural levee, enter "Q" for "questionable/unknown" in Column 4, and enter "Y" in Column 16 ("Field check needed," GIS field FLDCK_ALT) in Form E4-A.

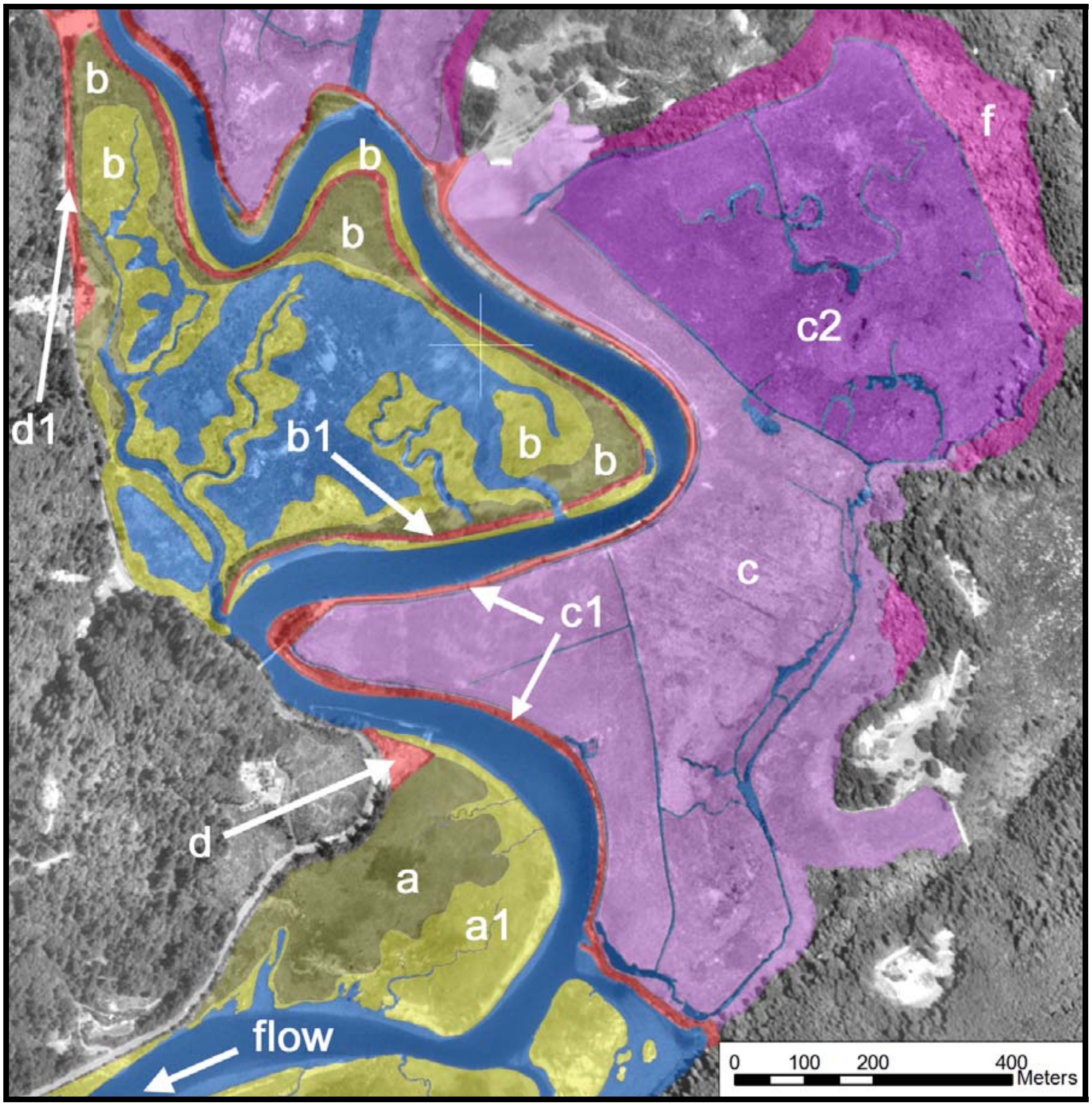


Figure 19. HGM polygons, area of Figure 13.

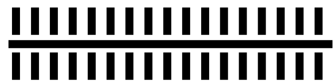
Labeled features: **a and a1** = polygons to merge for this assessment, because they form a single interconnected wetland and differ only by elevation; **b and b1** = polygons to merge (same reasons as a and a1); **c, c1 and c2** = polygons to merge because they share a similar level of alteration (all are diked and grazed, though c2 is less heavily ditched). Areas **b1 and c1** = dikes classified as Fill which should be retained as part of adjacent wetlands b and c respectively; **d and d1** = roads and building sites classified as Fill which should be deleted from study area because they are converted to developed uses (d has buildings, d1 is a road). Area **f** = polygon to keep as a separate site because its land use differs from c2 (c2 is grazed, f is ungrazed and forested). (Note: **d1** = road crossing at the upslope edge of a tidal wetland; such a road crossing has a lower impact on tidal wetland functions than a road or railroad crossing at the downslope edge, or a road that goes through the middle of a wetland.)

Individual HGM polygons are colored separately. Colors are not significant, but are used simply to illustrate the number and arrangement of separate HGM polygons in this area.

USGS topographic maps

USGS topographic maps show dikes using the following symbols:

Levee or dike – without road 

Levee or dike – with road 

In some cases, levees may be shown as a thin solid line, usually marked "LEVEE." However, many existing dikes are not shown on USGS maps. Older editions of USGS topographic maps may show levees that are not depicted on the most recent, digital versions, so you should also check historic USGS maps for marked dikes. Historic USGS topographic maps may be found at the University of Oregon Map and Aerial Photography Collection. An index to the maps is available at the Collection's website, http://libweb.uoregon.edu/map/, or call the Collection at (541) 346-3051.

If the USGS topographic map shows a dike or levee protecting one of your Map E1 polygons, enter "Y" in Column 4 of Form E4-A (GIS field DIKE_YN) for that polygon, and show the data source ("USGS") in the adjacent column. Mark the location of the dike on your aerial photo laminate.

NRCS soil survey mapping

NRCS soil surveys classify some soils as "protected," meaning they are behind dikes. In Oregon, a typical example is Map Unit 13A, "Coquille silt loam, 0 to 1 percent slopes, **protected.**" Unprotected Coquille silt loam is mapped with symbol 12A in the same survey.

Paper soil survey maps also show dikes, using symbols similar to the USGS topographic map symbols shown above. These may be labeled "levee" on the map. (Note that manmade levees are different from natural levees -- see glossary). Not all dikes are shown on paper soil survey maps, and no dikes are shown in GIS soil survey data. Also, many soils behind dikes are not classified as "protected." Still, soil survey information is a helpful supplement to your other data.

In your soil survey, check the Soil Legend (found just before the map section) for soils marked as "protected." Then check the soil survey maps for each of your Map E1 polygons for this soil type. For each Map E1 polygon that has "protected" soils, enter "Y" in Column 4 of Form E4-A (GIS field DIKE_YN) and enter the information source ("NRCS") in the adjacent column. If you had already marked the polygon as diked based on USGS mapping, just add "NRCS" to the list of data sources for diking in the next column (GIS field DIKE_SRC).

Also check the paper soil survey maps for dikes; draw the locations of any dikes on your aerial photo laminates. Enter "Y" in Column 4 of Form E4-A (GIS field DIKE_YN) for any Map E1 polygons where the paper maps show dikes, and enter/add the data source ("NRCS") in the adjacent column.

Oregon Estuary Plan Book (EPB)

In habitat maps of the Oregon Estuary Plan Book, the suffix “D” indicates diked tidal marsh. Examples include “2.5.11D” for diked low tidal marsh, “2.5.12D” for diked high tidal marsh, and “2.5D” for diked tidal marsh (elevation unspecified).

Placing your HGM overlay over the EPB mapping, check each polygon in Map E1 for EPB codes indicating diked tidal wetlands (2.5.11D, 2.5.12D, 2.5.13D, and 2.5.14D). For each polygon where EPB designates diked marsh, enter “Y” in Column 4 of Form E4-A (GIS field DIKE_YN) and show the data source (“EPB”) in the adjacent column. If you have already entered “Y” in Column 4, just add “EPB” to the list of data sources.

The Estuary Plan Book also shows designated dredged material disposal (DMD) sites within some estuaries. Some of these may have already been used to dispose of dredge spoils; others may be held in reserve for future use. For each Map E1 polygon that has a designated DMD site, enter “Y” in Column 6 of Form E4-A (GIS field SPL_YN) and show the source of the information in the adjacent column as “EPB.”

National Wetlands Inventory (NWI)

The National Wetlands Inventory uses several codes to indicate different types of alterations to wetlands. These codes are called “special modifiers” and are shown in lower case at the end of the wetland classification. The codes that will be used in this step of the assessment are:

d = Partially drained/ditched

h = Diked/Impounded

s = Spoil (i.e., fill material in the wetland resulting from excavation elsewhere)

x = Excavated

Diked, formerly tidal wetlands are generally classified as Palustrine wetlands. A common NWI classification for a diked former tidal wetland is “PEMCh,” indicating a palustrine emergent, seasonally inundated wetland that is diked; “PEMCd” is used for a ditched wetland of the same type. However, many diked former tidal wetlands have no modifiers indicating alterations. “Spoil” indicates presence of fill material; “excavated” indicates the grade has been lowered in the wetland, usually to create a pond or other open water area.

For each Map E1 polygon, examine the underlying National Wetlands Inventory mapping for modifiers indicating these alterations. For each mapped alteration, enter “Y” in the appropriate column in Form E4-A (Column 4 for diking, Column 6 for spoil, Column 8 for ditching, Column 10 for excavation), and show the data source in the adjacent column as “NWI.”

GIS tip: *If the NWI is available in digital format for your study area, intersect your MapE1 features with the NWI layer to obtain NWI classifications for each MapE1 polygon.*

Other maps

U.S. Coast and Geodetic Survey (USCGS) navigational charts from the 1800s may provide useful information on historic conditions in your study area. You can download these maps from the Office of Coast Survey's Historical Map & Chart Collection web page, http://nauticalcharts.noaa.gov/csdl/ctp/abstract.htm. For some areas, these maps show tidal channels and wetland vegetation types in enough detail to allow analysis of historic habitat change (e.g., Thomas 1983). You can use the charts in combination with the other procedures in this step to evaluate alterations to the Map E1 polygons.

Aerial photograph interpretation and field observation

Although a number of alterations are mapped on the HGM, USGS, EPB, NWI and NRCS maps, aerial photographs and field visits are your best source of information on wetland alterations. Your observations are also needed to confirm mapped alterations, since maps may be outdated. **Interpreting aerial photographs to confirm or assess alterations requires skill in aerial photograph interpretation, so you may need technical assistance for this task.** Areas with likely alterations that cannot be verified by aerial photograph interpretation may require field checks and/or discussion with landowners and others with good knowledge of local conditions. ***Never visit a site without the landowner's permission.***

Specific characteristics of each type of alteration are described below, along with detailed instructions on what to look for in aerial photos, and how to conduct field checks for these alterations.

General methods for aerial photograph interpretation

Starting with the earliest historic aerial photographs you can obtain, and continuing through the most recent available aerials, check each Map E1 polygon for alterations. Pay special attention to those polygons that need to be field-checked (marked "Y" in Column 16 of Form E4-A).

Calibrate your eye by examining areas that you know are altered, as recorded in Form E4-A during the steps above.

Starting at the downstream end of your estuary, check each Map E1 polygon for alterations. First, use the aerial photographs to verify the alterations you have marked on Form E4-A (this will also help calibrate your interpretation skills). When you see an alteration in an aerial photograph of a Map E1 polygon, mark the location of the alteration on your aerial photo laminates (these were prepared for Step 1, Assessment of Historic Extent), and mark the appropriate column in Form E4-A or E4-B, showing the alteration and the source of information. In this case, you should show the data source as "airphoto" and the date of the photo in which you observed the alteration. If you are not sure of your interpretation, enter "Y" in Column 16 in Form E4-A ("Field check/further info needed").

GIS tip*: Enter information on alterations in the attribute table of your MapE1 shapefile. Create a data column for each alteration shown in Form E4-A and E4-B. Suggested GIS field names are shown in the forms.*

Note that alterations can be present in earlier years and absent in later years, or vice versa. Some common examples are culverts that erode out from dikes due to daily tidal action, culverts that are replaced by bridges, and broken tide gates that are replaced with new ones.

General methods for field observation

Field observations will help you evaluate all of the alterations in this section. No specific instructions are provided for each alteration, since the descriptions of the alterations generally indicate what you need to look for. ***Never visit a site without the landowner's permission.***

You may conduct field checks after completing aerial photo interpretation, or you may find it works best to field-check groups of sites immediately after you study their aerial photos. Refer to Form E4-A. For all polygons where you have entered "Y" in Column 16 ("Field check/further info needed"), conduct a field check or seek further local information. To supplement your fieldwork, talk with landowners, local and regional agency staff, and other resource professionals – they can provide helpful information and make your assessment more accurate. Ask specifically about the features and alterations you marked "Q" in Forms E4-A and E4-B. During your conversation, ask for general information about the estuary; much local knowledge is otherwise unavailable and cannot be extracted from existing data sources, even aerial photos. For example, ask whether your study area contains any official diking districts or wetland conservation areas. Such information will help you interpret what you have seen on aerial photos and in the field.

When to conduct field observations

For efficiency, you will want to combine field observations for alterations with the field checks for historic tidal extent. For details on desirable timing, see **"Field observation and local knowledge"** in **"Identify the historic extent of tidal wetlands"** above.

Organize your aerial photo laminates and determine which areas you need to visit at low tide versus high tide. Many alterations (especially restrictive culverts and tide gates) are best viewed at low tide, preferably a minus tide. A boat trip is often the best way to gather data on many culverts and tide gates quickly. Visit diked areas at both low and high tide to gain maximum information on dike characteristics.

Dikes

Using your series of historic and current aerial photos, look for two kinds of dikes: "perimeter" dikes that run along the margins of the wetland (along the tidal bay, river, or tributary), and internal berms or "cross-dikes" that control water flow within the wetland (Figure 12). Either type of dike may be topped by a farm road or larger roadway (Figure 13). Both perimeter dikes and internal berms may have adjacent parallel ditches, from which material was removed to construct the dike or berm. Such a ditch is called a "borrow ditch" (Figures 12 & 13).

You can see a key indicator of perimeter diking in aerial photos by following the wetland's drainages towards the tidal river/bay. Use a magnifying loupe or magnifying stereoscope to inspect the mouth of each drainage. If a dike is present, drainages will generally be culverted beneath the dike, so that in aerial photos the drainages seem to "disappear" under the dike (Figure 12). Often the dike is topped by a road, so the drainage passes under the road through a culvert.

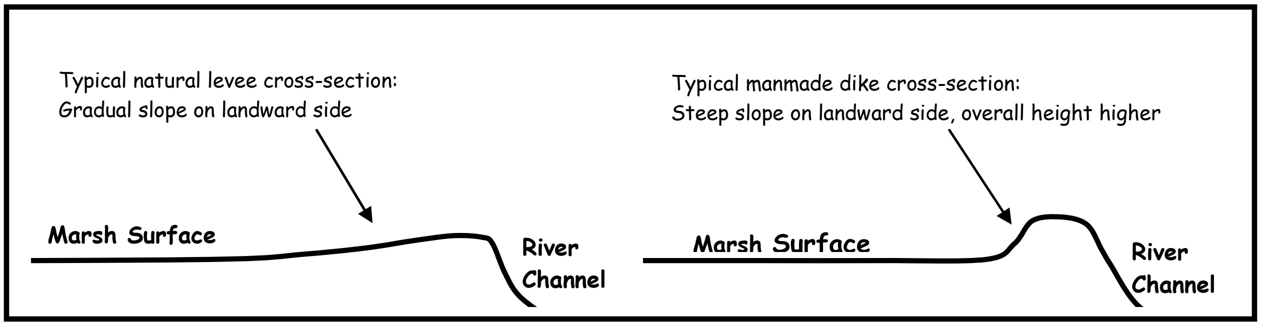


Figure 20. Dike and natural levee profiles. Drawings are conceptual and are not to scale.

Other clues to diking include: 1) a noticeable elevation rise above the marsh surface at the dike location (best seen in stereo pairs of aerial photos, with a magnifying stereoscope), and 2) different vegetation growing on top of the dike compared to the marsh surface. However, be aware that on grazed land, river banks are often fenced, allowing different vegetation to grow there, even in the absence of a dike. In this case, you will need to do a field check for diking.

Be aware that many tidal wetlands have "natural levees" along riverbanks that may look similar to dikes, even in the field. Natural levees 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. Over many years of flooding, the deposits build up until the natural levee is several inches to several feet higher than the marsh surface behind the natural levee. You can often distinguish natural levees from dikes in the field by comparing their width and slope (Figure 20).

Examples of natural levees on relatively undisturbed sites are shown in Figures 11 & 14. If you are uncertain whether the raised margin of a polygon is a dike, check early aerial photos (particularly 1930's through 1950's photos) for equipment tracks and soil disturbance, which are generally visible on top of a dike during its construction. You can also ask landowners and other individuals and agencies familiar with the local area, such as diking districts, Soil and Water Conservation District, historic societies, and agricultural groups.

In many areas in Oregon, landowners will add fill material on top of natural levees, often by adding spoils from river dredging or onsite excavation. The addition of fill material to natural levees changes wetland hydrology and sediment deposition patterns. Flood flows that once overtopped the natural levee may no longer overtop built-up levees. Ask local landowners and staff at your local Port office or County Planning Department for information on dredged material disposal areas and other levee build-up areas.

Schedule field visits to diked sites at both low and high tides, preferably at the time of the month when tides are highest (spring tide). At low tide, observe the dike profile (Figure 20). If a diked area has some tidal exchange (e.g., through a leaky tide gate or restrictive culvert), a high tide visit will give you good information on the extent of tidal influence and the area's range of elevations.

Check each Map E1 polygon for dikes and built-up natural levees. Where you observe diking or levee build-up, enter "Y" in Column 4 in Form E4-A (GIS field DIKE_YN) and record your data source in the adjacent column. Mark the locations of the dikes on your aerial photo laminates or in your GIS. If you are uncertain whether a particular polygon is diked, enter "Q" in Column 4, and enter "Y" in Column 16.

Ditches

Ditches are usually easily distinguishable from natural tidal channels. Natural channels in tidal marshes and swamps are generally sinuous, with tightly curving meanders (Figures 11 & 14), whereas ditches are straight (Figures 12 & 13). However, note that in some high-energy parts of the estuary, natural tidal channels may be fairly straight, due to the nature of flows and substrates in this estuary zone. In addition, meandering tidal channels are sometimes dredged or "cleaned out" to speed drainage. You may be able to identify dredged but otherwise natural channels by the presence of sidecast berms or mounds alongside the channel (Figure 12).

Check each Map E1 polygon for ditches. Where you observe ditching or channel dredging, enter "Y" in Column 8 in Form E4-A (GIS field DITCH_YN) and indicate your data source in the adjacent column. If you are uncertain whether a polygon is ditched, enter "Q" in Column 8, enter "Y" in Column 16, and seek further information.

Restrictive culverts

A culvert or tide gate is generally present where a road or dike crosses a tidal channel. In some cases, where the channel is wide, the channel may be bridged. Culverts are much more restrictive than bridges, often reducing tidal flow to a fraction of its original volume. You can often identify restrictive culverts by viewing aerial photos taken at low tide; a widening of the channel due to turbulence (called a "turbulence pool") will often be visible on the upstream and/or downstream side of the restrictive culvert (Figure 12). Note that turbulence pools are also seen where other types of structures, such as bridge abutments, restrict tidal flow (Figure 11).

To field-check culverts, observe the downstream end of the culvert at low tide. You may need to approach by boat if vegetation is thick. Photograph the culvert if it is visible, and record the culvert diameter. Observe the water elevation inside and outside the tide gate, looking for differences that may help explain how water flows into and out of the wetland. Detailed instructions are found in "**Identify the historic extent of tidal wetlands: Field observation**" above.

Restrictive culverts at roads and berms are often submerged by impounded freshwater flow on the upslope side. Look for differences in vegetation on the upslope and downslope sides. If the wetland vegetation on the downslope side of the culvert is brackish-tolerant (see Appendix E3), freshwater vegetation on the upslope side may indicate a restrictive culvert.

Check each Map E1 polygon for restrictive culverts. Where you observe evidence of a restrictive culvert, enter "Y" in Column 12 of Form E4-A, indicate the source of your information in the adjacent column, and mark the culvert location(s) on your laminates. If you have not field checked the location, enter "Q" in Column 14 of Form E4-A (GIS field TDGT_YN), because it is generally not possible to distinguish restrictive culverts from tide gates in aerial photos. If you are uncertain whether a particular polygon has a restrictive culvert, enter "Q" in both Columns 12 and 14, enter "Y" in Column 16, and seek further information.

Tide gates

Tide gates are devices that restrict tidal flow above a certain point in a channel system. Most tide gates in Oregon are "field drains" that restrict tidal entry into farm fields. "River mouth" and "tributary stream" tide gates limit tidal flow to entire sub-basins (Figure 16)**.** Such tide gates affect all wetlands upstream of the tide gate.

The tide gate itself is a heavy lid (also called a flap gate) attached to the downstream end of a culvert running through a dike. The tide gate closes during the rising tide, preventing tidal entry, and opens during the falling tide to allow freshwater drainage outwards. More detailed information on tide gates can be found in Giannico and Souder (2004 and 2005).

In aerial photos, tide gates are often indistinguishable from highly restrictive culverts. Turbulence pools may be present behind tide gates as well as restrictive culverts. Field-check sites to determine whether restricted drainages are culverted or tidegated.

To field-check a possible onsite tide gate, visit the drainage mouth at low tide (preferably a minus tide) and observe the downstream end of the culvert. Photograph the tide gate if it is visible, and record the location (including GPS coordinates if possible), culvert diameter, and the construction and condition of the tide gate lid. Look for evidence of malfunction (broken or frozen hinges, wood jammed in the opening, etc.). Observe the water elevation inside and outside the tide gate, looking for differences that help explain how water flows into and out of the wetland. See "**Identify the historic extent of tidal wetlands**" above for detailed instructions.

It is important to note that some drainages in the upper estuary may have "flap gates" (also called "flood gates") that are built like tide gates, but are installed to control freshwater flooding rather than tidal entry. These structures are located at a higher elevation than tide gates; they are generally not inundated by daily tidal cycles even on the month's highest tides (spring tides). Wetlands behind such flood gates may never have been tidal. The only way to determine possible tidal influence at such locations is to measure water levels inside and outside the tide gate / flood gate at low and high tides.

Check each Map E1 polygon and all of the tidal channels and streams in your estuary for possible tide gates. Mark the locations of known or possible tide gates on your aerial photo laminates and record their condition. For every Map E1 polygon affected by a tide gate -- whether onsite or offsite – enter "Y" in Column 14 of Form E4-A (GIS field TDGT_YN), and indicate the source of your information in the adjacent column. If you are uncertain whether a particular polygon is affected by a tide gate, enter "Q" in Column 14, and also enter "Y" in Column 16 of Form E4-A, because you will need to verify this information.

Roads/railroads

Many tidal wetlands are affected by roads and railroads. Roads/railroads built alongside tidal rivers often cross tidal channels that connect to fringing marshes, tidal sloughs, and pocket marshes. The crossing points, whether bridged, culverted, or tidegated, may restrict tidal exchange (Figure 11). (Bridges restrict flows much less than culverts or tide gates.) Roads and railroads that cross wetland surfaces are analyzed separately from culverts and tide gates because their embankments can disrupt surface water flow (Figure 11).

Check each Map E1 polygon for road and railroad alignments that block channelized or diffuse flow across wetlands. For each Map E1 polygon affected by a road or railroad, enter "Y" in Column 2 of Form E4-B (GIS field RDRR_YN), and indicate the source of your information in the adjacent column. If the road or railroad crossing acts as a dike, enter "Y" in Column 4 of Form E4-A as well.

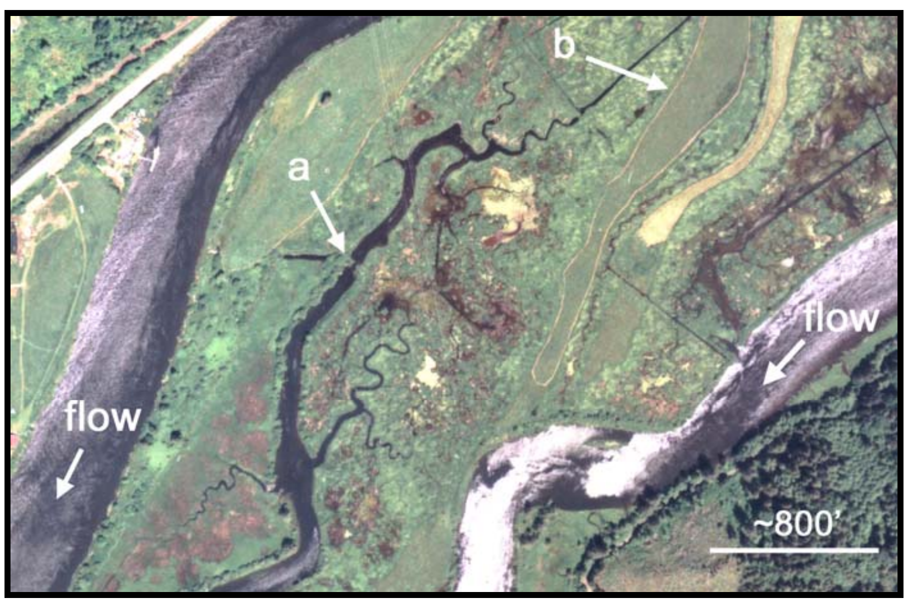
Earthen dams or other tidal channel blockages

In some estuaries, earthen dams were built to block or reduce tidal flows in tidal channels (Figure 21). (Some dams may contain culverts or tide gates, which will have been identified in earlier steps of this assessment.) Many dams have eroded away or been breached in recent years, but some still block flow.

Check tidal channels on each Map E1 polygon for dams or other man-made channel blockages. For each polygon where you observe a dam or blockages, enter "Y" in Column 4 of Form E4-B (GIS field DAM_YN) and indicate your data source in the adjacent column. Mark the location on your aerial photo laminates. If you are uncertain whether a particular polygon has a dam, enter "Q" in Column 4, and enter "Y" in Column 16 of Form E4-A.

Earthen dams are sometimes constructed in major channels that affect several different Map E1 polygons. If a dam completely blocks tidal flow to all upstream polygons, enter "Y" in Column 4 for all of those polygons. If the dammed channel is not the only source of tidal flow, it may be difficult to determine which areas are affected by the dam. For the purposes of this assessment, check all tidal channels in your study area for dams and enter "Y" in Column 4 of Form E4-B for all Map E1 polygons that are immediately adjacent to each dam or other manmade blockage.

Beaver often construct dams near head of tide in tidal wetlands. Beaver ponds offer high quality rearing habitat for juvenile salmonids (Miller and Sadro 2003); beaver dams are not considered alterations for this assessment.



Labeled features: a = earthen dam in major tidal channel, with recent breach in center of dam; b = fence line around elongated pasture area (higher ground).

Figure 21. Partially diked, restoring tidal wetland in an Oregon central coast estuary. Higher ground is in active pasture, lower areas are restoring to tidal marsh. Tidal exchange in upper right area of photo is muted due to remaining dikes.

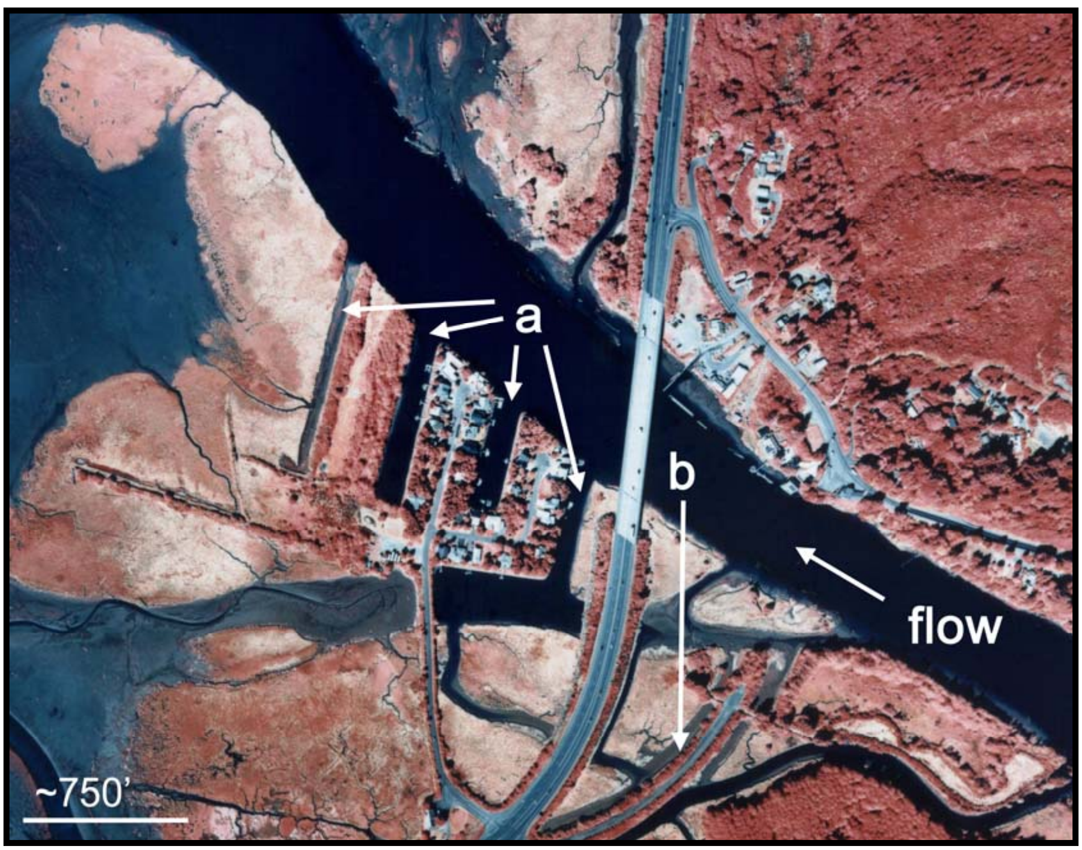
Channel armoring/riprap

Channel armoring and riprap are installed to limit shoreline erosion. These structures affect many natural processes such as development of streambank vegetation, sedimentation patterns, and surface water flow. You can often identify riprap and channel armoring as a sharply demarcated shoreline in developed areas of the estuary (Figure 22). In less-developed portions of the estuary, dikes, roads and railroads often function as channel armor (Figure 13).

Check each Map E1 polygon for channel armoring and riprap. For each polygon where you observe channel armoring and riprap along the margins of the polygon, enter "Y" in Column 6 of Form E4-B (GIS field ARMR_YN) and indicate the source of your information in the adjacent column. Mark the location on your aerial photo laminates. If the channel armor consists of a road or railroad, enter "Y" in Column 2 as well. In many of these cases, the road also acts as a dike; if so, also enter "Y" in Column 4 of Form E4-A. If you are uncertain whether a particular polygon has channel armoring or riprap, enter "Q" in Column 6 of Form E4-B, and enter "Y" in Column 16 of Form E4-A.

Spoil/Dredge material disposal

Tidal wetlands are sometimes used as disposal areas for material dredged from river channels; these are referred to as dredged material disposal ("DMD") areas. Each major estuary has a dredged material disposal plan that was developed in the 1970s or 1980s. Ask your local land-use planning



Labeled features: a = excavated boat basins with adjacent filled areas (residential development); b = spur road (old Highway 101) acting as channel armor on distributary tidal channel.

Figure 22. Excavated and filled tidal marsh in an Oregon north coast estuary. Highway 101 is located in center of photo. This is a color infrared photo in which actively growing plants appear pink to red, and water and pavement are black or gray-blue.

staff or check with the Oregon Department of Land Conservation and Development to view the plan's designated DMD areas; also see **Supplemental analyses: Land use regulations** below for details. Be aware that some areas that have received dredge material may not be mapped in the DMD plan; conversely, designated DMD sites may never have been used for dredged material disposal.

Unmapped, undesignated DMD areas can often be identified by unexpected vegetation patterns. For example, a DMD area may show as a patch of upland vegetation growing in an otherwise flat tidal marsh (Figure 23). If dredged material was placed along the riverbank, it can be hard to distinguish from a natural levee; local knowledge is helpful in this case.

Check each Map E1 polygon for spoil or dredged material disposal. Pay particular attention to polygons for which the NWI code in Column 9 of Form E1-A has the modifier "s" ("spoil"). For each Map E1 polygon where you observe DMD or other spoil disposal, enter "Y" in Column 6 of Form E4-A (GIS field SPL_YN), mark the location on your aerial photo laminates, and indicate your data source in the adjacent column (GIS field SPL_SRC). If you are uncertain whether a particular polygon has received dredge material, enter "Q" in Column 6 of Form E4-A, and enter "Y" in Column 16. It is especially important to obtain local knowledge for this investigation by consulting resource professionals, landowners and port authorities, as it can be challenging to identify DMD sites.

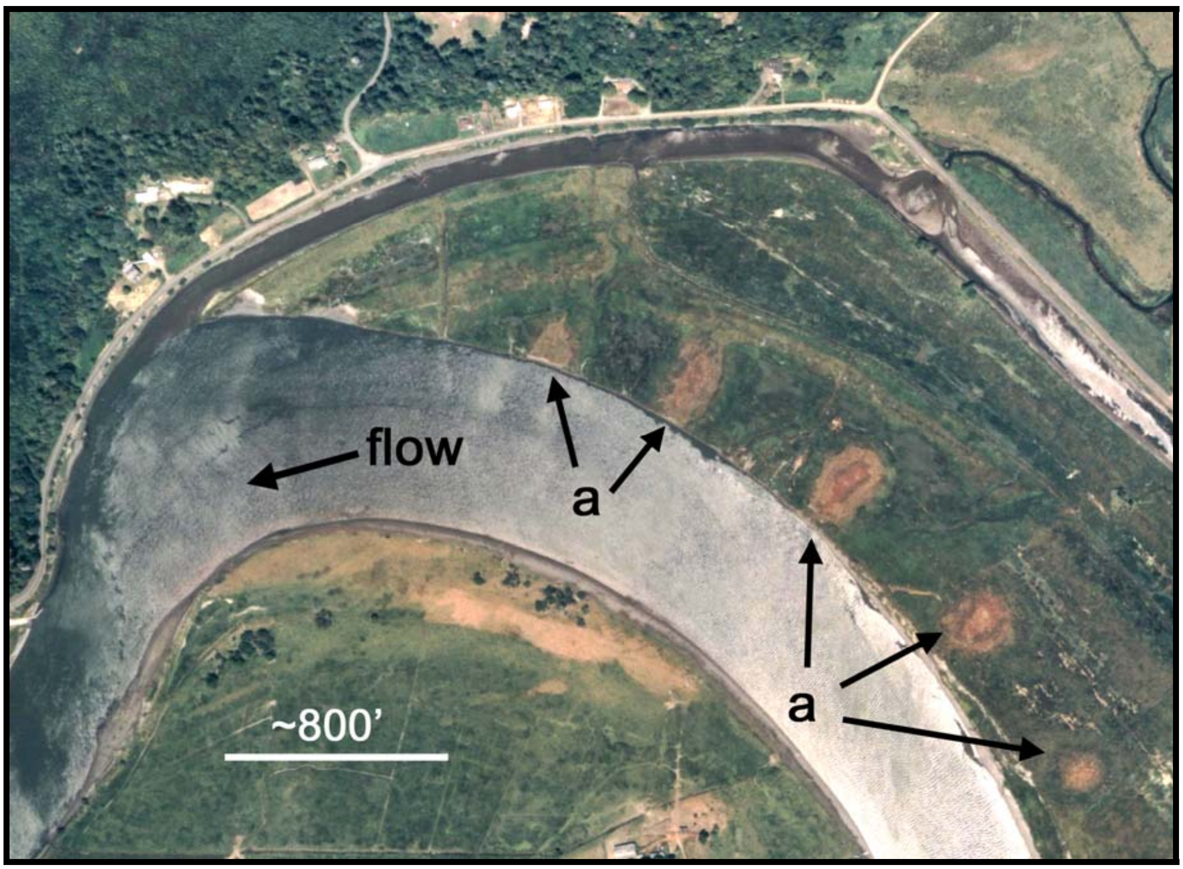


Figure 23. Dredged material disposal in a ditched tidal wetland, Oregon south coast estuary.

Labeled features: a = dredged material disposal areas (brown patches in green wetland).

Logging and driftwood removal

Many of Oregon's tidal wetlands are classified as emergent wetlands, also called "tidal marsh." By definition, these wetlands have few or no trees. However, the middle and upper portions of most Oregon estuaries historically contained substantial areas of forested tidal wetland, also known as tidal swamp. These swamps were often dominated by Sitka spruce, which were heavily logged during early settlement because of their accessibility. Driftwood removal for lumber and firewood has also been widespread in Oregon tidal marshes and swamps. Because of these factors, the current level of large wood in tidal wetlands is much lower than it was historically.

In Step 1 (**Identify the historic extent of tidal wetlands**), you analyzed historic vegetation to locate past tidal swamp areas; these polygons were been marked "Y" in Column 13 or 17 of Form E1-B. For areas marked "Y" in Column 13, check the ORNHIC classification for the polygon; spruce swamp is abbreviated FSL. Next, check your aerial photos or visit the area to see if spruce trees still dominate the vegetation. If the area was historically spruce swamp ("Y" in Column 13 and classified as FSL), or if spruce were dominant in the canopy in older aerial photos (Column 17 of Form E1-B), but spruce are no longer present, record the fact that the area has been logged by entering "Y" in Column 8 of Form E4-B (GIS field LOGD_YN). Show your data source in the adjacent column.

Grazing

Oregon's tidal marshes have been used for pasturing cattle since the early days of settlement. Most of these tidal wetland pastures have been diked. Many diked tidal wetlands are still grazed, but many have been abandoned and are no longer grazed. On the other hand, a few undiked tidal wetlands are currently grazed. Grazing is usually evident from casual observation in the field. However, for inaccessible areas, you can use aerial photos to view signs of grazing such as cattle paths, barns, fencelines, and trampled, muddy ground. In addition, grazing visibly alters tidal channels, because cattle trample the channel banks and move sediment into the channel. These changes are also visible in aerial photos; tidal channels in grazed areas appear shallower and broader, and are less distinct than in ungrazed wetlands.

Check each Map E1 polygon for evidence of current grazing. For each Map E1 polygon where you observe grazing, enter "Y" in Column 10 of Form E4-B (GIS field GRZ_YN) and indicate your information source in the adjacent column. If you are uncertain whether a particular polygon is grazed, enter "Q" in Column 10, and enter "Y" in Column 16 of Form E4-A.

Invasive species

Invasive species are a major concern in West Coast estuaries. This section addresses invasive plant species likely to be found in the habitat types assessed (low marsh, high marsh, and tidal swamp). Other invasives are briefly discussed below.

Four invasive plant species are of special concern in Oregon estuaries: Smooth cordgrass (*Spartina alterniflora*) (see sidebar), saltmeadow cordgrass (*Spartina patens*), purple loosestrife (*Lythrum salicaria*), and reed canarygrass (*Phalaris arundinacea*). Further information on these species is available at the Weedmapper website, http://www.weedmapper.org (for cordgrass and loosestrife) and at The Nature Conservancy's Global Invasive Species Initiative website, http://tncweeds.ucdavis.edu/esadocs.html, for reed canarygrass. Many other invasive plants (such as Japanese knotweed, giant knotweed, Scots broom, and Himalayan blackberry) are present within the estuary, but cordgrass, loosestrife and reed canarygrass are addressed in this assessment because: 1) They are already present in Oregon estuaries; 2) They are invasive wetland plants which can occupy large areas of tidal and formerly tidal marsh sites, to the exclusion of native species; 3) Three of the four (cordgrasses and loosestrife) are on the Oregon Department of Agriculture's "T" list, indicating they are considered economic threats to the state; 4) Three of the four are very tolerant of brackish water (all but reed canarygrass), making them particular threats in the estuary.

Both saltmeadow cordgrass and smooth cordgrass are listed by the Oregon State Weed Board as priority noxious weeds, as are other cordgrass species. Smooth cordgrass (including hybrid cordgrass) is considered a particular threat to Oregon estuaries because it colonizes mudflats, forming dense, single-species clones (see sidebar). According to the Oregon Department of Agriculture's website, "Mono-cultures of [smooth] cordgrass alter estuary hydrology and ecosystem functions through increased sedimentation and accretion, raising the elevation of infested areas several feet" (Oregon Department of Agriculture 2005). Such infestations could render thousands of acres of mudflats unsuitable for important economic activities (oyster production), recreational activities (clam harvest), and migratory waterfowl use.

To date, cordgrass has been found only in the Siuslaw River estuary (smooth and saltmeadow cordgrass) and the Coos River estuary (smooth cordgrass). These cordgrass populations are being actively controlled. As shown on the Weedmapper website (http://www.weedmapper.org), purple loosestrife has been reported from the Columbia, Necanicum, Tillamook, Umpqua, and Coos estuaries; biocontrol is underway in several locations.

ODA asks individuals who observe "T" list weed species to call 1-800-INVADER to report the observations. You can obtain information on how to identify *Spartina* from the Oregon Department of Agriculture (ODA) at 503-986-4621 (see sidebar). Early detection of *Spartina* will be critical to preventing large-scale damage to Oregon estuaries, and you can help with this effort. During your fieldwork, be on the lookout for *Spartina*. Low tide field trips will give you a better view of low marsh where smooth cordgrass may establish.

If you find even a single plant of *Spartina* or other "T" list species in your study area, mark the location in the field and on your aerial photo laminates, and immediately call the ODA invasive species hotline at 1-866-INVADER. For any Map E1 polygon where you observe invasive species (or where others report their presence), enter "Y" in Column 12 of Form E4-B (GIS field INVA_YN), and indicate your information source and the species observed in the adjacent columns.

A number of invasive species are of concern in other estuarine habitat types. Examples include the European green crab (*Carcinus maenas*, which lives in eelgrass beds and subtidal habitats), and Japanese eelgrass (*Zostera japonica*, found in aquatic beds). Further information is available at USDA's National Invasive Species Information Center website (http://www.invasivespeciesinfo.gov/profiles/greencrab.shtml) and at Oregon State University's "Invasive Species in Oregon's Estuaries" web page (http://science.oregonstate.edu/~yamadas/index.htm).

General estuary alterations

Besides alterations to individual tidal wetland sites, estuaries have undergone many alterations in open water areas, developed areas, adjacent uplands and freshwater wetlands. Estuary-wide alterations and larger watershed alterations are not specifically addressed in this module. However, many of these larger-scale factors which affect estuarine health are assessed in the other modules of the Watershed Assessment Manual, such as:

- Hatcheries
- Water withdrawals
- Changes to sediment sources and sediment movement
- Water pollution (nonpoint and point) and sediment contamination
- Changes to hydrologic regimes (peak flows, flooding)
- Upland habitat changes such as impervious surfaces

Once these factors have been evaluated in the overall watershed assessment, the results can be linked to this estuary assessment (see "**Linking the estuary assessment and other watershed assessment modules**" below).

Refine your map and list of alterations

As you consolidate your knowledge of alterations to tidal wetlands, use Forms E4-A and E4-B to record the new information gained. Be sure to mark the locations of the alterations on your aerial photo laminates, because you will need to know where these alterations are located in the next step of this assessment. That next step, "**Define units of analysis**", will use the forms and maps you have created.

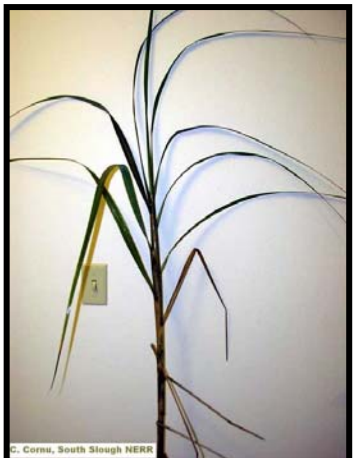
For polygons that you have field-checked for alterations, enter "Y" in Column 4 of Form E1-A.

Smooth Cordgrass (*Spartina alterniflora*) diagnostic information.

Photos and information courtesy of Oregon Department of Agriculture and the individual photographers credited.

a. Growth habit of *Spartina alterniflora*. Photo by Vanessa Howard, PSU-CLR.

b. Aerial view of circular *Spartina alterniflora* clonal patches in Willapa Bay, Washington. Photo provided by Oregon Department of Agriculture.



c. Individual stem of *Spartina alterniflora* showing potential height (note light switch in photo for scale). Photo by Craig Cornu, South Slough National Estuarine Research Reserve.

d. Leaf base of *Spartina alterniflora* showing ligule of fine hairs, one of the main diagnostic features of the species. Photo by Craig Cornu, South Slough National Estuarine Research Reserve.

Other diagnostic information for *Spartina alterniflora*:
Growth habit: Erect perennial to 5 feet tall, on intertidal mud or sand areas that have minimal wave action; occurs as low as eelgrass in the intertidal zone.
Leaves: Spiky and flat (when fresh) without a prominent midrib, taper to a sharp tip.
Stems: Round, with joints, hollow between the joints; often red at the base of healthy young plants.
Roots: White, fleshy with underground runners, aggressively spreading.
Notes: Stems not triangular in cross section; does have ligule of fine hairs at base of leaf where it attaches to stem.
Species identification: http://www.spartina.org/species.htm
Spartina watch in Oregon: http://www.clr.pdx.edu/projects/spartina/
General descriptive information: http://www.wapms.org/plants/spartina.html

GIS tip: *Enter data in your MapE1 attribute table to reflect the information you have gained. Digitize the locations of alterations into your GIS. You should also keep a separate computerized spreadsheet or paper file of notes on sites, since lengthy text fields can be difficult to manage in a GIS.*

STEP 3: DEFINE UNITS OF ANALYSIS ("SITES")

So far, you have worked with "Map E1 polygons," which were taken directly the HGM base map. Now you need to define different units of analysis, because the goals of the HGM study and the goals of your assessment are different. Your analysis units need to be suitable both for evaluation of ecological functions and for planning needs. In some cases, individual Map E1 polygons will become sites, but in other cases, Map E1 polygons will be combined or split to create your analysis units.

The unit of analysis for the remaining sections of this module will be referred to as a "site." A "site" is a contiguous wetland area characterized by an internally consistent level of alteration (or lack of alteration). Sites can be either conservation sites (with few or no onsite alterations) or restoration sites (with alterations). An individual restoration site can present a single obvious restoration opportunity. For example, a site might be relatively unaltered except for a single restrictive culvert, which could be upgraded or replaced by a bridge. Other sites offer a variety of restoration opportunities. For example, a diked and tidegated former tidal marsh could be restored by dike breaching, dike removal, channel restoration/ditch filling, and/or installation of fish-friendly tide gates.

Two principles guide site definition for this assessment:

Principle 1: Define contiguous, connected wetlands as a single site if they share a consistent level of alteration

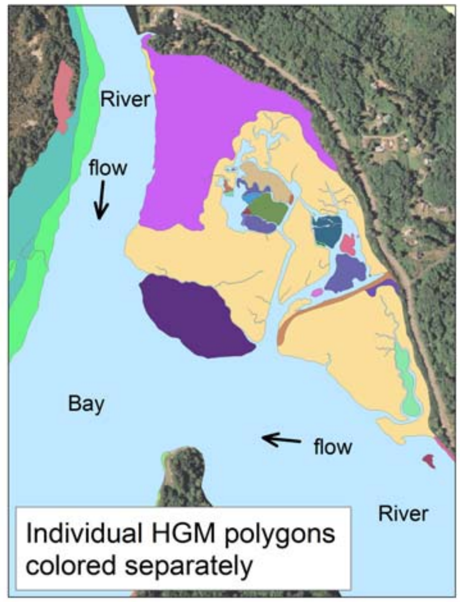
Large connected blocks of wetland offer superior ecological functions, such as greater opportunities for development of diverse plant and animal communities. This assessment recognizes the importance of large connected ("contiguous") wetland areas.

The HGM mapping divides the landscape according to "HGM class," which is partly based on elevation and degree of tidal influence. Low marsh, high marsh, and swamp are mapped separately in HGM. But in this assessment, it is important to recognize interconnected, contiguous tidal wetland areas as a single site where possible, *particularly* if that site incorporates a range of elevations and plant communities. Such a continuum of plant communities has high ecological value, as it allows movement of animals from one wetland zone to another in response to their needs or changing environmental conditions. If your study area contains groups of HGM polygons that cross such a gradient, it is important to define the entire continuum it as a single site for action planning purposes, *provided the polygons have a relatively consistent level of alteration.*

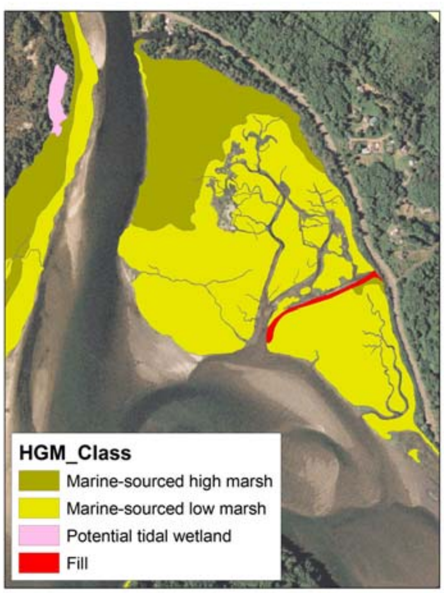
In practical terms, this means merging adjacent Map E1 polygons that have similar levels of alteration, regardless of their HGM, NWI or EPB class. Figure 24 shows an example of how to group HGM polygons where their level of alteration is similar.

A. Digital orthophoto of area showing similar level of alteration throughout marsh at upper right (below road)

B. Individual HGM polygons for same marsh (18 polygons).



C. HGM classes (just 3 in area of marsh).



D. Suggested grouping of HGM polygons into a single "site."

Figure 24: Example of HGM Polygon grouping.

Principle 2: Draw site boundaries to separate areas with distinctly different alteration levels

Since a site is defined as a contiguous wetland area with an internally consistent alteration level, it is logical that the reverse is also true: Geographically separate wetland areas or areas with very different alteration levels should be defined as separate sites. Alteration levels strongly affect wetland functions and restoration opportunities. Alteration levels will determine the ranking of a site during the prioritization step of this assessment.

In most cases, the HGM map already represents geographically separate wetlands as distinct polygons. So, your remaining task is to split any Map E1 polygon that has subareas with very different alteration levels. For example, if the west half of a Map E1 polygon is heavily ditched, grazed, and mowed, but the east half has natural meandering channels, woody vegetation, and no livestock use, divide this polygon into two separate sites. Such a situation is fairly unusual, because the HGM polygons generally have internally consistent alteration levels.

Develop your site map

Create your Map E2 overlay

In the first step of this assessment, you created Map E1 (*Historic Extent of Tidal Wetlands*), which consisted of HGM polygons. You marked HGM ID codes on each polygon of this map and located indicators of tidal status and alterations within each polygon. To make this map of historic extent accurate, you excluded HGM polygons where your investigation showed no evidence of current or historic tidal influence. You retained filled areas which were once tidal.

In this section, an overlay called "Map E2" will be developed by modifying Map E1 according to the two principles outlined above. Map E1 polygons will be merged and split to create Map E2 – your "Site map." The locations of alterations that you marked on your aerial photo laminates and the lists of alterations in Forms E4-A and E4-B will assist you in this task. Areas that have been filled and converted to developed uses will be deleted from the map. Detailed instructions are found below.

> ***GIS tip:*** *Create a new shapefile called "Sites" by making an exact copy of your MapE1 shapefile. Keep both shapefiles for future use; both contain valuable information.*

Exclude Map E1 polygons that are filled and developed

On Form E4-A, look at Column 2. In Step 2, you marked this column "Y" for those Map E1 polygons which were HGM Class F (*but not dikes*), and/or were filled and converted to developed uses. At this time, you should mark those polygons "F&D" for "filled & developed" on Map E1. If your study area contains dikes on which houses and other permanent structures have been built, also mark those polygons "F&D." Do not transfer the polygons marked "F&D" outlines to Map E2, since these filled and developed areas will be excluded from the remainder of this assessment.

> ***GIS tip:*** *In your new "Sites" shapefile, delete those polygons defined as HGM Class F, unless they are dikes without houses or other permanent structures.*

Lump adjacent Map E1 polygons that have similar levels of alteration

Working on your Map E2 overlay over Map E1, and referring to your aerial photos and Forms E4-A and E4-B, create an overall outline around adjacent Map E1 polygons that have a similar level of alteration. Each outlined area is a "site;" write a unique site number on each outlined area. Exclude filled and developed polygons as described in Step 2 above. Figures 19 & 24 show examples of how to group Map E1 polygons.

To define "similar levels of alteration," check the list of alterations in Forms E4-A and E4-B, and look for the presence of dikes, tide gates and culverts in aerial photos. Also consider the intensity of ditching, and the intensity of agricultural use (grazing, tillage). Look for remnant tidal channels and other indicators of "remnant" site conditions that may indicate greater ease of restoration. For example, adjacent Map E1 polygons that are both heavily ditched, with no visible remnant meanders, should be lumped together. Adjacent polygons where one polygon is diked but the adjacent polygon is not diked should not be lumped.

Disregard the "HGM class" of your Map E1 polygons when lumping – that is, lump all HGM classes into a single site unless they differ in level of alteration. HGM classes define different sources and degrees of tidal inundation, but for this assessment, your goal is to create inclusive sites that maximize the opportunities for conserving and restoring the full spectrum of wetland types across the tidal inundation gradient (see **Principle 1** above).

Be sure to merge dikes (which may be shown as HGM class "F" in Map E1) with the adjacent diked lands when defining sites. For restoration planning purposes, it is important to retain the dikes in the tidal wetland maps. You can refer back to the original HGM layer to locate the dikes at later site-specific planning stages.

> ***GIS tip:*** *In your new "Sites" shapefile, merge the MapE1 polygons that have similar levels of alteration (see Figures 19 & 24 for examples). Create a field called ALTERS in the attribute table. In the field ALTERS, list all alterations that were found on the merged polygons. Merge other fields from the underlying MapE1 polygons as appropriate. Add a Notes field for further details.*
> *You may wish to record notes about your sites (and the site definition process) in a separate spreadsheet, since long text fields can be difficult to manage in GIS.*

Split Map E1 polygons where the level of alteration is strikingly different within a polygon

Again, working on your Map E2 overlay over Map E1, and referring to your aerial photos and Forms E4-A and E4-B, draw lines to divide Map E1 polygons where well-defined subareas display noticeably different levels of alteration.

For example, if a single Map E1 polygon contains a section that is diked and heavily ditched and an adjacent section that is undiked and unditched, draw a line between the two sections to create two separate sites. Draw the dividing line along features like roads or obvious property boundaries. Note that multiple landowners are not a sufficient reason to split a polygon. A single polygon that has several landowners should be considered a single site, unless the different landowners have managed their land very differently, resulting in different levels of alteration.

GIS tip: *In your new Sites shapefile, split polygons that have well-defined subareas with different levels of alteration. Determine which of the alterations in the original polygon are found on which new site, and transfer those alterations to the field ALTERS for each new site resulting from the split. Transfer other Map E1 polygon attributes as appropriate.*

Record notes about your sites (and the site definition process) in a separate spreadsheet, since long text fields can be difficult to manage in GIS.

Finalize your site map

On your Map E2 overlay, you now have a series of outlines that define "sites" – each of which has an internally consistent level of alteration. In most cases, you will have merged several Map E1 polygons (of different HGM classes) to form a single site. You may have split some Map E1 polygons that have subareas with very different levels of alteration.

Mark each newly defined site on your Map E2 overlay with a unique site number.

GIS tip: *You now have a shapefile called "Sites" which consists of the new polygons you formed by merging and splitting the Map E1 polygons. You have entered alterations to each site in the attribute table field called "ALTERS" and transferred MapE1 attributes as appropriate.*

Create a new field called "Site_No" and assign a unique site number to each site. Archive your original MapE1 shapefile, which contains detailed information on the types of alterations present.

STEP 4: IDENTIFY CONSERVATION SITES

Working with your new map of sites, determine the alterations found within each site by checking Forms E4-A and E4-B for each underlying Map E1 polygon. If a site has no alterations, it is defined for this assessment as a ***conservation site***. List conservation sites in Form E5; record both the site number (Column 1, Form E5) and the underlying Map E1 polygon numbers (Column 2, Form E5). Record your notes about sites in Column 4. In the next step of this assessment (**Site prioritization**), conservation sites and restoration sites will be prioritized for action planning purposes.

In Form E5, you may wish to include sites that have only minor alterations to small areas of the site **and are otherwise undisturbed**. Examples would be sites that have a road or railroad crossing at the edge the site, if that road/railroad does not appear to have a major impact on tidal circulation; or sites with minor ditching but most tidal channels intact. Use Column 3 of Form E5 to record any minor alterations observed.

It is important to keep in mind that even conservation sites may offer opportunities for resource management or wetland enhancement. Examples include removal of exotic species and establishment of offsite buffers.

It is also important to remember that the distinction between conservation sites and restoration sites is somewhat subjective. For example, an undiked, unditched tidal wetland with a large, open culvert on the main tidal channel may allow almost complete tidal exchange; conservation of such a site is a logical choice for action planning. However, a culvert is a substantial alteration compared to an open tidal channel, and it can be difficult to determine a culvert's effect on site hydrology. Therefore, the site could also be considered a restoration site; a potential restoration plan could be to replace the culvert with a bridge. **To achieve both conservation and restoration goals, all conservation plans should include investigation of potential restoration actions, and all restoration plans should include mechanisms to protect the existing wetlands.**

> *GIS tip: Create a field in the attribute table in your Sites shapefile called "Cons_Rest," and enter "Cons" for each site that has no alterations (or only minor alterations) listed in the field ALTERS.*

STEP 5: IDENTIFY RESTORATION SITES

Restoration is defined as "return of an ecosystem to a close approximation of its condition prior to disturbance" (National Research Council 1992). Restoration practitioners work to achieve this goal by removing alterations and/or reconstructing natural features in order to re-establish pre-disturbance ecological functions. Therefore, any site with alterations is a potential "restoration site," provided the landowner is willing and interested.

Working with your new map of sites, find those sites for which alterations were listed in Forms E4-A and E4-B for underlying Map E1 polygons. These are *restoration sites*, areas that provide restoration opportunities. List these sites, and their alterations, in Form E6. Record the site number (Column 1, Form E6) and the underlying Map E1 polygon numbers (Column 2, Form E6). Record the alterations found within each site in Column 3; record your notes in Column 4.

If some of the restoration sites were created by splitting Map E1 polygons, you will need to determine which of the original polygon's alterations are found on which of the final sites. Check the annotations you made on your aerial photo laminates in Step 2 (Assess Alterations to Tidal Wetlands) for the locations of identified alterations on each polygon. You may need to go back to your original data sources in some cases. Be sure to enter "offsite tide gate" for sites behind a system-wide, river or tributary mouth tide gate (see **Tide gates** above).

> *GIS tip: In the "Cons_Rest" field within your Sites shapefile attribute table, enter "Rest" for each site that has alterations listed in the field ALTERS. Use a spreadsheet (Form E6) to record your notes on these sites.*

Specific restoration activities appropriate to each site are discussed in **"Recommended restoration actions"** below.

STEP 6: IDENTIFY LANDOWNERS

For purposes of action planning, it is important to identify landowners for each site. Obtain tax parcel maps from your county tax assessor's office. Reproduce the tax parcel maps at a scale to match your Map E2 overlay. Since land ownership boundaries are often visible in aerial photographs (due to differences in land management), you can use your aerial photographs to help you place the overlay correctly.

Locate the tax parcels within each Map E2 site and list the parcel numbers in Form E7. After determining the tax parcels for each site, obtain landowner names from your county assessor's office. Obtain addresses at the same time so you can contact landowners. Enter the data in Form E7; keep addresses and other contact information in a separate spreadsheet.

GIS tip: Contact your county assessor's office or tax department to determine whether land ownership information is available in GIS format. Often, GIS data will contain tax lot numbers, landowner names, landowner addresses, and other information. If GIS landownership data are available for your study area, determine owners for each site by intersecting the GIS sites with ownership parcels. Include all owners that own part of a site, but use judgment regarding "slivers" due to imperfect registration between tax parcels and your sites layer. List the owners in Form E5. Electronic spreadsheet format rather than GIS is best for this data, which can be lengthy.

IV. SITE PRIORITIZATION

A. Concepts and approach

This section prioritizes the restoration and conservation opportunities you identified in previous steps of the assessment. The prioritization is science-based and focuses on biological and ecological factors, but supplementary analyses consider some logistical and social factors. Your prioritization will rank sites (rather than specific actions), because each site is a unique physical land area with specific biological characteristics that correlate to current or potential wetland functions. In addition, each site offers a range of potential restoration opportunities, allowing consideration of a gradual or staged restoration process that may improve economic and social feasibility.

B. Critical question

1. Where will restoration and conservation opportunities offer the highest ecological benefits?

Prioritization of restoration and conservation opportunities is critical. Every estuary study area offers a wide variety of project opportunities. Because time, skill, and money are limited, only a limited number of opportunities can be realized. This module's prioritization will help you focus on those locations in the landscape that may offer the biggest ecological "bang for the buck" – that is, those sites that may offer the highest potential to protect or increase estuary functions. Most conservation funding groups prefer to fund organizations that have a strategic plan in place, so your prioritization will help you gain funding. It will also provide you with an organizational framework for tracking and evaluating your estuary restoration and conservation activities.

C. Materials needed

The following materials are needed for the prioritization process. You may use either a GIS, or paper maps and overlays. Sources for both types of data are listed below. Materials are listed in the order that they are used in the analysis.

- **Products of Steps 1 through 6** above (Maps E1 and E2; Forms E1, E2, E3, E4-A, E4-B, E5, E6 and E7).
- **Drafting materials:** Acreage grid (dot grid or area scale) for measuring areas on maps; map wheel for measuring distances along streams; ruler. These are not needed if you are using a GIS.
- **Aerial photographs** (see **Estuary Assessment** section)
- **National Wetlands Inventory** and any available **Local Wetlands Inventories** (see **Estuary Assessment** section)
- **Oregon Estuary Plan Book** (see **Estuary Assessment** section)
- **Oregon Department of Fish and Wildlife (ODFW) salmonid distribution mapping**. Printable maps are online at the ODFW fish distribution/habitat map web page, http://rainbow.dfw.state.or.us/nrimp/information/fishdistmaps.htm. GIS data can be downloaded from the ODFW fish distribution/habitat GIS data web page, http://rainbow.dfw.state.or.us/nrimp/information/fishdistdata.htm.
- **Oregon Natural Heritage Program historic vegetation mapping** (see **Estuary Assessment** section)
- **Land ownership information.** County tax parcel maps are the best source of this information. Scanned images of tax maps are available online at the Oregon Maps Online web page, http://www.ormap.org/maps/index.cfm. If you are using a GIS (Geographic Information System), ask your county tax assessor's office if they have tax parcel maps in GIS format.
- **Land use planning documents**, such as the Oregon Estuary Plan Book (Cortright et al. 1987), your County Comprehensive Plan and dredged material disposal plans. These documents will help you understand opportunities and limitations related to local land use planning designations. Obtain these documents from your County Planning and Port offices.
- **Field observation and interviews** with local landowners and others with knowledge of local conditions and land use history. Detailed instructions below describe the information needed.

D. Necessary skills

Same as for assessment, plus:

- Ability to use and understand ODFW fish distribution mapping.

E. Final products

This prioritization will result in:

Form E8: Tidal wetland prioritization scoring

Form E9: Channel condition scoring

Map E3: Tidal wetland prioritization map

F. Prioritization methods

This section addresses prioritization of sites within a given estuary for both conservation and restoration actions. The method is not intended for prioritization across different estuaries.

1. ECOLOGICAL CRITERIA

In this step, ecological criteria are used to prioritize tidal wetland sites for restoration and conservation actions. The criteria are:

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

Each factor is scored on a consistent scale of 1 to 5, and the six scores are summed for the final total score (with tidal channel condition double-weighted). A high score indicates high priority.

How the criteria were selected

This prioritization method was developed specifically for Oregon estuaries south of the Columbia River. The criteria were selected to address the specific characteristics of estuaries in this region. For example, potential industrial contamination was not included as a prioritization criterion, because industrial land uses are relatively rare in this region. By contrast, channel condition and tidal exchange (diking/ditching) are heavily weighted, because these are the characteristics most impacted by prevalent land uses in the region.

Each prioritization criterion was selected because it affects a broad range of tidal wetland functions. For example, the size of a site affects the quantity of sediment the site can store; the quantity of nutrients it can process; the amount of primary productivity it can support; and the amount of wildlife habitat it provides.

This prioritization is not intended to be an assessment of specific site functions. A rapid functional assessment method has recently been developed for Oregon's tidal wetlands (Adamus 2006), and other functional assessment methods are available (Simenstad et al. 1991).

Although this prioritization uses ecological criteria, non-ecological factors also affect restoration potential and decision-making, such as number of landowners, landowner type, and land use zoning. These factors are analyzed separately in **Supplementary analyses** below. Additional analyses (community perceptions and economics) are optional for this assessment, and are described in **Further analyses** (Appendix E5).

Prioritizing restoration and conservation sites jointly

This method prioritizes restoration sites and conservation sites jointly by analyzing broad indicators of current and potential tidal wetland functions.

Although prioritizing restoration and conservation 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 replanting of spruce that were removed during the early logging era. Development of potential restoration projects will be addressed after you complete this assessment, during your site-specific project planning phase.

Summary of criteria and scoring approach

Table 3 summarizes the ecological criteria used to prioritize sites. The rationale and methods for each factor are provided in the narrative sections below. Note that scoring is on a consistent scale (1 to 5) to maintain equal weighting for each criterion. The sole exception is the tidal channel condition score, which is double-weighted in the final score (see **Combined ecological score** below). Also, criterion scores are intended only to express relative ecological potential, not absolute levels of any characteristic or functions. That is, a score of 5 does not imply a functional level 5 times better than a score of 1.

> ***GIS tip:*** *Create new fields in the attribute table of your "Sites" shapefile for each column in Forms E8 and E9. Suggested field names are shown in the forms.*

Table 3. Summary of ecological prioritization criteria

Factor	Data source	Description	Levels and scoring
Size of site	Map of sites	Size in hectares or acres. You may choose to omit sites under 1 ha (2.5 A) in size.	Convert full range of values for study area to scores of 1 (smallest) to 5 (largest).
Tidal channel condition	Aerial photograph interpretation and field observation; Forms E4-A and E4-B	Look for visible tidal flow restrictions, ditching, dikes, and remnant channels.	See scoring matrix (Table 4). **This score is doubled in the final total score.**
Wetland connectivity	National Wetlands Inventory, Estuary Plan Book Habitat types mapping	Total area of wetlands and eelgrass beds within 1 mile of site, excluding the site itself.	Convert full range of values for study area to scores of 1 (smallest area) to 5 (largest area).
Salmonid diversity	ODFW salmonid distribution data	Number of salmon stocks spawning upstream of site ***in the stream system on which the site is located*** (main stem or tributary), including areas of historic use.	Convert full range of values for study area to scale of 1 (lowest # stocks) to 5 (highest # stocks).
Historic wetland type	Oregon Natural Heritage Program historic vegetation mapping and ranking	Percentage of site area that was historically tidal swamp (ranked by ORNHIC as critically imperiled) or other tidal swamp.	Convert full range of values for study area to scores of 1 (smallest percentage) to 5 (largest percentage).
Diversity of current vegetation classes	National Wetlands Inventory/Air photo interpretation	Number of Cowardin vegetation classes (emergent, scrub-shrub, forested wetlands) mapped on site, excluding classes mapped on <10% of site area.	One Cowardin class: score = 1 Two Cowardin classes: score = 3 Three Cowardin classes: score = 5
TOTAL SCORE			Add all 6 criteria scores, doubling the tidal channel condition score (maximum possible score = 35; minimum possible score = 7)

Scores for each of these factors will be recorded in Forms E8 and E9.

Size of site

Rationale: Site size is central to most wetland prioritizations (e.g., Tiner 2002; White et al. 1998; Schreffler and Thom 1993; Skagit Watershed Council 1998; Simenstad et al. 1999; Lebovitz 1992; Brophy 1999; Costa et al. 2002). The science of biogeography (McArthur and Wilson, 1967) has established that larger sites are more likely to be self-sustaining; more likely to have higher diversity of plant and animal species; and better buffered against outside disturbances such as pollution and invasive species. Larger sites may also be cheaper to restore on a per-acre basis due to efficiencies of scale.

How to calculate: Place a dot grid over your sites map (Map E2). Count the dots within each site and convert to area (size). Record the size of each site in Column 2 of Form E8. If your study area is large, you may choose to omit sites smaller than 1 ha (about 2.5A), to speed further analysis. However, if your study area is small, you may wish to retain small sites for a more complete picture.

How to score: After you have calculated the size for all of your sites, convert the range of sizes to a scale of 1 to 5 (see sidebar "Rescaling site values"). Record this score in Column 3 of Form E8. Keep the score separate from the actual size of the site so you can re-check the values later.

Rescaling site values for prioritization scoring

You will use this procedure to rescale individual site values to produce scores that range from 1 to 5. The method allows you to compare the different criteria on a common scale.
Find the highest and lowest values among all sites in your study area, for the factor you are scoring. Subtract the lowest value from the highest value to get the range. Then subtract the lowest value from each site's value. Divide the result by the range. Multiply the result by the scaling factor of 4. Add 1 to get the final rescaled site score.
Expressed as a formula:

$$Scaled\_Site\_Score = \left[\left\{ \frac{Site\_Value - Minimum\_Value}{Maximum\_Value - Minimum\_Value} \right\} \times 4 \right] + 1$$

*Example 1: Site size is 23 ha. Smallest site in study area is 2 ha, largest is 85 ha. Rescaled size score is: {[(23-2) / (85-2)] * 4} + 1 = [(21/83)*4] + 1 = 2.01*

*Example 2: Site size is 80 ha. Smallest site in study area is 2 ha, largest is 85 ha. Rescaled size score is: [(80-2) / (85-2)*4] + 1 = [(78/83)*4] + 1 = 4.76*

GIS tip: *Using your GIS software, calculate the area for each polygon in your "Sites" shapefile. Make this calculation in the SITE_SZ field of the Sites attribute table. If your study area is large, you may choose to delete sites under 1 ha in size.*

In the field SZ_SCO, rescale size range to a scale of 1 to 5.

Tidal channel condition

Rationale: Tidal wetlands depend on tidal flow for their distinctive functions. Alterations to tidal channels that restrict and redirect tidal flow -- such as tide gates, restrictive culverts, and ditching – reduce tidal wetland functions. The restoration potential of a site relates closely to the nature of tidal restrictions, their locations, and the degree to which the internal drainages of a site have been altered.

Logistically, it can be challenging to restore sites affected by river-mouth, major tributary, or slough system tide gates located offsite (e.g., Figure 17). Restoration of tidal flow to such sites may require cooperation among many stakeholders as well as major changes like relocation of the river-mouth tide gate, extensive dike construction, and/or installation of multiple field drain tide gates. Onsite tide gates (field drains or tributary tide gates affecting only one site) are logistically simpler, since removing or modifying these tide gates may affect only a single site.

Internal channels at most tidally-restricted sites are ditched to improve their agricultural potential. Ditching degrades many functions of natural tidal channels. For example, ditches have different flow velocities, depths, and profiles compared to natural tidal channels. These altered characteristics affect their accessibility to juvenile salmon, and reduce salmonid habitat functions such as shelter from predators and escape from high velocity river flows. Even if a site's channels are not ditched, tidal flow restrictions cause tidal channels to gradually degrade over time and become less distinct. A complete lack of visible remnant tidal channels may indicate lower restoration potential compared to a site with many distinct remnant channels. Remnant channels can "jump-start" the process of restoring natural tidal hydrology by providing natural conduits for returning tidal flow. Visible remnant channels also indicate that a site is less intensively altered in terms of surface soil manipulation, subsidence, compaction, and vegetation changes. Subsidence can greatly alter restoration potential (Frenkel and Morlan 1991).

Tidal channel condition is also related to cost-efficiency. Sites with meandering tidal channels in good condition (low alteration) may be cheaper to restore than sites with high degrees of alteration. Sites with minimal tidal restriction and internal channels in good shape may require only relatively low-cost restoration methods (such as culvert upgrades, grazing setasides or culvert upgrades) to return to full wetland functions. More highly altered sites, by contrast, may require more expensive and technically complex restoration techniques such as dike breaching, ditch filling, and excavation of tidal channels.

How to calculate and score: Use the tidal channel condition scoring reference chart (Table 4, below) to evaluate each site. Choose the category in each column that best describes the site, selecting categories independently for each subfactor (see examples, Table 5). Assign a score to each site for each subfactor, then add the scores from all 4 subfactors and divide by 4 to obtain the final score for each site. Use information from your largest-scale aerial photos, local knowledge, and field surveys to choose the appropriate category for each column. Record the subfactor scores, their sum, and the final score for each site in Form E9 (Appendix E1), then transfer the final score to Column 4 of Form E8.

GIS tip: Create and populate fields in your Sites attribute table for the columns in Form E9.

Table 4. Tidal channel condition scoring reference chart.

	Tidal exchange		Tide gate location		Ditching		Remnant channels	
	Condition description	Score	Condition description	Score	Condition description	Score	Condition description	Score
Highly altered condition	None	1	Offsite	1	Heavy	1	None	1
Medium alteration level	Restricted	3	Onsite	3	Some	3	Some	3
Least-altered condition	Full	5	None	5	None	5	Many*	5

*or: channels are undisturbed; or site is an existing restoration site

Examples of tidal channel condition scoring (from most to least altered):

- Site A has no tidal exchange, offsite tide gates, heavy ditching, and no visible remnant channels.
- Site B has tidal exchange restricted by culverts, no tide gates, heavy ditching, and some visible remnant channels.
- Site C has no tidal exchange, offsite tide gates, no ditching, and undisturbed channels.
- Site D has full tidal exchange, no tide gates, no ditching, and undisturbed channels.

Table 5. Tidal channel condition example scoring.

Site #	Tidal exchange TID_X	Tide gate location TG_LOC	Ditching DITCH	Remnant channels RMCH	Tidal channel condition sum TCC_SUM	Final score (TCC_SUM/4) TCC_SCO
Site A	1	1	1	1	4	1
Site B	3	5	1	3	12	3
Site C	1	1	5	5	12	3
Site D	5	5	5	5	20	5

Wetland connectivity

Rationale: In ecological terminology, connectivity (spatial connection of habitats to one another) is the opposite of fragmentation (isolation of habitats). Wetlands with good connectivity – i.e., connected via habitat corridors or waterways to other nearby wetlands -- can perform many of their functions better, compared to isolated wetlands (Amezaga et al. 2002, Haig et al. 1998). Wetland-dependent animals can find refuge from human or natural disturbances more easily if there are other wetlands nearby. Mobile species such as anadromous fish, waterfowl, and native landbirds and mammals often feed and rest in several wetlands, depending on distance and size of the nearby habitats (Haig et al. 1998, Simenstad et al. 2000). Thus, the suitability of an individual wetland cannot be assessed fairly without considering the distance to other wetlands and the total nearby wetland area.

This assessment uses a simple scoring method based on total area of wetlands within a 1-mile buffer around each site's perimeter. NWI emergent, scrub-shrub and forested wetlands, as well as and aquatic beds mapped in the Estuary Plan Book, are included in the analysis. Aquatic beds are included because of their importance as habitat for invertebrates, fish, and waterfowl (Phillips 1984; Rozas and Odum 1988). Other methods for calculating wetland connectivity could be used, including methods that calculate distance along stream networks. The method presented below was chosen because data on surface water connections were not available at a suitable scale (and could not be generated within the scope of this assessment), and because mobile wetland-dependent species like shorebirds do not require surface water connections.

How to calculate: Using your Sites overlay, draw a 1-mile diameter buffer around the outside edge of each site. Using your dot grid, determine the area of NWI mapped wetlands within this buffer (but outside the site itself). Use only NWI wetlands from Estuarine and Palustrine systems (E and P) that are in classes EM, SS, and FO (E2EM, E2SS, E2FO, PEM, PSS, and PFO). Include all modifiers. Exclude wetlands in other classes such as RB, AB, US, and OW.

Next, determine the area of aquatic bed habitats within the 1-mile buffer. Use the aquatic beds mapped in the Estuary Plan Book (eelgrass habitat types, 1.3.9 and 2.3.9, and algal beds, 1.3.10, and 2.3.10). If you have more recent maps of aquatic beds for your study area (such as Strittholt and Frost 1996), use those instead of the Estuary Plan Book map. Where aquatic beds (eelgrass or algae) and NWI wetlands overlap, count the overlap area only once.

Add up the non-overlapping NWI wetland and aquatic bed areas to get a total wetland area within the 1-mile buffer. (Do not count the area of the site itself, because the "size of site" criterion already accounts for site size.) Enter the total area of NWI wetlands plus aquatic beds within the 1-mile buffer around each site in Column 5 of Form E8.

GIS tip: *Create buffers 1 mile around the perimeter of each site, but excluding the sites themselves. Intersect the NWI layer (classes EM, SS and FO only) and EPB layer (aquatic bed classes only) with this buffer to obtain total area of EM, SS, FO and aquatic bed wetlands within each site's buffer. Enter the results in the field WCON_SZ in the Sites attribute table.*

How to score: After you have calculated the total area of EM, SS, FO and aquatic bed wetlands within the 1 mile buffer around each site, convert the full range of areas for all sites to a scale of 1 to 5 (see sidebar, "**Rescaling site values for prioritization scoring**"), so that 1 = lowest nearby wetland area and 5 = highest nearby wetland area. This rescaled value is your "wetland connectivity" score. Record this score in Column 6 of Form E8. Keep the score separate from the actual value for the nearby wetland area, so you can re-check the values later.

GIS tip: *Rescale the WCON_SZ values to a scale of 1 to 5. Make this calculation in the WCON_SCO field of the Sites attribute table.*

Salmonid diversity

Rationale: The watersheds draining to your estuary may support spawning populations of several different anadromous salmonids. Salmonids of interest for this analysis include coho, fall and spring chinook, summer and winter steelhead, and chum. (Sea-run cutthroat are also of interest, but can not currently be analyzed because no equivalent distribution data are available for this species.) All of these anadromous fish must exit the watershed through the estuary, so all tidal wetlands could potentially provide salmon habitat functions (see **Salmon in estuaries** above). However, individual sites may provide these functions at different levels depending on their location, characteristics, number of salmonids using the site, and many other factors.

This section calculates a score for "salmonid diversity" that expresses one aspect of the potential importance of salmon habitat functions at each site. This score is not intended to evaluate actual use levels; data on fish use of tidal wetlands are only beginning to be developed for Oregon (Bottom, Fleming, Jones and Simenstad, 2004). (Also see **Further analyses**, Appendix E4.)

The rest of the ecological criteria you are evaluating in this prioritization -- site size, channel condition, wetland connectivity, historic vegetation type, and vegetation diversity – also strongly affect salmon habitat functions, so the rest of your analysis also helps prioritize sites for salmon habitat functions.

This analysis uses Oregon Department of Fish and Wildlife (ODFW) fish distribution maps to obtain the number of stocks, counting all stocks that spawn upstream of each site (or did historically). Although juvenile salmon can move both downstream and upstream in their rearing period (Miller and Sadro 2003), this analysis looks at upstream spawning because the general movement of salmon populations during their development is downstream towards the ocean.

How to calculate number of salmonid stocks: Download fish distribution maps from the ODFW websites listed in **Materials needed** above. Download a map for each salmonid stock (chum, coho, fall chinook, spring chinook, summer steelhead, and winter steelhead) to determine where the spawning and rearing areas are located. These areas are defined as "areas where eggs are deposited and fertilized, where gravel emergence occurs, and where at least some juvenile development occurs."

On each map, look for stream reaches classified as "spawning and rearing areas" ("Usetype 1") or "historic use" (Usetype 4). For each of your sites, count the number of different salmonid stocks with spawning/rearing or historic use in stream reaches that are either directly adjacent to the site, or upstream of the site. Enter this number in Column 7 of Form E8. Your values may range from zero to six. If a site is not directly adjacent to an ODFW-mapped stream, count the number of species spawning in the tributary or river closest to the site.

How to score number of salmonid stocks: Convert the total number of salmonid stocks spawning or rearing in the entire study area to a scale of 1 to 5 (see sidebar, "**Rescaling site values for prioritization scoring**"). For example, if the entire study area supports 3 stocks, a site located on the lower mainstem (with all 3 stocks spawning or rearing upstream) would receive a score of 5; a site with no stocks spawning or rearing upstream would receive a score of 1. Enter the rescaled value for number of stocks spawning or rearing above each site in Column 8 of Form E8.

GIS tip: *Download GIS data on salmonid distribution from the ODFW website http://rainbow.dfw.state.or.us/nrimp/information/fishdistdata.htm. In the GIS, symbolize the ODFW distribution data so that only spawning and rearing areas (usetype = 1) are shown on the mapping. Display the spawning and rearing areas for all stocks simultaneously, by symbolizing each stock differently (using offset lines if necessary).*

Visually inspect the mapping and enter the number of salmonid stocks spawning upstream from each site in the NSTOCKS field of the Sites attribute table. Rescale this value to a scale of 1 to 5 in the NSAL_SCO field.

Historic wetland type

Rationale: A key principle of tidal wetland restoration is to re-establish the continuum of habitat types that existed historically (see Appendix E3, **Restoration principles**). Therefore, this assessment prioritizes tidal wetland types that have disproportionately lost from watersheds. In Oregon, a major tidal wetland type that has been disproportionately lost is the tidal swamp type (forested or scrub-shrub tidal wetlands). Tidal swamps have been almost entirely converted to agricultural land or other development. This conversion has been so extensive that Sitka spruce swamp -- once the predominant wetland type in the upper estuary -- is now assigned the highest ranking of rarity ("critically imperiled") by the Oregon Natural Heritage Program (Kagan et al. 2005). In addition, tidal swamps in the upper estuary (brackish to freshwater tidal zone) are considered a high priority for restoration because of the value of this zone for juvenile salmonid rearing (Simenstad and

Bottom 2004). Tidal swamps provide a valuable osmotic transition zone; a rich foraging environment; shaded, cool channels with overhanging banks for shelter from predators; and large woody debris that supports a complex food web. For these reasons, areas within your tidal wetlands mapping that were historically swamps are prioritized within this study.

Once sites are altered through ditching, tree removal and diking, it can be difficult to determine which areas were originally tidal swamps. The best data source available is the 1:24,000 scale historic vegetation map produced by the Oregon Natural Heritage Information Center (Hawes et al. 2002, Christy et al. 2001), which maps coastal vegetation during the mid-1800s based on General Land Office (GLO) survey records. The ORNHIC map does not distinguish between tidal and nontidal swamp, but other steps of this assessment have already assessed the likelihood of current or historic tidal influence within sites.

Most of the tidal swamp in Oregon was probably the type known as tidal spruce swamp or tideland spruce meadow, with Sitka spruce (*Picea sitchensis*) as the dominant tree species (Jefferson 1975). Other swamp types that may be found within the tidal zone are shown in Table 2 in **Step 1** above. Swamp vegetation abbreviations include FALW, FL, FSL, HC, HD, HSS, HW, OFSL, WSP, and WSU. See Table 2 above for key to codes; abbreviations are found in the field VEG_ABB in the historic vegetation layer's attribute table.

How to calculate historic percent swamp: To determine the percentage of each site's area that was historically tidal swamp, use the Oregon Natural Heritage Information Center (ORNHIC) historic vegetation mapping. You marked the areas that were mapped as historic (1850's) swamp by ORNHIC in Column 13 of Form E1-B; these areas had the ORNHIC vegetation abbreviations in Table 2 of Step 1 (VEG_ABB = FALW, FL, FSL, HC, HD, HSS, HW, OFSL, WSP, or WSU). Using your dot grid, determine the total area of these vegetation types within each site. Enter this area in Column 9 of Form E8. Divide the total historic swamp area for each site (Column 9) by the site size (Column 2) to get a percentage value and enter this value in Column 10 of Form E8.

The ORNHIC map does not extend all the way to head of tide in some estuaries. If there are no historic vegetation data for your entire study area, you can skip this step and omit the historic wetland type criterion from your prioritization. If historic vegetation data is missing for only a portion of your study sites, leave Columns 9 and 10 of Form E8 blank, but assign a "neutral" score of 3 in Column 11 of Form E8 for those sites. (A neutral score is reasonable, because most tidal wetlands in the upper estuary are swamps.) If you find other information suggesting that any of these sites were swamps in the 1850's, assign them a score of 5 in Column 11 of Form E8.

GIS tip: *Display the ORNHIC shapefile and select polygons classified as swamp (see list of abbreviations above). Intersect the selected polygons with your Sites shapefile. Sum the areas of intersection (all historic swamp within each site) in the field SWMP_SZ. In the field SWMP_PCT, calculate percent of each site that was historically swamp by dividing SWMP_SZ by SITE_SZ.*

How to score: After you have calculated the percentage of historic swamp for each site, convert the full range of percentages for all sites to a scale of 1 to 5, so that 1 = lowest percentage and 5 = highest percentage (see sidebar, "**Rescaling site values for prioritization scoring**"). This rescaled value is your “historic vegetation” score. Record this score in Column 11 of Form E8. Keep the score separate from the actual percentage of swamp, so you can re-check the values later.

> ***GIS tip:*** *Rescale the SWMP_PCT values to a scale of 1 to 5. Make this calculation in the SWMP_SCO field of the Sites attribute table.*

Diversity of current vegetation classes

Rationale: Cover classes are broad plant community types, such as coniferous forest and shrub swamp. Other Oregon wetland functional assessment methods use diversity of vegetation cover classes as an indicator of functional level (Adamus 2006, Adamus and Field 2001, Roth et al. 1996). A diversity of cover classes provides a variety of habitat types, which results in more ecological niches and presumably higher animal species diversity. This section scores vegetation diversity by analyzing the three NWI cover classes (herbaceous, scrub-shrub, and forested).

How to calculate and score diversity of vegetation classes: Using your Sites overlay over the NWI or any available LWI mapping, count the number of cover classes (EM, SS, or FO) within each site. Enter the score directly in Column 12 of Form E8. Score as follows: Three cover classes give a score of 5; two cover classes score 3 points, and one cover class scores 1 point.

> ***GIS tip:*** *Intersect the NWI / LWI mapping with your Sites layer. Visually (or by examining the intersection attribute table), determine the number of Cowardin classes per site and record the site’s score in the field CWDN_SCO. Scoring method is described above.*

2. COMBINED SCORING

Calculating the combined score

In the steps above, each prioritization factor (criterion) was scored for each individual site on a scale of 1 to 5. Based on this study’s criteria, a score of 1 represents relatively poor condition or low potential (from the standpoint of tidal wetland ecological functions) and 5 corresponds to the best condition/potential. For the total score, add all six scores, but multiply the channel condition score by two, because this factor is considered particularly important in site functions and restoration potential (Simenstad 2005). The formula for the total score is:

Combined ecological score = (site size score) + 2(channel condition score) + (wetland connectivity score) + (salmon diversity score) + (historic wetland type score) + (current vegetation diversity score).

Enter the combined score in Column 13 of Form E8.

Priority groups

Next, separate your sites into “priority groups.” Priority groups provide a more practical basis than raw scores for making decisions among sites, because small differences in total score make little practical difference in priority. (For example, if your site scores ranged from 8 to 32, a site scoring 15 should be considered similar in priority to a site with a score of 17, but a site scoring 25 should be considered higher priority.) So, sites within the same priority group may be thought of as approximately equivalent in priority.

Enter your site numbers and total scores into a spreadsheet. Sort the sites by score, in decreasing order. This places the highest priority sites at the top of the list. Now, roughly divide the sites into 3 to 5 similar-sized "priority groups," depending on your total number of sites. To do this, look for natural groupings of scores, keeping in mind that the total scores can range from 7 to 35. An example for a small study area (12 sites) is illustrated in Table 6 below.

Table 6. Example of priority grouping for a small study area.

Site number	Total ecological score	Priority group
4	32.4	High
3	29.5	High
11	26.3	High
12	22.4	High
8	19.0	Medium
1	18.6	Medium
5	15.5	Medium
7	12.1	Medium
6	9.3	Low
10	8.5	Low
2	7.3	Low
9	7.0	Low

For a larger number of sites, you may wish to use five categories (add medium-high and medium-low). Enter the priority group in Column 14 of Form E8.

If you do not see natural groupings in the data, divide the sites into equal-sized groups, but avoid separating sites with similar scores into two different priority groups. For illustration, in the example above, placement of Site 7 in the Medium group is subjective; it could arguably go in either Medium or Low, but was placed in Medium to keep group sizes the same.

Working from your annotated Map E2, create a new map on which each site is color-coded to show its priority group. This is Map E3, Prioritization of Tidal Wetlands, the final outcome of your prioritization.

GIS tip: *Separate the sites into priority groups as described above; enter the resulting group names in the field PRI_GRP in your Sites attribute table.*

You can now re-symbolize your Sites shapefile, color-coding by priority group. This is your Step 3 product, MapE3 ("Prioritization of Tidal Wetlands").

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 your action planning decisions, you also need to consider the supplemental analyses in the next section, as well as the detailed data you collected on sites, recorded in Forms E1-A, E-1B, E2, E3, E4-A, E4-B, E5, E6, and E7.

3. SUPPLEMENTAL ANALYSES

This section uses county and state data to determine land ownership and land use regulations that affect restoration planning.

Number and type of landowners

Land ownership patterns affect restoration planning in several ways. If a site has several landowners, it can be difficult to gain uniform landowner agreement and coordinate restoration activities. Ownership type (for example, private *vs.* public) affects decision-making in several ways. Ownership type may influence the potential for loss of a wetland, since it influences the likelihood of development. Ownership type may also affect the availability and sources of funding for restoration, community perception of the restoration work, and the appropriate strategies for obtaining funding and organizing the work.

In this prioritization, some high-priority restoration sites may have multiple landowners. If not all landowners want to participate in restoration or conservation of the site, it may be possible to begin restoration on sub-areas of the site without affecting other areas. The feasibility of such partial restoration depends on the particular characteristics of the site. Partial restoration should be considered during restoration design.

How to calculate number and type of landowners: Using the data you entered in Form E7, determine the number of different landowners for each site. Talk with local landowners to determine whether similar-sounding names (e.g., "J. Martin" *vs.* "John Martin") are different people. Enter the results in Column 8 of Form E7.

Examine your list of landowners to determine the type of ownership. Use the categories in Table 7 below, or create new categories applicable to your study area. Enter the land ownership type in Column 9 of Form E7.

Table 7. Land ownership categories

Land ownership category	Description/examples
Tribe	Tribal lands
Federal	USFS, BLM, USFWS, etc.
State	OR Dept. of State Lands, ODFW, Game Commission, etc.
County	County lands
Port	Port lands
City	City and school district lands
Private Industrial	Industrial timber lands or other large-scale private industrial operations
Private Non-Industrial	Private lands other than industrial (residential, small business, etc.)
Mixed	Any combination of the above types

GIS tip: *Intersect your GIS land ownership data with your sites layer. Visually inspect the results to determine number of landowners and land ownership type for each site. Enter the results in the fields NUM_OWN and OWN_TYPE in the Sites attribute table.*

In some cases, registration may be poor between the land ownership shapefile and your sites shapefile. A typical example is state ownership of mud flat tidelands: the NWI boundary for the state-owned mud flats may not coincide with the parcel's tax lot map boundary. Poor registration may lead to misleading results in your GIS analysis of land ownership. If you observe registration problems, you may need to obtain input from knowledgeable local residents to establish the correct number of owners for each site.

Land-use regulations

Local land use plans and regulations have considerable bearing on the scope of uses that may occur on any given parcel of land. All of the areas that you have been investigating throughout this assessment will be subject to local land use regulations. All cities and counties in Oregon have adopted local comprehensive plans and land use regulations for their implementation. The local comprehensive land use plan will contain various inventories, analyses, priorities, and projections, all of which are used in the development of local land use policies. Local comprehensive plans are generally implemented through local zoning or land use regulations. The most efficient way to evaluate the effect of local planning regulations on possible restoration projects is to consult directly with local planning staff. *In your meetings with planners, emphasize that your assessment is not intended to supplant their planning efforts, but only to provide guidance for Watershed Council and other organizations' restoration and conservation activities.*

Determine how the sites are zoned. Lands near estuaries are now generally designated for forestry or agriculture use, urbanization, or rural development. Areas that are designated for urban-level development will fall within an Urban Growth Boundary or a Community Growth Boundary (collectively referred to here as UGBs). By definition, lands inside UGBs are designated for future development. UGBs may also contain some of the most altered former tidal lands in your inventory. However, not all tidal wetlands in UGBs are designated for development. UGBs are available as a GIS layer from the Oregon Geospatial Data Clearinghouse (http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml); details may be obtained from your local land use planning office.

Most lands outside UGBs are designated for agricultural or forest use, or for some kind of rural development. Coastal areas also include recreational land use designations.

There may be some potential restoration sites inside UGBs or inside cities, but most of your sites are likely to be subject to county land use regulations. Therefore, begin your investigation about the effect of land use regulations at the county planning office. Using the tax lot numbers you recorded in Form E7, ask the planning staff to identify the zoning for each of the parcels. Acquire a copy of the regulations that pertain to each of the zones. Make sure you get copies of any supplemental zoning regulations ("overlay" zones) that apply to any of the sites.

Determine if special designations apply to the site. Oregon has two land use planning goals that apply to estuaries and estuarine shorelands—areas that are likely to be in your inventory. Goal 16 applies to estuarine areas, and specifically permits restoration activities under certain conditions. Goal 17-Coastal Shorelands applies to lands adjacent to the ocean and estuaries. Because of their unique location, shorelands are high priorities for a range of land use activities that cannot occur in other areas away from water. The goals contain special provisions for the protection of sites for such uses, which include dredged material disposal, water-dependent development, mitigation sites, and restoration sites. Goal 17 also provides for the designation of significant habitats. These special site designations -- and there may be others -- will either enhance or limit restoration and conservation opportunities. Therefore, it is important to determine from the local planning office if there are any special site designations that apply to the areas in your inventory.

Finally, note that the land use designation for areas where tidal influence has been completely restricted may be based on Goal 17-Coastal Shorelands, which does not specifically refer to estuarine restoration projects. Local planning review and approval of projects in such areas will probably be necessary. Restoration of tidal influence should lead to a change in the local planning designation from a shoreland to an estuarine land use category.

The local planning staff should be able to tell you immediately if any of the local land use designations would affect a landowner's ability to undertake a restoration project. Likewise, they can tell you which sites are expected to undergo significant change due to the local zoning designation. Because of Goal 16, for the most part, areas subject to tidal inundation are not subject to development pressures. However, a couple of exceptions were granted in the early 1980s. The local planning office will know what sites are still subject to development planning.

Record the land use planning/designation data you collect in the "Notes" section of Form E5 or E6. Highlight information about land use designations that may enhance or limit restoration or conservation opportunities.

Note that consultation with land use planning staff becomes even more important during development of site-specific restoration and conservation plans (see **Permits and regulatory coordination**, Appendix E5).

Native American cultural history and archaeological sites

Before European settlement, Oregon's estuaries were widely used by Native American peoples for dwelling 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. Cultural resource contacts for each tribe can be found at the Oregon Legislative Commission on Indian Services website (http://www.leg.state.or.us/cis/statetribe_govrel_culturalcontacts.pdf).

Synthesis of supplemental analyses

On your prioritization map (Map E3), mark the following types of sites with distinctive symbols:

- Sites that have a single landowner
- Publicly-owned sites
- Sites with land use designations likely to enhance or limit restoration and conservation opportunities
- Sites of potential cultural interest

Sites with a **single landowner** and **publicly owned sites** may offer advantages for restoration and conservation. Obtaining landowner permission and involvement may be simpler on these sites compared to sites with multiple private landowners. Sites that have a single, interested landowner or public ownership AND had high ecological scores in this assessment are good starting points for restoration and conservation actions.

Sites with special planning designations that may limit restoration and conservation opportunities may be a lower priority, even if they have high ecological scores. However, such designations are subject to change, so it is important to keep this data separate from the ecological prioritization and recheck the status of these sites frequently.

Sites of potential cultural interest (e.g., archaeological sites) require special efforts to avoid damage to cultural resources. Contact the appropriate tribes for further advice (web link above).

V. LINKING RESTORATION TO TIDAL WETLAND FUNCTIONS

Alterations to tidal wetlands affect their functions in many ways. For every site alteration, there are corresponding functional changes -- and corresponding restoration actions that can help restore lost functions. A practical approach to tidal wetland restoration focuses on removal of human alterations or disturbances, so that natural tidal wetland-forming processes are reinstated. These natural processes will help re-establish desired wetland functions. (See **Restoration principles,** Appendix E3 for details.)

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 flows, removal of invasive species, planting of woody (tidal swamp) species, and meander restoration to carry tidal flow throughout a site.

Major tidal wetland functions in Oregon (Adamus 2006) include:

- Maintain Natural Botanical Conditions
- Produce Aboveground Organic Matter
- Export Aboveground Plant & Animal Production
- Maintain Element Cycling Rates and Pollutant Processing; Stabilize Sediment
- Wildlife habitat functions:
    - Maintain Habitat for Native Invertebrates
    - Maintain Habitat for Anadromous Fish
    - Maintain Habitat for Visiting Marine Fish

- Maintain Habitat for Other Visiting and Resident Fish
- Maintain Habitat for Nekton-feeding Wildlife
- Maintain Habitat for Ducks and Geese
- Maintain Habitat for Shorebirds
- Maintain Habitat for Native Landbirds, Small Mammals, & Their Predators

Table 8 shows alterations, wetland functions likely to be most strongly affected by those alterations, and corresponding restoration actions. Additional recommendations are provided in **Restoration approaches** (Appendix E6).

Table 8. Tidal wetland alterations evaluated in this module, functions likely to be affected, and restoration alternatives

Alteration type	Functions likely to be most strongly affected*	Restoration alternatives (from most to least intensive)
Dikes	All (because tidal flow is reduced or blocked)	Dike breaching Dike removal / dike setback
Ditches	All wildlife habitat functions (particularly for fish); Maintain Element Cycling Rates and Pollutant Processing; Stabilize Sediment	Ditch filling Channel restoration Ditch blocking Channel reconnection
Restrictive culverts / tide gates	All (because tidal flow is reduced or blocked)	Remove culvert, substitute bridge Culvert upgrades Tide gate removal Tide gate upgrades
Road and RR crossings	All functions, if tidal flow is reduced / blocked	Elevate road, build causeway Replace culvert with bridge Culvert installation / upgrade
Dams	All, if tidal flow is reduced/blocked	Dam removal
Channel armor/riprap	Maintain Natural Botanical Conditions; Maintain Element Cycling Rates and Pollutant Processing; Stabilize Sediment; all Wildlife habitat functions	Riprap removal (substitute bioengineered solutions) Riparian plantings
Spoil/DMD	All (if filled areas are no longer tidal wetlands)	Remove spoil / dredged material
Logging and driftwood removal	Maintain Natural Botanical Conditions; Maintain Element Cycling Rates and Pollutant Processing; Stabilize Sediment; all Wildlife habitat functions	Large wood placement Tree planting
Excavation	Depends on location and nature of excavation	Fill excavated area to match original wetland contour
Grazing	Maintain Natural Botanical Conditions; Maintain Element Cycling Rates and Pollutant Processing; Stabilize Sediment; all Wildlife habitat functions	Remove grazing Reduce grazing Riparian setbacks Pasture management

*Based on Adamus (2006), Pacific States Marine Fisheries Commission 1999. Little detailed information is available on the effects of alterations on tidal wetland functions; further research is needed to establish these relationships.

To begin planning restoration at a particular site, match the alterations listed in Forms E4-A and E4-B with the alteration types in the table above. Restoration options are shown in the right-hand column. The most intensive restoration options are shown first, followed by less intensive options.

Expert assistance is recommended for restoration design; see the **Monitoring** section below, as well as **Restoration principles** and **Restoration approaches** (Appendices E5 and E6), for more details.

VI. LINKING THE ESTUARY ASSESSMENT TO OTHER ASSESSMENT COMPONENTS

Landscape-scale watershed management requires consideration of multiple factors to arrive at the "big picture." To make your action plan effective and efficient, you will want to ensure your estuary assessment is linked to other components of your watershed assessment. A recommended method is to cross-reference your prioritized tidal wetland sites with high-performing stream systems, subwatersheds, and other resources identified in your overall watershed assessment. Examples of methods that could help you maximize your success in protecting and restoring watershed resources include:

- **Cross-reference your tidal wetland prioritization with other multi-factor watershed analyses.** If you have already compiled multi-factor analyses of subwatershed performance (for example, identifying subwatersheds with exceptionally high capacity for salmonid spawning and rearing), you may wish to focus your action planning on conservation and restoration of tidal wetlands connecting to those subwatersheds. For example, you could work to protect a high-priority fringing tidal marsh along a stream that drains a high-performing subwatershed.

- **Cross-reference prioritized tidal wetlands with stream systems supporting healthy salmonid populations.** Even if you have not performed multi-factor analyses of watershed conditions, you can use knowledge of salmon populations to focus your tidal wetland conservation efforts. Tidal wetlands provide important habitat for juvenile salmon, so you may want to focus action planning on a subgroup of your top-priority tidal wetland sites that are connected to streams that support high salmon populations.

- **Refine action planning by focusing tidal wetland action planning on habitat requirements for salmon species of concern.** Current research is rapidly expanding our knowledge of tidal wetlands by juvenile salmon, so it is a good idea to contact regional experts on this topic before setting priorities for salmon habitat restoration. See "**Incorporate Salmon Life History"** in Restoration Principles (Appendix E3).

VII. MONITORING

Component XI of the Oregon Watershed Assessment Manual addresses monitoring for watershed assessment, and the information provided there can be effectively applied to the estuary. Many other documents provide guidance for monitoring in estuaries; a partial list is provided in **Additional resources for monitoring methods** below. This section is not intended to be a thorough review of monitoring goals or methods; it simply highlights some monitoring issues and needs specific to the estuary. Additional recommendations specific to the estuary are found in Appendices E5 and E6, "**Restoration principles**" and "**Restoration approaches**." As described in Component XI, technical assistance is highly recommended for development of monitoring plans.

A. Types of monitoring

The term "monitoring" refers to repeated, consistent collection of quantitative data. Several types of monitoring are commonly used during assessment and restoration efforts. The following definitions are taken from Component XI:

Monitoring to fill data gaps is usually undertaken following a watershed assessment. The assessment identifies information needs, which are then filled through this type of monitoring.

Baseline monitoring is undertaken to establish conditions prior to management activities, or in a paired watershed or reference site.

Implementation monitoring is designed to answer the question "Was the management practice or restoration activity implemented properly?"

Effectiveness monitoring is designed to answer the question "Were restoration actions effective in meeting the restoration objectives and in attaining the desired outcome?"

B. Monitoring to fill data gaps

One type of monitoring will help you fill data gaps identified during your estuary assessment. In most cases, these data gaps will not prevent you from moving ahead with restoration and conservation actions. Nevertheless, planning to fill these data gaps will help you improve the accuracy of your assessment and update it in the future.

Some data gaps can be addressed with one-time analyses, qualitative field observations or measurements. Others require ongoing sampling and standardized, quantitative sampling and analytical methods. A few examples of data gaps you may encounter in the estuary are listed in Table 9 below.

Table 9. Examples of potential data gaps identified during estuary assessment

Module component	Potential data gaps
Historic extent of tidal wetlands	• Head of tide for smaller tributaries • Historic proportions and spatial distribution of different tidal wetland types
Alterations to tidal wetlands	• Determination of dikes versus natural levees • Updated mapping of dikes and tide gates • Determination of channel condition in forested/shrub areas • Cultural history (e.g. Native American settlements, locations of artifacts, old homesites) • Locations of populations of invasive species
Site prioritization	• Accurate estimates of salmonid populations for each tributary • Salmonid juvenile populations and distribution (snorkel surveys) • Proportional loss of different tidal wetland types (marsh, swamp) within study area
Land ownership	• Current landowner database • Property boundaries for high-priority sites

You can use methods listed in this module, as well as those listed in Component XI, to fill these data gaps. In most cases, these data gaps can be filled by applying this module's methods, or by conducting optional analyses listed in this module (e.g., **Further analyses**, Appendix E4).

A few monitoring parameters specific to the estuary are described here. Many other parameters can and should be measured; other documents (listed in the next section) describe a range of monitoring programs for estuary restoration and reference sites.

C. Baseline and effectiveness monitoring parameters

Selection of tidal wetland monitoring parameters depends on the goals of the monitoring, but several documents identify priorities. Thayer et al. (2005), Zedler (2001) and Simenstad et al. (1991) emphasize monitoring of the parameters listed in Table 10 at both restoration sites and matched, multiple reference sites. These are considered a **minimum** set of monitoring parameters; many others are listed in the references below. Recommended frequency of monitoring is shown, but frequency and timing choices should be determined by site characteristics and restoration goals.

As described in Rice et al. (2005), emphasis should be placed on monitoring of controlling factors that influence development of tidal wetland functions. Examples of controlling factors at a site scale include tidal inundation regime, salinity, soil characteristics and sediment supply.

Table 10. Recommended tidal wetland monitoring parameters (based on Thayer et al. 2005, Callaway et al. 2001, Simenstad et al. 1991, and other sources). Top priorities in Thayer et al. are in bold.

Monitoring parameter	Recommended frequency and timing
Tidal inundation regime (frequency, depth, duration and seasonality of tidal flooding)	4 times per year (summer, fall, winter, spring) during new moon or full moon (spring tide cycle); use data logger (recording water level gauge) if possible
Surface water salinity, temperature, turbidity and dissolved oxygen	Monthly at same tide stage; surface and bottom of channel water; data logger if possible
Ground surface elevation (including channels)	Initially during site planning; then annually or after major floods
Soil organic matter content, available nitrogen, pH, texture, electrical conductivity	Initially during site planning; then annually or after major floods
Plant community composition (frequency and % cover by species, woody stem density and basal area)	Annually during summer
Habitat types (area and interspersion)	Annually during summer
Channel morphology (length, sinuosity, width:depth ratio)	Initially during site planning; then annually or after major floods
Sediment accretion and erosion	Annually or after storms or floods
Water table depth (in upper estuary)	Weekly in spring and summer
Invertebrate macrofauna (species occurrence; optionally, abundance and taxonomic composition)	Annually at same time of year
Fish use (species occurrence; optionally, density and standing stock)	Annually in spring; may require several visits to observe use
Migratory bird species occurrence	Weekly in fall-spring, biweekly in summer

See "**Resources for monitoring methods**" for further information.

D. Baseline monitoring for restoration design

An obvious use of baseline monitoring data is for comparison to post-restoration conditions, to track changes due to restoration. In addition, baseline monitoring data from both reference and restoration sites is vital for restoration design.

Reference sites: Building design guidelines

Estuary restoration in Oregon is still in its infancy, and in many cases, we do not yet have quantitative design guidelines for estuary restoration work. Ideally, such guidelines consist of quantitative data averaged from several carefully selected, least-disturbed reference sites. The reference sites should be located in landscape settings similar to the planned reference site, with similar elevation ranges and tidal and freshwater hydrology. Reference site data should include the parameters shown in Table 10, as well as other characteristics important to the specific project.

Reference site data have four main uses:

1) Restoration site selection: Restoration sites need to be located in an appropriate landscape setting for development of the target wetland type. Due to major landscape changes and site-specific changes like subsidence, we cannot assume that a site that once had a particular tidal wetland type will restore to that same type (see Appendix E6, **Restoration principles**). Solid data on the physical site characteristics of least-disturbed reference sites will allow selection of appropriate restoration locations.

2) Guidance for site-specific restoration design: Design specifications such as dike breach width and depth, channel sinuosity, and locations of plantings should be based on the characteristics of reference sites.

3) Evaluation of restoration success: During effectiveness monitoring, characteristics of restoration sites are measured. Only by comparing the results to characteristics of reference sites (the design guidelines) can restoration success be evaluated. We cannot expect a restoration site to immediately return to reference site conditions, but we can expect a "restoration trajectory" that shows a transition towards desired conditions. Because of high year-to-year variability in estuary systems, simultaneous data from reference sites are needed to interpret restoration site monitoring data (Thayer et al. 2005).

4) Guidance for adaptive management after restoration is implemented. When effectiveness monitoring or implementation monitoring shows that site development is deviating from expectations, adaptive management should be used to move a site towards the desired characteristics. Again, reference site data are necessary as a "yardstick" to interpret restoration site development.

Examples of important reference site data are described below. Recommendations on how to collect the data can be found in "**Resources for monitoring methods**" below.

Surface elevations, tidal regime, and groundwater

To establish design guidelines for restoration of tidal wetlands, we need data on three closely related parameters: ground surface elevations, tidal regime, and groundwater hydrology of reference sites. Some data on surface elevations and tidal regime are available for Oregon tidal marshes (e.g., Eilers 1975, Jefferson 1975). However, no such data are available for Oregon's tidal swamps (such as tidal spruce swamps, crabapple swamps, and willow swamps). Restoration of tidal swamps cannot proceed without at least some preliminary data on swamp surface elevations relative to local tidal range, the duration and frequency of tidal inundation, the depth of groundwater, and the seasonal changes in these factors. Such information is important for selecting appropriate restoration sites, determining appropriate locations for woody plantings, and tracking success of restoration. Tools for these measurements include continuous-recording tide gauges (water depth gauges), shallow water table observation wells, and traditional survey equipment. Methods can be found in "**Resources for monitoring methods**" below.

Channel morphology and flow characteristics

To plan successful restoration, we need baseline data on channel morphology and channel flow characteristics at reference sites. Many wetland functions, especially fish use, are strongly affected by the channels' width and depth, and the degree to which they retain water at low tide. Water quality protection and floodwater detention depend on the winding form, highly branched network, and deep, narrow profile of typical undisturbed tidal channels. In order to design restored channel systems and evaluate restoration success, we need quantitative data on these characteristics from relatively undisturbed tidal wetlands of all types.

In contrast to the extensive data available on stream morphology in the nontidal portion of the watershed, we have little or no information on the morphology of tidal channels in Oregon. This is particularly true for the upper estuary (tidal swamps and freshwater tidal wetlands). The few design parameters available (for example, Coats et al. 1995) are based on data from marshes outside Oregon, and may not be appropriate for use in Oregon tidal wetlands.

Important *channel morphology* parameters include sinuosity, branching/order, density, gradients, and width-to-depth ratios. Important *flow characteristics* include velocities, volumes, and depths in different parts of the tidal cycle and different seasons. Collection of these baseline reference data from a variety of tidal wetland types would allow better restoration design, achieving closer similarity to natural systems and their functions.

Plant communities

Plant communities at reference sites should be monitored at the same locations and times as physical site characteristics, because plant communities are key to developing restoration design guidelines. Many plant community characteristics (e.g. growth and decomposition rates, shading, vegetation structure, and large woody debris) are closely tied to wetland functions (e.g. primary productivity, nutrient cycling, wildlife habitat and sediment capture). Only by documenting plant community composition, vigor, turnover, and distribution can we evaluate these factors and plan for their restoration. Since plant communities develop in response to physical site conditions, plant community monitoring is an efficient way to evaluate a broad range of site characteristics.

In addition, reference site plant community data gives us the context for interpreting physical site data like channel morphology and tidal inundation. Low marsh, high marsh, and tidal swamp are each characterized and defined by particular plant species and associations, so to relate our physical site data to other locations, we need to know the associated plant communities.

Restoration sites: Building a restoration design

Baseline monitoring at restoration sites must begin early – that is, before making any design decisions. This is because some monitoring parameters are needed for input into design decisions. Only a few examples are described below; consult "**Resources for estuary monitoring methods"** below for further guidelines.

Surface elevations and hydrology

The previous section describes elevation, tidal range, and shallow groundwater hydrology monitoring at reference sites. These parameters should also be investigated at restoration sites to provide input into design. First, it is important to measure the maximum and minimum tide heights outside a restoration site -- and inside, if the site already has muted tidal flow -- before finalizing restoration design. This tidal range data, combined with site surface elevations, will help determine how much of the restoration site will flood on high tides. If any structures are located on or near the restoration site (e.g. roads, buildings), tidal range data are needed to address the question of possible effects of restoration on these structures. Tidal range data are also needed to plan the sequencing of restoration site work: when to breach dikes, whether tidal inflow must be temporarily blocked, etc.

Elevation and hydrology data are also needed to determine the potential impacts of restoration on existing freshwater wetlands behind tidal flow barriers (see Appendices E3 and E4 for details).

Sediment deposition rates

There is a strong need for data on the rate of sediment deposition (also called "accretion") at tidal restoration and reference sites. Accretion rates are important, because they can determine the restoration trajectory of subsided former tidal marshes. Many former tidal marshes have subsided (that is, the soil surface sank) after they were diked or tidegated. Because of subsidence, restoration of tidal flow to many former high marsh sites will result in more frequently inundated tidal wetlands, like tidal flats or low marsh. However, over time, sediment accretion can raise the marsh surface, and eventually the site may regain its original elevation. The rate at which this happens depends on the rate of sediment delivery (Frenkel and Morlan 1991).

Little information is available on accretion rates at tidal wetland reference and restoration sites in Oregon. A few sites have been monitored in the Salmon River estuary and at South Slough National Estuarine Research Reserve, but every estuary has unique sediment movement patterns. Collection of estuary-specific baseline data is important, because many restoration decisions should be based on such information. Data should be collected at reference sites (showing natural sediment accumulation levels), and at existing restoration or "muted tidal" sites (with natural breaches or restrictive culverts). After restoration, sediment accretion at the restoration site should be monitored periodically to determine restoration trajectory and provide design input into future restoration projects.

One use for sediment accretion data is to help make decisions on whether to remove or simply breach dikes. Dike removal may result in higher sediment deposition rates, as dike removal allows the "sheet flow" that can carry high sediment loads onto the marsh surface during winter flood events. Sediment deposition rates can be measured easily with simple techniques (e.g., feldspar marker horizons as described by Cornu and Sadro, 2004). Monitoring of sediment accumulation can be done by volunteers coordinated by watershed councils, following guidelines in the documents listed in "**Additional Resources for estuary monitoring methods**" below.

Salinity

Salinity of surface water flows strongly determines plant communities at tidal wetlands. Successful restoration design requires information on the salinity of the tidal flows to be restored to diked or tidegated sites. For example, reed canarygrass is an invasive plant commonly found in diked former tidal wetlands. Restoration of such sites should include plans to control reed canarygrass. However, reed canarygrass appears to be relatively intolerant of brackish water. Therefore, reed canarygrass that is inundated by restored brackish tidal flow will probably be suppressed, and may not require control (Brophy, 2003).

E. Effectiveness monitoring

Effectiveness monitoring at restoration sites is a complex and technical field. This section provides only a few comments; consult Component XI of the Watershed Assessment Manual and the **Additional resources for estuary monitoring methods** below for detailed guidance.

As explained above, effectiveness monitoring attempts to determine whether a restoration site is meeting restoration goals. These goals are established, in part, through baseline monitoring at a series of least-altered reference sites. This reference dataset must be developed before restoration is designed, because design should reflect the conditions documented at the reference sites (see **Reference sites: Building design guidelines** above). Recommended monitoring parameters, likely to be closely related to many project goals, are described in "**Baseline and effectiveness monitoring parameters**" above.

Because the estuary is dynamic and restoration is a gradual process, effectiveness monitoring should be conducted repeatedly over a substantial period of time. Most authors suggest a minimum of 5 years of monitoring to address structural stability of a restoration site, and a minimum of 10 to 20 years to determine whether the site is on an appropriate trajectory for recovery of ecological functions. If the site appears to be on the wrong trajectory (e.g., failing to develop wetland conditions, or undergoing severe erosion), adaptive management should be practiced to adjust site conditions.

F. Monitoring for invasive species

Step 2 of this assessment (**Assess alterations to tidal wetlands**) contains a section entitled **Invasive species**. Consult that section for details on the threats posed by invasive plants and animals, and how to monitor and report sightings.

G. Monitoring versus Rapid Assessment

The term "monitoring" refers to repeated, consistent collection of quantitative data. Repeated sampling using consistent methodology is important, because ecosystems are naturally variable, and a single sampling event may not capture typical data. When we monitor estuary sites, we collect data that directly relate to ecosystem functions we value, so that we can improve our understanding of those functions at each site and in estuaries in general.

The term "assessment" has been used in many ways by scientists and practitioners. In the Watershed Assessment Manual, quantitative and qualitative methods are used to evaluate watershed conditions. Assessment has also been described as "the quantitative evaluation of selected ecosystem attributes" (Zedler 2001). One of the most detailed guides to monitoring Pacific Northwest estuary habitats is called the "Estuary Habitat Assessment Protocol" (Simenstad et al. 1991).

The term "assessment" is also widely used to refer to rapid assessment methods for wetland functional assessment, such as hydrogeomorphic (HGM) methods (next section). Rapid functional assessment methods may have specific regulatory purposes, such as land-use regulation and evaluation of wetland mitigation site performance. Most rapid assessment methods are based on indicators of function rather than the underlying, quantitative data that are normally collected in monitoring programs. HGM assessment is described in the next section.

Hydrogeomorphic (HGM) assessment method

The hydrogeomorphic (HGM) method uses a broad range of indicators to estimate the level at which a particular wetland performs specific functions. Results can be used to compare to other tidal wetlands of the same HGM class that have been assessed using the same method. The HGM method's focus on levels of individual wetland functions at a specific location makes it a highly valuable tool for regulatory purposes such as removal-fill permit decisions, mitigation requirements, and evaluation of mitigation success, as well as many other purposes. The HGM method should be supported and complemented by other assessment activities such as watershed assessment; by sustained monitoring programs at state and watershed scales; and by site-scale monitoring of actual functions.

To contrast the HGM method with this assessment module, HGM focuses on levels of individual functions (and risks to those functions) within a specific wetland, while this module uses landscape-scale tools to provide broad guidance for estuary-wide decision-making. This module does not evaluate specific wetland functions. Such evaluation of specific functions is best left to the next step in action planning: the development of site-specific restoration and conservation plans. HGM assessment can be used to advantage during that step – but should also be accompanied by monitoring of actual functions (see **Baseline and effectiveness monitoring parameters** above).

Although its primary goal is site-specific evaluation of specific wetland functions and risks to those functions, the HGM guidebook for Oregon tidal wetlands (Adamus 2006, 2005a, 2005b) also contains several landscape-level tools and analyses. The map of tidal and potentially tidal wetlands developed during the Oregon tidal wetland HGM project (Scranton 2004) serves as the base layer for this assessment. The HGM guidebook also contains several original reference data sets collected from 120 tidal marshes of the Oregon coast. These cover hundreds of variables, such as tidal channel incision depth and channel top width, plant species richness by relative elevation and substrate type, and percent cover of non-native plants. Because the data were collected at numerous sites representing the full range of conditions expected in Oregon tidal marshes, the data and statistics that can be generated from them are potentially useful for design and evaluation of individual tidal marsh restoration projects. At a landscape scale, the HGM guidebook also includes compilations of total wetland acreage (both tidal and non-tidal) by HGM class and Cowardin type for each coastal Oregon watershed (Adamus 2005b). Finally, the HGM guidebook includes a comprehensive review of technical literature on tidal wetlands of the Pacific Northwest (Adamus 2005a).

H. Monitoring and science

Restoration science is still in its infancy. In many geographic areas and habitat types, we have very sparse information on reference conditions, structure-function linkages, appropriate restoration design strategies, and trajectories of site recovery. As stated in Simenstad et al. (1991), *"Neither the science nor the technology of estuarine habitat restoration can progress until we treat restoration as rigorous experimentation in which consistent data are gathered in an inductive format."* Wherever possible, practitioners should encourage scientific research at restoration sites. Research at restoration and reference sites will increase our knowledge of tidal wetlands and help us develop better restoration strategies. See **Restoration principles**, Appendix E6, for further details.

I. Additional resources for estuary monitoring methods

The following documents contain detailed methods for estuary monitoring. They are arranged in order from less technical (for volunteers) to more technical (for scientists). See **Literature Cited** for full citations.

Carlisle, B.K., et al. 2002. **A volunteer's handbook for monitoring New England salt marshes.** Massachusetts Office of Coastal Zone Management, Boston, MA. Available online at http://www.mass.gov/czm/volunteermarshmonitoring.htm.

Neckles, H.A. and M. Dionne, Editors. 2000. **Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine.** Wells National Estuarine Research Reserve Technical Report, Wells, ME. 21 p. plus appendices. Available online at http://www.pwrc.usgs.gov/resshow/neckles/gpac.htm

Niedowski, N.L. 2000. **New York State Salt Marsh Restoration and Monitoring Guidelines.** Prepared for the New York State Department of State Division of Coastal Resources, Albany, NY, and New York State Department of Environmental Conservation Division of Fish, Wildlife and Marine Resources, Bureau of Marine Resources, East Setauket, NY. Available online at: www.edc.uri.edu/restoration/html/resource/nymarsh.pdf

Rice, C.A., et al. 2005. Monitoring Rehabilitation in Temperate North American Estuaries. *In* P. Roni (Ed.) 2005. Monitoring Stream and Watershed Restoration. American Fisheries Society.

Thayer, G.W., et al. 2005. **Science-Based Restoration Monitoring of Coastal Habitats.** NOAA Coastal Ocean Program Decision Analysis Series No. 23. NOAA National Centers for Coastal Ocean Science, Silver Spring, MD. 628 pp. plus appendices. Online at http://coastalscience.noaa.gov/ecosystems/estuaries/restoration_monitoring.html.

Callaway, J.C., et al. 2001. **Assessment and Monitoring.** Chapter 6 in Zedler, J.B. (Ed.), Handbook for Restoring Tidal Wetlands.

Simenstad, C.A., C.D. Tanner, R.M. Thom, and L.D. Conquest. 1991. **Estuarine Habitat Assessment Protocol.** EPA/910/9-91-037. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, WA.

The following three publications address volunteer monitoring of wetlands in general. They are not specific to estuaries.

Volunteer Wetland Monitoring: An Introduction and Resource Guide (U.S. EPA 2000). Available online at http://www.epa.gov/owow/wetlands/monitor/volmonitor.pdf.

Volunteer Wetland-Monitoring: A Preliminary Compendium of Materials. Available online at http://www.epa.gov/owow/wetlands/monitor/vmcom.html.

Volunteer Wetland Monitoring Manuals: An Annotated Bibliography. Available online at http://www.4sos.org/wssupport/ws_rest/biblio2.html.

VIII. LITERATURE CITED

Adamus, P.R. 2006. Hydrogeomorphic (HGM) Assessment Guidebook for Tidal Wetlands of the Oregon Coast, Part 1: Rapid Assessment Method. Produced for the Coos Watershed Association, Oregon Department of State Lands, and U.S.E.P.A.-Region 10. Charleston, OR: Coos Watershed Association.

Adamus, P.R. 2005a. Science Review and Data Analysis for Tidal Wetlands of the Oregon Coast. Part 2 of a Hydrogeomorphic Guidebook. Report to Coos Watershed Association, US Environmental Protection Agency, and Oregon Dept. of State Lands, Salem.

Adamus, P.R., J. Larsen, and R. Scranton. 2005b. Wetland Profiles of Oregon's Coastal Watersheds and Estuaries. Part 3 of a Hydrogeomorphic Guidebook. Report to Coos Watershed Association, US Environmental Protection Agency, and Oregon Depart. of State Lands, Salem.

Adamus, P.R., and D. Field. 2001. Guidebook for Hydrogeomorphic (HGM)-based assessment of Oregon Wetland and Riparian Sites. I. Willamette Valley Ecoregion, Riverine Impounding and Slope/Flats Subclasses. Volume IA: Assessment Methods. Oregon Division of State Lands, Salem, OR.

Amezaga, J.M., L. Santamaría, and A.J. Green. 2002. Biotic wetland connectivity—supporting a new approach for wetland policy. Acta Oecologica 23: 213–222

Baker, M. 2004. Socioeconomic Characteristics of the Natural Resources Restoration System in Humboldt County. Forest Community Research, March 2004. Available online at: http://www.sierrainstitute.us/Humboldt/HumboldtRestor.pdf.

Benner, PA. 1992. Historical reconstruction of the Coquille River and surrounding landscape. Sections 3.2, 3.3 in: The action plan for Oregon coastal watersheds, estuaries, and ocean waters. Near Coastal Waters National Pilot Project, Environmental Protection Agency, 1988-1991. Portland, Oregon: Conducted by the Oregon Department of Environmental Quality.

Bottom, D., I. Fleming, K. Jones, and S. Simenstad. Salmonid Use of Restored Estuarine Wetlands: Regional Application of the Salmon River Estuary Study. Oregon Sea Grant project #R/ECO-14.

Bottom, D., B. Kreag, F. Ratti, C. Roye, and R. Starr. 1979. Habitat Classification and Inventory Methods for the Management of Oregon Estuaries. OR Dept. of Fish and Wildlife, Portland, OR.

Brophy, L.S. (Green Point Consulting). 2005. Tidal wetland prioritization for the Siuslaw River Estuary. Prepared for the Siuslaw Watershed Council, Mapleton, OR.

Brophy, L.S. (Green Point Consulting). 2004a. Yaquina estuarine restoration project: Final Report, March 2004. Prepared for MidCoast Watersheds Council, Newport, OR. 99 pp.

Brophy, L.S. (Green Point Consulting). 2004b.Yaquina Estuarine Restoration Project: Annual Monitoring Report. Prepared for the MidCoast Watersheds Council, Newport, OR. 50 pp.

Brophy, L.S. (Green Point Consulting). 2003a. Wetland Site Prioritization, Lower Elk and Sixes Rivers, Curry County, Oregon. Prepared for Oregon Trout, Portland, OR. 52 pp., plus 18 pp tables.

Brophy, L.S. (Green Point Consulting). 2003b. Yaquina estuarine restoration project: Annual Monitoring Report, October 2003. Prepared for the MidCoast Watersheds Council, Newport, OR. 13 pp.

Brophy, L.S. (Green Point Consulting). 2002. Siletz Bay NWR and Nestucca Bay NWR Tidal Marsh Restoration and Reference Sites: Baseline Plant Community Monitoring and Mapping. Prepared for USFWS Oregon Coast National Wildlife Refuge Complex, Newport, OR.

Brophy, L.S. (Green Point Consulting). 2001. Siletz Estuary plant community mapping. Prepared for the Confederated Tribes of Siletz Indians, Siletz, OR. 44 pp.

Brophy, L.S. (Green Point Consulting). 1999. Yaquina and Alsea river basins estuarine wetland site prioritization project. Final Report prepared for the MidCoast Watersheds Council, 50 pp.

Brophy, L.S. (Green Point Consulting), and K. So. 2005a. Tidal wetland prioritization for the Nehalem River Estuary. Prepared for the USFWS Coastal Program, Newport Field Office.

Brophy, L.S. (Green Point Consulting), and K. So. 2005b. Tidal wetland prioritization for the Umpqua River Estuary. Prepared for the USFWS Coastal Program, Newport Field Office.

Brophy, L.S. (Green Point Consulting), and K. So. 2005c. Tidal wetland prioritization for the Smith River Estuary (Umpqua Basin of Oregon). Prepared for the USFWS Coastal Program, Newport Field Office.

Callaway, J.C., G. Sullivan, J.S. Desmond, G.D. Williams, and J.B. Zedler. 2001. Assessment and monitoring. Chapter 6 in Zedler, J.B. (Ed.), Handbook for restoring tidal wetlands. CRC Press, Boca Raton, FL.

Carlisle, B.K., A.M. Donovan, A.L. Hicks, V.S. Kooken, J.P. Smith, and A.R. Wilbur. 2002. A volunteer's handbook for monitoring New England salt marshes. Massachusetts Office of Coastal Zone Management, Boston, MA. Available online at http://www.mass.gov/czm/volunteermarshmonitoring.htm.

Christy, J.A., E.R. Alverson, M.P. Dougherty, S.C. Kolar, C.W. Alton, S.M. Hawes, J.A. Hiebler, and E.M. Nielsen. 2001. Classification of historic vegetation in Oregon, as recorded by General Land Office surveyors. Oregon Natural Heritage Program, 9 May 2001.

Coats, R.N., P.B. Williams, C.K. Cuffe, J. Zedler, D. Reed, S. Watry and J. Noller. 1995. Design Guidelines for Tidal Channels in Coastal Wetlands. Report prepared for the U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS. Philip Williams & Assoc., Ltd. San Francisco, CA. 46 pp.

Cornu, C.E., and S. Sadro. 2003. Physical and functional responses to experimental marsh surface elevation in Coos Bay's South Slough. Restoration Ecology 10(3): 474-486. http://www.oregon.gov/DSL/SSNERR/docs/reclkunz.pdf

Cortright, R., J. Weber, and R. Bailey. 1987. Oregon Estuary Plan Book. Salem, OR: Oregon Dept. of Land Conservation and Development.

Costa, J, J. Rockwell and S. Wilkes. 2002. Atlas of Tidally Restricted Salt Marshes in Buzzards Bay Watershed. Buzzards Bay Project National Estuary Program / Massachusetts Office of Coastal Zone Management. Wareham, MA. Available online at http://www.buzzardsbay.org/smatlasmain.htm.

Coulton, K.G., P.B. Williams, and P.A. Benner. 1996. An Environmental History of the Tillamook Bay Estuary and Watershed. Produced by Philip Williams & Associates and Oregon State University. 120 pp. Large (43MB) download of report available online at http://gisweb.co.tillamook.or.us/library/reports/EnivronmentalHistoryOfTillBay.pdf. Accessed 6/15/06.

Eilers, H. Peter. 1975. Plants, plant communities, net production, and tide levels: the ecological biogeography of the Nehalem salt marshes, Tillamook County, Oregon. Doctoral dissertation. Oregon State University, Corvallis, OR 368 pp.

Euliss, N.H., and D.M. Mushet. 1996. Water-level fluctuations in wetlands as a function as a function of landscape condition in the prairie pothole region. Wetlands 16(4):587-593. Northern Prairie Wildlife Research Center Online. Version 01DEC97, accessed June 2006. http://www.npwrc.usgs.gov/resource/wetlands/h2ofluct/index.htm

Frenkel, R. E. and J. C. Morlan. 1991. Can we restore our salt marshes? Lessons from the Salmon River, Oregon. *The Northwest Environmental Journal*, 7:119-135.

Giannico, G.R., and J.A. Souder. 2004. The effects of tidegates on estuarine habitats and migratory fish. Oregon Sea Grant. ORESU-G-04-002. 10 p.

Giannico, G.R., and J.A. Souder. 2005. Tide gates in the Pacific Northwest: Operation, types and environmental effects. Oregon Sea Grant. ORESU-T-05-001.

Good, J.W. 2000. Summary and Current Status of Oregon's Estuarine Ecosystems. Chapter 3, Section 2, pages 33-44 in *Oregon State of the Environment Report*. Oregon Progress Board: Salem, OR.

Good, J. W. 1999. Estuarine science, management and restoration. *In* Watershed Stewardship: A Learning Guide, Chapter 10. Corvallis, OR: Oregon State University Extension Service.

Gray, A., C.A. Simenstad, D.L. Bottom, and T.J. Cornwell. 2002. Contrasting functional performance of juvenile salmon habitat in recovering wetlands of the Salmon River estuary, Oregon, USA. Restoration Ecology 10(3): 514-526.

Haig, S.M., Mehlman, D.W. & Oring, L.W. 1998. Avian Movements and Wetland Connectivity in Landscape Conservation. Conservation Biology 12 (4), 749-758.

Hawes, S.M., J.A. Hiebler, E.M. Nielsen, C.W. Alton & J. A. Christy. 2002. Historic vegetation of the Pacific Coast, Oregon, 1851-1910. ArcView coverage, Version 1.0. Oregon Natural Heritage Information Center, Oregon State University.

Jefferson, C.A. 1975. Plant communities and succession in Oregon coastal salt marshes. PhD thesis, Department of Botany and Plant Pathology, Oregon State University. 192 pp.

Miller, B., and S. Sadro. 2003. Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. Transactions of the American Fisheries Society 132: 546-559.

Lebovitz, A. 1992. Oregon estuarine conservation and restoration priority evaluation: Opportunities for salmonid habitat and wetlands functional enhancement in Oregon's estuaries. Technical report to Oregon Trout, Portland, Oregon.

Miller, B.A., and S. Sadro. 2003. Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. Trans. Am. Fish. Soc. 132: 546-559.

Mitsch, W.J. 2000. Self-design applied to coastal restoration. *In* Weinstein, M.P., and D.A. Kreeger. 2000. *Concepts and Controversies in Tidal Marsh Ecology.* Kluwer, Boston.

National Research Council. 1992. Restoration of Aquatic Ecosystems: Science, Technology and Public Policy. National Academy Press, Washington, D.C.

Neckles, H.A. and M. Dionne, Editors. 2000. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME. 21 p. plus appendices. Available online at http://www.pwrc.usgs.gov/resshow/neckles/gpac.htm

Niedowski, N.L. 2000. New York State Salt Marsh Restoration and Monitoring Guidelines. Prepared for the New York State Department of State Division of Coastal Resources, Albany, NY, and New York State Department of Environmental Conservation Division of Fish, Wildlife and Marine Resources, Bureau of Marine Resources, East Setauket, NY.

Oberrecht, K. 1997. Salmon and trout in estuaries. Part of the South Slough Estuarine Management Issue series. Downloaded on June 16, 2006 from http://www.oregon.gov/DSL/SSNERR/docs/EMIpubs/salmon.pdf.

ODFW (Oregon Department of Fish and Wildlife). 1979. Estuary inventory report. Prepared by Research and Development Section, Oregon Dept. of Fish and Wildlife, Portland, OR, for the Oregon Land Conservation and Development Commission. [*Note: Individual estuary reports are entitled "Natural Resources of ______ Estuary."*]

Oregon Watershed Enhancement Board (OWEB). 2002. Investments in Lincoln County. Online at: www.oregon.gov/OWEB/docs/pubs/Countyinfo/Lincoln.pdf.

Pacific States Marine Fisheries Commission. 1999. Appendix A: Description and Identification of Essential Fish Habitat, Adverse Impacts and Recommended Conservation Measures for Salmon; Amendment 14 to the Pacific Coast Salmon Plan, Pacific Fishery Management Council, January 1999. Available online at: http://www.pcouncil.org/salmon/salfmp/a14/99efh3.pdf.

Perillo, G.M.E. 1995. Geomorphology and Sedimentology of Estuaries. Definitions and Geomorphologic Classifications of Estuaries, *Developments in Sedimentology* 53.

Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: A community profile. U.S. Fish Wildl. Serv. FWS/OBS-84/24.

Pritchard, K. 1995. Combination staff gauge/crest gauge. The Volunteer Monitor, Vol. 7, No. 2, Fall 1995. http://www.epa.gov/owow/monitoring/volunteer/newsletter/volmon07no2.pdf

Pritchard, D. W. 1967. What is an estuary? Physical viewpoint. In Estuaries (G. H. Lauff, ed.), p. 3-5. Publication 83 of AAAS. (Am. Assoc. Advancement Sci.), Washington, D.C.

Reimers, P.E. 1973. The length of residence of juvenile fall Chinook salmon in Sixes River, Oregon. Research Reports of the Fish Commission of Oregon 4: 1-43.

Rice, C.A., W.G. Hood, L.M. Tear, C.A. Simenstad, G.D. Williams, L.L. Johnson, B.E. Feist, and P. Roni. 2005. Monitoring Rehabilitation in Temperate North American Estuaries. *In* P. Roni (Ed.) 2005. Monitoring Stream and Watershed Restoration. American Fisheries Society.

Roth, E., R. Olsen, P. Snow, and R. Sumner. 1996. Oregon Freshwater Wetland Assessment Method. Wetlands Program, Oregon Division of State Lands, Salem, OR.

Rozas, L.P., and W.E. Odum. 1988. Occupation of submerged aquatic vegetation by fishes: testing the roles of food and refuge. Oecologia 77: 101-106.

Scranton, R. 2004. The application of Geographic Information Systems for delineation and classification of tidal wetlands for resource management of Oregon's coastal watersheds. Thesis, Marine Resource Management Program, Oregon State Univ., Corvallis. [Note: Thesis products included a GIS layer which is used as the base layer for this module; the layer is available online at http://www.coastalatlas.net/download/shapes/tidal_marsh.zip.]

Seliskar, D.M., and J.L. Gallagher. 1983. The ecology of tidal marshes of the Pacific Northwest coast: A community profile. U.S. Fish and Wildlife Service, Division of Biological Services, Washington, D.C. FWS/OBS-82/32. 65 pp.

Shalowitz, A.L., and M.W. Reed. 1962-64. Shore and Sea Boundaries, Vols. 1 and 2. U.S. Coast and Geodetic Survey Publication 10-1.

Shalowitz, A.L., and M.W. Reed. 2000. Shore and Sea Boundaries, Vol. 3. U.S. Coast and Geodetic Survey Publication 10-1.

Simenstad, C.A. 2005. Personal communication.

Simenstad, C.A. 1996. Restoration potential of diked estuarine wetlands: Inferring fate and recovery rate of historically-breached sites. Univ. of Wash. School of Fisheries Wetland Ecosystem Team and U.S. EPA Region 10. U.S. EPA publication #910/R-96-005.

Simenstad, C.A. 1983. The ecology of estuarine channels of the Pacific Northwest coast: A community profile. U.S. Fish Wild. Serv. FWS/OBS-83/05. 181 pp.

Simenstad, C.A., and D. Bottom. 2004. Guiding ecological principles for restoration of salmon habitat in the Columbia River Estuary. Online at http://www.fish.washington.edu/research/wet/publications/ecol_principles.doc. Accessed 14 February 2005.

Simenstad, C.A., and B.E. Feist. 1996. Restoration potential of diked estuarine wetlands: Inferring fate and recovery rate of historically-breached sites. University of Washington, School of Fisheries, Wetland Ecosystem Team and U.S. Environmental Protection Agency-Region 10. Subtask 93C8 Phase I Report. EPA publication 910/R96-005. May 1996.

Simenstad, C.A., B.E. Feist, K. Bierly, J. Morlan, and P.B. Williams. 1999. Assessment of potential dike-breach restoration of estuarine wetlands in Tillamook Bay, Oregon. Technical report to Tillamook Bay National Estuary Project. Available online at http://gisweb.co.tillamook.or.us/library/reports/DikeBreachAssessment.pdf.

Simenstad, C.A., C.D. Tanner, R.M. Thom, and L. Conquest. 1991. Estuarine Habitat Assessment Protocol. UW-FRI-8918/-8919 (EPA 910/9-91-037), Rep. to U.S. Environ. Protect. Agency - Region 10. Wetland Ecosystem Team, Fish. Res. Inst., Univ. Wash., Seattle, WA. 191 pp., Appendices.

Skagit Watershed Council. 1998. Habitat protection and restoration strategy. Prepared by the Habitat Restoration and Protection Committee of the Skagit Watershed Council, October 13, 1998 (Revised). Available online at http://www.skagitwatershed.org/pdf/SWCSTRA4.pdf.

Solazzi, M.E., T.E. Nickelson, and S.L. Johnson. 1991. Survival, contribution, and return of hatchery coho salmon (Oncorhynchus kisutch) released into freshwater, estuarine, and marine environments. Canadian Journal of Fisheries and Aquatic Sciences 57: 906-914.

Strittholt, J.R., and P.A. Frost (Earth Design Consultants, Inc.). 1996. Determining abundance and distribution of eelgrass (Zostera spp.) in Tillamook Bay Estuary, Oregon using multispectral airborne imagery. Prepared for Tillamook Bay National Estuary Project, Garibaldi, Oregon.

Thayer, G.W., T.A. McTigue, R.J. Salz, D.H. Merkey, F.M. Burrows, and P.F. Gayaldo (Eds.). 2005. Science-Based Restoration Monitoring of Coastal Habitats, Volume Two: Tools for Monitoring Coastal Habitats. NOAA Coastal Ocean Program Decision Analysis Series No. 23. NOAA National Centers for Coastal Ocean Science, Silver Spring, MD. 628 pp. plus appendices.

Thayer, G.W., T.A. McTigue, R.J. Bellmer, F.M. Burrows, D.H. Merkey, A.D. Nickens, S.J. Lozano, P.F. Gayaldo, P.J. Polmateer, and P.T. Pinit. 2003. Science-Based Restoration Monitoring of Coastal Habitats, Volume One: A Framework for Monitoring Plans Under the Estuaries and Clean Waters Act of 2000 (Public Law 160-457). NOAA Coastal Ocean Program Decision Analysis Series No. 23, Volume 1. NOAA National Centers for Coastal Ocean Science, Silver Spring, MD. 35 pp. plus appendices.

Thomas, D.W. 1983. Changes in Columbia River Estuary habitat types over the past century. Columbia River Estuary Data Development Program, Columbia River Estuary Study Taskforce. 51 pp, Appendices.

Tiner, R.W. (Ed.). 2002. Watershed-based Wetland Planning and Evaluation. A Collection of papers from the Wetland Millennium Event (August 6-12, 2000; Quebec City, Quebec, Canada). Distributed by the Association of State Wetland Managers, Inc., Berne, NY. 141 pp.

U.S. Army Corps of Engineers. 2001. Biological Assessment for Columbia River Channel Improvements Project.

U.S. Army Corps of Engineers. 1995. Engineering Manual 1110-201810: Coastal Geology. Available online at http://www.usace.army.mil/publications/eng-manuals/em1110-2-1810/toc.htm.

Watershed Professionals Network. 1999. Oregon Watershed Assessment Manual. June 1999. Prepared for the Governor's Watershed Enhancement Board, Salem, Oregon.

White, J., T. Dean, Z. Schwartz, and C. Tanner. 1998. Site selection for estuarine habitat restoration: A model criteria. People for Puget Sound, Seattle, WA. 9 pp.

Zedler, J.B. (Ed.). 2001. Handbook for restoring tidal wetlands. CRC Press, Boca Raton, FL.

Zedler, J.B., and R. Lindig-Cisneros. 2000. Functional equivalency of restored and natural salt marshes. *In* Weinstein, M.P., and D.A. Kreeger, *Concepts and Controversies in Tidal Marsh Ecology.* Kluwer, Boston

IX. GLOSSARY

Accretion: The accumulation of sediment, deposited by natural fluid flow processes.

Aquatic bed: A wetland dominated by plants that grow principally on or below the surface of the water. In Oregon estuaries, aquatic beds are generally dominated by algae or eelgrass, so aquatic beds may also be called algal beds or eelgrass beds.

Berm: Another term for a dike (see dike).

Brackish marsh: Another term for tidal marsh; implies moderate salinity (see **salinity zones**).

Breach: A natural or deliberate break in a dike.

Dike: Manmade structure along a river built to protect the adjacent lands from flooding by high water. Many dikes are built on top of natural levees.

Dredging: Excavation of the bottom or shoreline of a water body

Ebb tide: Falling (outgoing) tide; occurs twice a day in Oregon.

Embankment: An artificial bank or dike built to hold back water or to carry a roadway.

Emergent wetland: A wetland dominated by erect, rooted, nonwoody vegetation such as grasses and sedges. Tidal emergent wetlands are often called tidal marshes.

Estuary: A semi-enclosed coastal body of water which has a free connection with the open sea and, within which, seawater mixes and usually is measurably diluted with freshwater from land runoff (Pritchard 1967). In Oregon, the regulatory definition of an estuary includes estuarine water, tidelands, tidal marshes, and submerged lands, and extends upstream to the head of tidewater (except in the Columbia River estuary, where the regulatory definition stops well short of the head of tide).

Estuarine wetland: Tidal wetland (defined below).

Flood tide: Incoming (rising) tide. Flood tide occurs twice a day in Oregon.

Forested wetland: A wetland dominated by woody vegetation more than 6m (20 ft) tall. Tidal forested wetlands are often called tidal swamps.

Freshwater tidal wetland: A wetland where the water regime is influenced by the tides, but salinity is less than 0.5 ppt (parts per thousand).

Geographic Information System (GIS): A computerized mapping system that stores and allows the user to manipulate spatially referenced data.

Geomorphology: That study of the form of the Earth, its surface configuration, the distribution of land, water, etc., and the history of geologic changes through the interpretation of these topographic forms.

HGM: Hydrogeomorphic. Used in the context of the hydrogeomorphic method for functional assessment of wetlands. This module uses a map of tidal wetlands and potential tidal wetlands (Scranton 2004) developed for Volume 3 of the HGM Guidebook for Tidal Wetlands of the Oregon Coast (Adamus et al. 2005b). The map is referred to as the **HGM map**. Areas mapped in the HGM map are referred to as **HGM polygons**.

HGM map: See **HGM** above.

HGM polygon: See **HGM** above.

Intertidal: The zone between the high and low water marks.

Levee: A barrier constructed to block water flow; in tidelands, often consists of a long, narrow embankment built to block tidal flow (see **dike**). Also see **natural levee** below.

Marsh: A wetland characterized by nonwoody, low-growing vegetation (usually grasses, rushes, sedges, and some broadleaved herbs).

Mud flat: An intertidal area without vegetation, with a substrate of unconsolidated sediment, mostly silt and clay. Mud flats are exposed only at low tide.

Natural levee: A narrow strip of higher ground along a river bank, resulting from sediment deposition during flood flows. Natural levees, by definition, are not man-made. However, they are sometimes built up for flood protection purposes, in which case they qualify as dikes.

Neap tide: A tide of relatively small range, occurring when the moon is at quarter.

Pier: A structure extending into the water to serve as a landing place for boats, or for recreational activities.

Piling: A thick wooden or metal pole driven into a channel bottom or sea bed to provide support or protection.

Piping: Erosion of subterranean channels by water moving through soil.

Range of tide: The difference in height between consecutive high and low waters. Also called the "tidal range."

Riprap: Broken rock used to protect structures, foundations, etc. from wave action, erosion by currents, or slumping.

Marine salinity zone: See salinity zones below.

Salinity zone: The geographic area of an estuary where surface waters are characterized by a particular salinity range. Several classification systems exist for salinity zones. For Oregon estuaries, the zones include the **marine** salinity zone (>30 ppt), the **brackish** salinity zone (0.5 to 30 ppt), and **freshwater** zone (less than 0.5 ppt). A more precise classification includes subdivisions of the brackish salinity zone: oligohaline (0.5-5 ppt), mesohaline (5-18 ppt), and polyhaline (18-30 ppt) (Cowardin *et al.* 1987).

Salinity: Number of grams of salt per thousand grams of sea water, usually expressed in parts per thousand.

Salt marsh: Another term for tidal marsh; implies high salinity.

Scrub-shrub wetland: A wetland dominated by woody vegetation less than 6m (20 ft) tall. Tidal scrub-shrub wetlands are often called tidal swamps.

Seawall: A structure built along the coastline to prevent erosion and wave damage. Earth is held against the shore side of the structure.

Sediment: Fine-grained fragments of soil, rock, or organic material which are carried by water or air and deposited away from their source.

Sheet flow: Movement of water in a shallow, broad layer across the surface of a wetland (not confined to channels).

Slack water (slack tide): The period of low water velocity between flood and ebb tides, when the tidal current reverses.

Slough: A water body characterized by low flow, often with a muddy bottom, edged by marshes and other wetlands.

Spring tide: A tide of relatively large range, occurring when the moon is new or full. The word "spring" does not refer to the season of the year; spring tides occur during every month of the year.

Staff gauge: A long rod marked at intervals, for measuring water level.

Subsidence: Sinking of the soil surface.

Swamp: A forested or scrub-shrub wetland.

Tidal channel: For this module, defined as any channel in which water levels are influenced by the tides. Some tidal channels carry both tidal flow and drainage from the watershed; others carry only tidal flow. The latter are called "blind channels."

Tidal flat: An area inundated by all high tides and exposed only at low tide. Some tidal flats have extensive growth of algae or seagrass; others are bare mud.

Tidal marsh: An emergent tidal wetland.

Tidal swamp: A scrub-shrub or forested tidal wetland.

Tidal waters: Waters that rise and fall in a predictable and measurable rhythm or cycle due to the gravitational pull of the moon and sun.

Tidal wetland: A vegetated wetland that is periodically inundated by tidal waters. Tidal wetlands include emergent, scrub-shrub, and forested wetland types.

Tide gate (or tidegate): A device to prevent tidal flow into a tidal channel. Usually a hinged flap hung on the downstream end of a culvert set into a dike or riverbank. Each rising tide pushes the flap closed against the culvert's end, stopping tidal inflow.

Tide gauge: A device for measuring or recording the rise and fall of the tides.

Tide staff: A staff gauge for reading the height of the tide. A "fixed staff" is secured in place; a "portable staff" can be moved from place to place.

Tide tables: Tables showing times and heights of daily high and low tides.

Unconsolidated: Used to refer to sediment grains that are loose, separate, or unattached to one another.

Upland: An area that is not wetland.

Water table: The upper surface of the zone of saturation in soil.

Wetland: An area characterized by soil saturation that occurs often enough to influence soil development and plant communities.

Abbreviations:

BLM	Bureau of Land Management
DOQ	Digital Orthoquadrangle
DSL	Department of State Lands
EPB	Estuary Plan Book
GIS	Geographic Information System
GPS	Global Positioning System
HGM	Hydrogeomorphic
LWI	Local Wetlands Inventory
MHHW	Mean higher high water
MHW	Mean high water
MLLW	Mean lower low water
MLW	Mean low water
NRCS	Natural Resource Conservation Service
NWI	National Wetlands Inventory
ODA	Oregon Department of Agriculture
ODFW	Oregon Department of Fish and Wildlife
ORNHIC	Oregon Natural Heritage Program
PDF	Portable Document Format (copyright Adobe Inc.)
SWCD	Soil and Water Conservation District
USGS	U.S. Geological Survey

Appendix E1. Blank Forms

Form E1-A. Indicators of tidal influence, Part 1: GIS tidal wetland mapping

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11
Map E1 polygon # or #s POLY_NO	Project ID code PROJ_ID	Field check required? Y/N FLDCK_RQ	Field check done? Y/N FLDCK_DN	HGM classes (list) HGM_CD	HGM class MSL/MSH? Y/N HGM_MSLH	Mapped in EPB? Y/N EPB_MAP	EPB habitat codes (list) EPB_CD	NWI codes (list) NWI_CD	NWI tidal or diked? Y/N NWI_TID	ORNHIC tidal marsh? Y/N ONHP_TID

Form E1-B. Indicators of tidal influence, Part 2: Soils, new data, and summary

Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17	Col. 18	Col. 19*	Col. 20*	Col. 21*	Col. 22	Col. 23
Polygon number or ID code POLY_NO or PROJ_ID	ORNHIC swamp? Y/N ONHP_SMP	Tidally-influenced soils? Y/N & list types SOIL_TID	Airphotos: Active tidal channels? Y/N/Q & list year CHACT_YR	Airphotos: Remnant tidal channels? Y/N/Q & list year CHREM_YR	Airphotos: Sitka spruce dominant? Y/N & list year SPRUCE_YR	Local knowledge confirms tidal influence? Y/N LOCAL_TID	Field: Tidal inundation? Y/N/Q FLD_INUN	Field: Tidal channels? Y/N/Q FLD_TIDCH	Field: Brackish-tolerant wetland vegetation?* Y/N FLD_BRKV	Tidal score: Enter 10 if Col. 6,8, 9,11, OR 19 = "Y" Otherwise, add # of "Y" or "Q" entries on this page TID_SUM	Tidal/formerly tidal status, based on Col. 22 score: Score of 3-10 = Y (at least partly tidal); 1-2=Q (possibly tidal); 0 = N (nontidal) TIDAL_YNQ

*For Columns 19 and 20, record details in Form E2. For Column 21, record details in Form E3.

Form E2. Field observations: Hydrology

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13
Map E1 polygon # or #s	Date	Time	Location (code & mark on aerial photo)	Channel type (natural/ ditched)	Name of nearest tidal river/tributary	Approx. distance along channel to tidal riverbank	Tide stage (ebb/flood/ high slack/ low slack)	Does water level fluctuate with tide stage? (Y/N)	Ground surface inundated? (Y/N)	Approx. depth of inundation	Approx. % of polygon inundated (mark areas on airphoto)	Other notes and observations

Form E3. Field observations: Vegetation

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Map E1 polygon # or #s	Date	Time	Location (code & mark on aerial photo)	Brackish-tolerant vegetation present? (Y/N)	Brackish-tolerant plant species observed (list, and describe prevalence and locations, e.g. channel banks / marsh surface / natural levee / dike)	Other plant species observed (list, and describe prevalence and locations, e.g. channel banks / marsh surface / natural levee / dike)

Form E4-A. Alterations to tidal wetlands – Part 1.

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16
Map E1 polygon # or #s	Filled & developed / HGM Class F? (Y/N)	Data source for fill	Diked? (Y/N/Q)	Data source for dikes	Spoil/ DMD? (Y/N/Q)	Data source for spoil/ DMD	Ditched? (Y/N)	Data source for ditches	Exca-vated? (Y/N/Q)	Data source for exca-vation	Restric-tive culvert? (Y/N/Q)	Data source for culvert	Tide-gate? (Y/N/Q)	Data source for tide gate	Field check/ further info needed? (Y/N)
POLY_NO	FILLDEV_YN	FILL_SRC	DIKE_YN	DIKE_SRC	SPL_YN	SPL_SRC	DTCH_YN	DTCH_SRC	EXCV_YN	EXCV_SRC	CLVT_YN	CLVT_SRC	TDGT_YN	TDGT_SRC	FLDCK_ALT

Form E4-B. Alterations to tidal wetlands – Part 2.

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
Map E1 polygon # or #s	Road/ RR? (Y/N)	Data source for road/ RR	Dam? (Y/N/Q)	Data source for dam	Channel armor/ riprap? (Y/N/Q)	Data source for channel armor/ riprap	Logged? (Y/N/Q)	Data source for logging	Grazed? (Y/N/Q)	Data source for grazing	Invasive species? (Y/N/Q)	Data source for inva-sives	List invasive species observed
POLY_NO	RDRR_YN	RDRR_SRC	DAM_YN	DAM_SRC	ARMR_YN	ARMR_SRC	LOGD_YN	LOGD_SRC	GRZ_YN	GRZ_SRC	INVA_YN	INVA_SRC	INVA_SPP

Form E4-A SAMPLE. Alterations to tidal wetlands. SAMPLE FILLED-IN DATA SHEET (simulated data).

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16
Map E1 polygon # or #s	Filled & developed / HGM Class F? (Y/N)	Data source for fill	Diked? (Y/N/Q)	Data source for dikes	Spoil/ DMD? (Y/N/Q)	Data source for spoil/ DMD	Ditched? (Y/N)	Data source for ditches	Exca-vated? (Y/N/Q)	Data source for exca-vation	Restric-tive culvert? (Y/N/Q)	Data source for culvert	Tide-gate? (Y/N/Q)	Data source for tide gate	Field check/ further info needed? (Y/N)
POLY_NO	FILLDEV_YN	FILL_SRC	DIKE_YN	DIKE_SRC	SPL_YN	SPL_SRC	DTCH_YN	DTCH_SRC	EXCV_YN	EXCV_SRC	CLVT_YN	CLVT_SRC	TDGT_YN	TDGT_SRC	FLDCK_ALT
HGM-3025, 3026, 3028	N		Y	aerial photo 1959	N		Y	aerial photo 1959	N		Y	Field observ 5/22/04	Y	Field observ 5/22/04	Y
HGM-507, 509, 513	N		N		Y	EPB, aerial photo 2002	Y	aerial photo 1943	N		Y	Aerial photo 2002	N		N

Form E5. Conservation sites

Col. 1	Col. 2	Col. 3	Col. 4
Map E2 site #	**Map E1 polygon #s**	**Minor alterations present? (Y/N; list if Y) GIS field: ALTERS**	**Notes**

Form E5 SAMPLE. Conservation sites (with sample data)

Col. 1	Col. 2	Col. 3	Col. 4
Map E2 site #	**Map E1 polygon #s**	**Minor alterations present? (Y/N; list if Y) GIS field: ALTERS**	**Notes**
1	HGM 2034, 2035, 2036	Y: Farm road crosses site at far E end, doesn't cross any tidal channels	Farm road doesn't appear to affect tidal circulation. Site appears otherwise unaltered, so the 2 underlying HGM polygons were merged to form this site.
2	HGM-15, 18, 19, 34	N	Site appears relatively unaltered.
3	HGM-1007, 1008	Y: Possible mound of dredged material disposal on E end of site.	Blackberries on possible DMD area suggest spoil. Check soil profile for evidence of dredged material disposal; if present, consider removal of spoil.

Form E6. Restoration sites

Col. 1	Col. 2	Col. 3	Col. 4
Map E2 site #	**Map E1 polygon #s**	**Alterations (list) (GIS field: ALTERS)**	**Notes**

Form E6 SAMPLE. Restoration sites (with sample data)

Col. 1	Col. 2	Col. 3	Col. 4
Map E2 site #	**Map E1 polygon #s**	**Alterations (list) (GIS field: ALTERS)**	**Notes**
1	HGM-909, 910	Dikes, culverts, tide gates, ditches	Site is affected by tide gate at mouth of Tributary A. No tide gates within site, only restrictive culverts. Entirely ditched.
2	HGM-5,8, 11	Excavation (stock pond); dredged material disposal	About 10% of site (W end) is affected by spoil (dredged material disposal). Old excavated stock pond in center of site has milfoil.

Form E7. Landowner information

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
Site #	**Parcel #1**	**Landowner 1**	**Parcel #2**	**Landowner 2**	**Parcel #3***	**Landowner 3***	**Total # owners**	**Ownership type****
SITE_NUM	------------------------------------(enter in spreadsheet, not in GIS)--						NUM_OWN	OWN_TYPE

*continue site data on next line if needed for additional owners

** Land ownership types include Tribe, Federal, State, County, City, Port, Private Industrial, Private Non-Industrial, and Mixed.

Form E8. Prioritization scoring

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
	Size	Size score	Tidal channel condition score	Wetland area within 1 mile buffer*	Score for wetland connectivity	# of salmonid stocks spawning upstream	Score for number of salmonid stocks	Historic tidal swamp area	% of site that was historically tidal swamp	Score for historic tidal swamp	Score for # of Cowardin classes	Total score	Priority Group
Site #	Show units	Convert Col. 2 range to scale of 1-5	Use final score from Form E9	Show units	Convert Col. 5 range to scale of 1-5	Enter actual # of stocks	Convert Col. 7 range to scale of 1-5	Show units	Show actual % of area	Convert Col. 10 range to scale of 1-5	3 classes: score=5; 2 classes: score=3; 1 class: score=1	Double Col. 4, then add to sum of Cols. 3,6,8, 11 & 12	High, medium-high, medium, medium-low, or low
SITE_NO	SITE_SZ	SZ_SCO	CHAN_SCO	WCON_SZ	WCON_SCO	NSTOCKS	NSAL_SCO	SWMP_SZ	SWMP_PCT	SWMP_SCO	CWDN_SCO	TOT_SCO	PRI_GRP

*excluding the site itself

Form E9. Tidal channel condition scoring

Scoring reference chart:

	Tidal exchange		**Tide gate location**		**Ditching**		**Remnant channels**	
	Condition description	Score	Condition description	Score	Condition description	Score	Condition description	Score
Highly altered condition	None	1	Offsite	1	Heavy	1	None	1
Medium alteration level	Restricted	3	Onsite	3	Some	3	Some	3
Least-altered condition	Full	5	None	5	None	5	Many*	5

*or: channels are undisturbed; or site is an existing restoration site

Data entry form:

Site #	**Tidal exchange**	**Tide gate location**	**Ditching**	**Remnant channels**	**Tidal channel condition sum**	**Final score (TCC_SUM/4)**
	TID_X	**TG_LOC**	**DITCH**	**RMCH**	**TCC_SUM**	**TCC_SCO**
(example)	1	3	1	3	8	2

Appendix E2. Tidal Wetland Classifications

Oregon Estuary Plan Book habitat classification

This page lists major habitat classes and subclasses. Combinations may also be mapped, such as 2.3.9/10 (mixed seagrass and algal bed) or 2.3.10(3) (algal bed on mud).

1. Subtidal habitats

1.1 Unconsolidated bottom

1.1.1	Sand
1.1.2	Sand/Mud (mixed)
1.1.3	Mud
1.1.4	Shell
1.1.6	Cobble/Gravel

1.2 Rock Bottom

1.2.7	Boulder
1.2.8	Bedrock

1.3 Aquatic Bed

1.3.9	Seagrass Bed
1.3.10	Algal Bed

2. Intertidal habitats

2.1 Shore

2.1.1	Sand
2.1.2	Sand/Mud (mixed)
2.1.3	Mud
2.1.4	Shell
2.1.5	Wood Debris/Organic
2.1.6	Cobble/Gravel
2.1.7	Boulder
2.1.8	Bedrock

2.2 Flat

2.2.1	Sand
2.2.2	Sand/Mud (mixed)
2.2.3	Mud
2.2.4	Shell
2.2.5	Wood Debris/Organic
2.2.6	Cobble/Gravel

2.3 Aquatic Bed

2.3.9	Seagrass
2.3.10	Algal

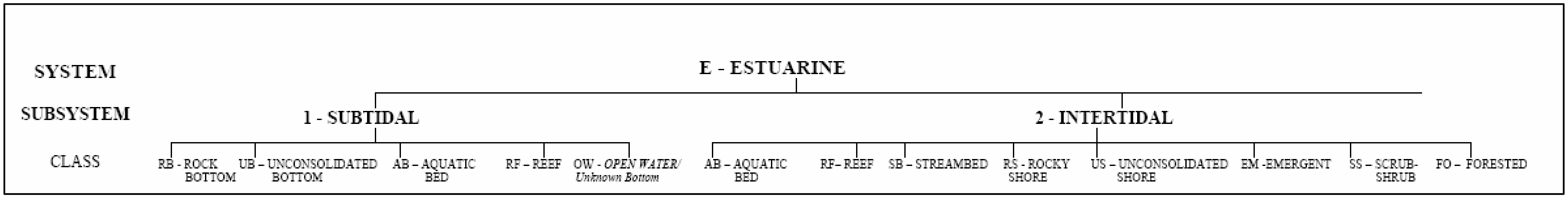
2.4 Beach/Bar

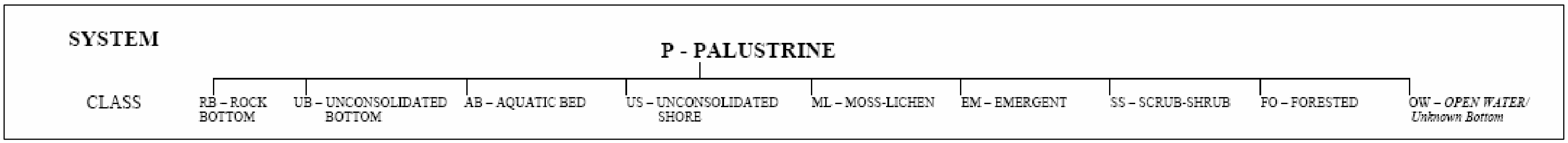
2.4.1	Sand
2.4.2	Sand/Mud (mixed)
2.4.3	Mud
2.4.6	Cobble/Gravel

2.5 Tidal Marsh

2.5.11	Low Salt Marsh
2.5.11 D	Diked Low Salt Marsh
2.5.12	High Salt Marsh
2.5.12 D	Diked High Salt Marsh
2.5.13	Fresh Marsh
2.5.13 D	Diked Fresh Marsh
2.5.14	Shrub
2.5.14 D	Diked Shrub

National Wetlands Inventory classification (Cowardin system)





MODIFIERS

In order to more adequately describe the wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

WATER REGIME				WATER CHEMISTRY			SOIL	SPECIAL MODIFIERS	
Non-Tidal		**Tidal**		**Coastal Halinity**	**Inland Salinity**	**pH Modifiers for all Fresh Water**			
A Temporarily Flooded B Saturated C Seasonally Flooded D *Seasonally Flooded/ Well Drained* E *Seasonally Flooded/ Saturated* F Semipermanently Flooded G Intermittently Exposed	H Permanently Flooded J Intermittently Flooded K Artificially Flooded W Intermittently Flooded/Temporary Y Saturated/Semipermanent/ Seasonal Z Intermittently Exposed/Permanent U *Unknown*	K *Artificially Flooded* L Subtidal M Irregularly Exposed N Regularly Exposed P Irregularly Flooded	*S Temporary-Tidal *R Seasonal-Tidal *T Semipermanent-Tidal *V Permanent-Tidal U *Unknown* *These water regimes are only used in tidally influenced, freshwater systems.	1 Hyperhaline 2 Euthaline 3 Mixohaline *(Brackish)* 4 Polyhaline 5 Mesohaline 6 Oligohaline 0 Fresh	7 Hypersaline 8 Eusaline 9 Mixosaline 0 Fresh	a Acid t Circumneutral i Alkaline	g Organic n Mineral	b *Beaver* d *Partially Drained/Ditched* f Farmed	h *Diked/Impounded* r Artificial Substrate s *Spoil* x Excavated

HGM classification key for Oregon's tidal wetlands

This key (excerpted from Adamus 2006) is used to place Oregon's tidal wetlands into the appropriate HGM subclass.

1. Tidal forces cause the wetland to be flooded with surface water at least once annually, during most years. Excluded are wetlands whose water level or soil saturation may be influenced by tidal fluctuations but which lack a regular (at least annual) surface connection to tidal waters. Plant species that typically characterize upland habitats are absent or nearly so, and some wetland species that are present may be characteristically tolerant of brackish as well as fresh salinity conditions. Channels, if present, are often narrow, winding or branched, and deeply incised as a result of tidal action. Regardless of the wetland's salinity, it is located downriver from the recognized head-of-tide of its associated estuary. Drift logs and growth of trees and moss often mark the upper boundary of annual flooding, i.e., the transition to non-tidal wetland or upland.

YES: Estuarine Fringe HGM Class. go to #2
NO: other wetland classes; the HGM guidebook is not applicable.

2. Tidal forces cause the wetland to be flooded at least once annually with saline or brackish surface water originating partly or wholly from the ocean (i.e., marine-sourced). Often located within or along the fringes of a major estuarine embayment or a slough off the embayment. Typically located within zones classified as "Marine" or "Brackish" on maps published by Hamilton (1984), the National Estuarine Inventory (1986, 1988), and/or as "Estuarine" on maps of the National Wetlands Inventory. The wetland and/or its immediate receiving waters may have one or more of the following indicators suggestive of marine water: barnacles, stranded seaweed, salt marsh plant species (halophytes, e.g., *Salicornia*, *Triglochin, Distichlis, Plantago maritima*), springtime minimum salinities of >5 ppt, or a preponderance (in adjacent flats) of rounded sediment particles indicative of marine-derived sediments.

YES: *Marine-sourced*, go to #3
NO: ***River-sourced Tidal Fringe Wetland*** *(RS)*

3. All of the wetland is inundated at high tide at least once during the *majority of days during each month of the year*. This may be indicated by a combination of direct observation of tidal inundation, predominance of plant species characteristic of "low marsh" marine environments in Oregon, absence of woody plants, and/or by reference to data on local tidal range paired with precise measurements of elevation and tidal fluctuations relative to an established geodetic benchmark. Less definitively, a boundary between low and high marsh may be evidenced by a vertical break in the marsh surface or by accumulations of fresh wrack (seaweed, plant litter).

YES: ***Marine-sourced Low Tidal Fringe Wetland*** *(MSL),* commonly called "low marsh"
NO: ***Marine-sourced High Tidal Fringe Wetland*** *(MSH),* commonly called "high marsh"

Additional categories in HGM map (Scranton 2004)

The HGM map used as a base layer for this module (Scranton 2004) contains two other wetland mapping categories that are important to this assessment, but which are not included in the key above. They are "Potential Tidal Forested Wetland" (PF) and "Restoration Consideration Area" (RCA). Adamus (2006) provides the following definitions of those categories:

> PF = Wooded nearshore areas that may be flooded by tides at least once annually
>
> RCA = Restoration consideration areas, i.e., nontidal wetlands at about the same elevation as tidal waters and which, in some cases, might have been tidal wetlands prior to blockage by dikes, roads, etc.

Our observations indicate that some of the areas mapped by Scranton as "RCA" may be hydrologically modified as described above, but others appear to be hydrologically connected to tidal waters and were designated RCA because the degree of tidal influence could not be determined during Scranton's thesis work. Many of these areas are in landscape positions and at elevations where it is quite challenging to determine the degree of current or former tidal influence. The methods described in Step 1 of this module (**Identify the historic extent of tidal wetland**), particularly the section **Field observation and local knowledge**, are key to determining tidal influence in these RCA areas.

Scranton (2004) provided details on the methods used to map the PF and RCA areas. The following three paragraphs are excerpted from Scranton (2004):

> **Potential Tidal Forested Wetland (*PF*).** This classification includes lands currently covered by woody vegetation that are suspected of experiencing tide-related inundation at least once annually, but for which definitive field data are lacking. This includes wetlands labeled E2F* or E2S* by the NWI, as well as wetlands that NWI labeled PSS* or PFO* and which adjoin tidal channels and apparently are not diked. It also includes wetlands coded 2.5.14* by ODFW in the Oregon Estuary Plan Book. These are mostly relict spruce swamps and willows existing near their physiological threshold for salinity. Many probably became established in tidal zones due to fresher hillslope seepage. However the classification label "potential" was derived also as a result of the inability to interpret true hydrology remotely through the canopy. This classification needs to be refined in future work to reclassify these polygons as Tidal Forested Wetlands, Forested Wetlands or Upland Forest.
>
> **Restoration Consideration Areas (RCA):** Due to the uncertainty of response in terminology the classification of "Restoration Consideration Areas" was changed from its original classification, Potential Tidal Wetlands. This classifies lands, which could not be accurately classified based on existing remote sensing data or lands that are presently defined as upland or non-tidal wetland areas by other sources, which deserve closer scrutiny as possible candidates for restoration of tidal circulation. These areas were identified based solely on coarse-scale geotechnical information from available data sets. No on-site feasibility investigations were conducted, and sociopolitical factors were not

considered. These are generally lands that are diked or may have been partially filled or ditched for agricultural or commercial purposes.

RCAs were identified primarily by reviewing digital elevation information, NWI and ODFW habitat maps, the hydric soils layer from NRCS and other historical sources. Rigid criteria were not developed to identify and map these areas systematically. Rather, mapping employed considerable judgment and consequently the results are very approximate, but err on the side of over-approximation based on the “precautionary principle” of resource management (Cican-Sain 1998). Unknown portions of the RCAs are palustrine wetlands or riparian uplands that never experienced tidal flooding, due to naturally-formed barriers.

Appendix E3. Wetland Plants Tolerant of Brackish Water

This table shows a list of common plant species tolerant of brackish water that are found in Oregon's tidal marshes and tidal swamps. Many of these species are also found in freshwater wetlands. However, if a wetland is dominated only by brackish-tolerant species, it is likely to have brackish water.

Species	**Abbreviation**	**Common name**
Argentina egedii	ARGEGE	Pacific silverweed
Atriplex patula	ATRPAT	Saltbush
Carex lyngbyei	CARLYN	Lyngbye's sedge
Cotula coronopifolia	COTCOR	Brass buttons
Cuscuta salina	CUSSAL	Saltmarsh dodder
Deschampsia caespitosa	DESCES	Tufted hairgrass
Distichlis spicata	DISSPI	Seashore saltgrass
Eleocharis palustris	ELEPAL	Creeping spikerush
Eleocharis parvula	ELEPAR	Spikerush
Festuca rubra	FESRUB	Red fescue
Galium trifidum	GALTRI	Small bedstraw
Glaux maritima	GLAMAR	Sea-milkwort
Grindelia stricta	GRISTR	Gumweed
Hordeum brachyantherum	HORBRA	Meadow barley
Jaumea carnosa	JAUCAR	Fleshy jaumea
Juncus balticus	JUNBAL	Baltic rush
Juncus gerardii	JUNGER	Mud rush
Lilaeopsis occidentalis	LILOCC	Lilaeopsis
Lonicera involucrata	LONINV	Black twinberry
Malus fusca	MALFUS	Pacific crabapple
Picea sitchensis	PICSIT	Sitka spruce
Plantago maritima	PLAMAR	Seaside plantain
Rumex maritimus	RUMMAR	Golden dock
Salicornia virginica	SALVIR	Pickleweed
Schoenoplectus (Scirpus) maritimus	SCIMAR	Seacoast bulrush
Spergularia canadensis	SPECAN	Canada sandspurry
Spergularia macrotheca	SPEMAC	Beach sandspurry
Spergularia marina	SPEMAR	Saltmarsh sandspurry
Symphyotrichum (Aster) subspicatum	SYMSUB	Douglas' aster
Trifolium wormskioldii	TRIWOR	Springbank clover
Triglochin maritimum	TRIMAR	Seaside arrowgrass

Appendix E4: Further analyses

Community perceptions

This assessment prioritizes tidal wetland sites according to ecological criteria. However, peoples' ideas, values and attitudes about the land are equally important to the process. Restoration and conservation can only proceed if landowners are interested and willing, and broader community perceptions are often critical during decision-making as well.

Landowner willingness is best evaluated during the next phase of action planning after completion of this assessment (landowner contacts and site-specific action planning). However, even prior to landowner contacts, community input can be gathered to help keep the action planning process open and responsive. Community workshops can help spread the word about the value of tidal wetlands, and important information can be gathered from the community that may be vital during action planning.

There are many possible ways to engage the community in the estuary assessment and prioritization process. The ideal is full involvement of a diverse group of community members in the assessment and prioritization process. For community members who cannot participate at that level, a short workshop can be held to gather feedback during the assessment and prioritization process. This workshop should occur after sites are identified and each site's level of alteration has been determined. Priorities should not yet be determined, because information gathered during the workshop may affect the prioritization.

One successful approach (Brophy and So, 2005b) has been to hold a workshop in which landowners and other local residents are asked to rank each tidal wetland site on a scale of 1 to 5 in terms of acceptability of restoration or conservation activity at that site. A score of 1 represents low acceptability of restoration (at altered sites) or low acceptability of conservation (at relatively unaltered sites). A score of 5 represents high acceptability.

Subjective decision making is welcome at such a workshop; organizers should emphasize that the workshop is intended to gather perceptions, not to evaluate the ecological importance of sites. The reasons for the rankings can be as diverse as the group attending the workshop. Besides the rankings, useful information about sites can be gathered if participants are given cards for recording their thoughts, ideas, and knowledge about sites, and the cards are collected at the end of the meeting.

Economics of restoration

Many former tidal wetlands are currently in agricultural production. The economic value of these lands should be balanced against the value of the ecological functions that could be provided by restored tidal wetlands. Such economic analysis is difficult, but may be undertaken if it is viewed as important by a Council. Expert assistance is recommended for such an analysis; the analysis should consider both private and public economic value.

In a practical sense, landowners usually consider economics (private costs and benefits) when deciding whether to restore tidal wetland on their own property. Non-economic values (aesthetics, family history, neighbor relations, and many other factors) can be equally important.

By consulting with the landowner or local resource experts, it may be possible to estimate the value of agricultural production from a former tidal wetland site. Three other important factors may be less obvious but should be considered in any economic analysis of restoration: 1) the restoration economy, 2) the value of ecosystem services, and 3) the low productivity of wet pastures.

The restoration economy. Wetland restoration uses considerable labor, materials, expertise, and equipment, both for the initial implementation and for ongoing maintenance. Most of these purchases are made locally, supporting the local economy (Baker 2004, OWEB 2005). Studies have shown that 80% of OWEB grant funds for restoration stay in the county in which the grants were awarded, and every dollar spent on restoration has a "multiplier effect" generating an additional $1.65 to $2.50 in economic benefits to the local economy (OWEB 2005). These benefits bring millions of dollars to coastal counties in Oregon, a factor that should be considered when evaluating economic trade-offs of restoration.

Ecosystem services. Another important factor, much harder to document, is the economic value of the ecological functions or "ecosystem services" provided by tidal wetlands. Ecosystem services are "critical to the functioning of earth's life-support system" and "contribute to human welfare, both directly and indirectly" (Costanza 1997). The ecosystem services provided by tidal wetlands are discussed in **Estuary Basics** above; they are estimated at $4,000 annually per acre of tidal wetland.

Wet pastures. Many former tidal wetlands have undergone land surface subsidence after diking or other blockage of tidal flow. Most of these were altered to create or improve pasture. After subsidence, these areas often become freshwater wetlands rather than the more agriculturally desirable upland pastures. Subsidence is caused by oxidation of organic matter in soils, loss of flotation, and compaction by trampling and agricultural machinery. Impoundment of diffuse flows behind dikes, poor tide gate function, and sedimentation in ditches may also contribute to this phenomenon. These wet pastures may be usable only during the driest part of the summer. Economics may favor restoration of such areas, particularly given the availability of government programs for agricultural setasides. Examples of such programs include the Conservation Reserve Program (CRP) and Wetlands Reserve Program (WRP).

SALMONID HABITAT ANALYSES

This module's prioritization method evaluates broad indicators of potential tidal wetland functions, including salmon habitat functions. More precise analyses of potential salmonid habitat functions would be desirable. However, consistent and comprehensive data needed to conduct many analyses are not available at an appropriate scale. For example, the assessment might be improved by evaluating the number or percentage of "ocean-type" salmon stocks within subdivisions of the study area and prioritizing those subwatersheds with a high proportion of such stocks (Simenstad 2005). However, to conduct such an analysis, comprehensive and consistent data would be needed detailing the life-history strategies of salmon populations in each subarea. Currently, no such data are available, but if such data become available, further analyses are recommended.

Geomorphic characteristics of tidal wetlands were also considered as possible prioritization criteria. For example, behavioral data and population biology studies to date suggest that some types of tidal wetlands may be particularly important to juvenile salmon. Tidal wetlands at tributary junctions, tidal wetlands that have freshwater inputs and are located in the marine salinity zone, and oligohaline (low-salinity) wetlands in the upper estuary have all been suggested as high priorities for protection and restoration. However, expert opinions on this topic are diverse, suggesting that available data may not yet be adequate to support the use of geomorphic prioritization criteria. In addition, physical site data are not yet adequate to support such analyses. For example, available data on salinity zones lack the spatial resolution required for site-specific analysis. With improved data in future years, development of geomorphic prioritization criteria may become possible. Alternatively, such analyses may be possible in the context of a more intensive assessment that moves beyond the scope of this module.

HISTORIC VEGETATION ANALYSES

This assessment uses proportion of historic tidal swamp as a prioritization criterion, because coastwide, tidal swamps have been disproportionately impacted by human activities. If you wish to develop a more thorough understanding of the historic array of habitat types within your study area, you can conduct further analyses using the ORNHIC historic vegetation layer along with your tidal wetland layer.

After completing Map E1 (historic extent), determine the area of each historic vegetation type within the extent of Map E1. This will tell you the historic proportions of different wetland types in your study area. Next, use the HGM subclass (MSL=low marsh, MSH=high marsh, PF=potential tidal forested wetland), along with NWI mapping and your analysis of alterations, to determine the proportions of current vegetation types and tidal influence classes (fully tidal, muted tidal, nontidal) for each polygon within each historic vegetation type. Through this analysis, you will be able to determine which historic vegetation types have been disproportionately lost or converted to other types. For example, historic tidal swamps may have been converted to tidal marsh, diked pasture, nontidal forested wetlands, uplands, or other types. You can use the results of this analysis to modify your prioritization if desired.

Appendix E5. Restoration Approaches

This section addresses some of the many issues to consider when planning restoration. Not all issues can be addressed here, so consultation with technical experts is highly recommended.

PERMITS AND REGULATORY COORDINATION

Restoration activities often require extensive coordination with many different regulatory agencies. Numerous permits and approvals may be needed, so it is 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.

CULTURAL HISTORY AND ARCHAEOLOGICAL SITES

Before European settlement, Oregon's estuaries were widely used by Native American peoples for dwelling 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 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. 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 leads to public support of wetland conservation.

It is 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 will also buffer the watershed against future basin-wide hydrologic changes or sea-level rise due to earthquakes or climate change.

DIKE BREACHING AND DIKE REMOVAL

To restore tidal flow to diked sites, dikes can be breached at selected locations, preferably at locations of former natural tidal channels. Alternatively, dikes can be removed completely, enhancing sheet flow, nutrient cycling and natural sedimentation patterns. Alternatively, dikes may be reconstructed further from the tidal water body ("dike setbacks") to protect lands or structures where tidal inundation must be prevented.

Dike breaching and removal can be technically challenging operations, with complex trade-offs in biological functions, hydrology, sediment erosion and deposition patterns, and engineering constraints. Techniques for successful dike breaching, dike removal, and dike setbacks are still evolving in Oregon. Consult with experts (such as wetland scientists, hydrologists, and engineers) before designing these types of restoration projects.

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. This is particularly true if the ditches are deeper than the remnant tidal channels – often the case on muted tidal, abandoned pastures where remnant channels are often filled with sediment and tidal ditches are "scoured".

Partial excavation of meandering channels, preferably following visible or surveyed remnant channels, may speed the restoration process. However, excavation is not always recommended, and this process presents many 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 to restore meandering channels may be unnecessary. "Self-design," in which water flows are allowed to create their own meandering path through processes of erosion and deposition, is the best approach in many cases. 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 TIDE GATE UPGRADES

Detailed information on culverts and tide gates that affect tidal flows is needed for good restoration planning. These structures cannot be seen on aerial photos, 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, carefully evaluate 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 tide gates (free or impeded?), differences in water levels at the upstream and downstream ends of culverts, impounded water at 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 (see **Conservation of existing wetlands** above).

One restoration option for tidegated sites is installation of "fish-friendly" tide gates, which increase fish access to streams and wetlands above the gate. Such devices may be a good option where a landowner does not want to allow restoration of tidal flow. However, providing fish access to a site does not restore the ecological functions of tidal wetlands, since tidal flow is still impeded. Tide gate removal (usually accompanied by a culvert upgrade) is a better option for restoration of the full tidal wetland ecosystem. Whichever restoration option is chosen, the information described in the previous paragraph is needed.

GENERAL HYDROLOGIC RESTORATION

If a tidal wetland restoration area is located near roads, buildings or other structures, careful planning is necessary. Many tidal wetlands can be restored with no risk to adjacent structures, because the restoration area is usually at a considerably lower elevation than the 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 water table depth, surface and subsurface water movement, and tidal range 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. It is important to consult with hydrologists and engineers who are experienced in the tidal zone.

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 important zones for wildlife; these interfaces are preferred by many species, for they represent the natural gradient from one type of habitat to another.

Buffer establishment around the margins of wetland sites should preferentially use native upland plantings. Native plantings require a weed control plan. 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 (e.g., urban areas) are excluded from this assessment. Most of these areas have been converted to economically valuable uses like residential and commercial development. 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 are few native plant communities nearby to provide seeds and propagules for revegetation.

However, some sites have small areas of fill that could be removed to improve wetland functions. Driveways that are no longer used, piles of material from construction activities, and small areas of dredged material might offer such opportunities.

LIVESTOCK EXCLUSION

Livestock grazing alters plant communities and the physical structure of tidal wetlands. Livestock degrade tidal channels, lowering the quality of fish habitat and altering water characteristics. Trampling by livestock compacts soils and causes oxidation of soil organic matter, greatly altering soil biology. Therefore, exclusion of livestock from tidal wetlands is an important component of many restoration projects. Exclusion of livestock from buffer areas around wetlands is also desirable, because fully vegetated buffers enhance biological functions of wetlands (see **Buffer establishment** above).

LARGE WOOD PLACEMENT

Tidal wetlands were easily accessible to early logging operators, so spruce were probably removed from most of Oregon's tidal swamps during the 1800s. Drift logs on tidal marshes were removed for lumber and firewood. Large woody debris appears to provide important shelter for juvenile salmon and may be important for other nutrient cycling functions as well. Therefore, large wood placement should be considered for every tidal wetland restoration project. Wood may need to be anchored, particularly in low-elevation areas where tidal inundation is deep.

Appendix E6. Restoration Principles

Tidal wetland restoration is most likely to be successful if it follows basic principles of restoration design. These principles should be carefully incorporated into every restoration project. The titles of the principles listed below 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 following each principle is specific to this assessment and to Oregon estuaries south of the Columbia; review of the original document is recommended.

PROTECT FIRST – RESTORE SECOND

The immediate need for every current and former tidal wetland site in Oregon is protection of existing wetlands. This is particularly true for relatively 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 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 (road, tide gate or restrictive culvert) should be carefully analyzed to determine the likely effects of removing the tide gate 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 simply drain the current freshwater wetland. In other words, it is important to examine the possibility of trade-offs between restoring tidal wetlands and draining impounded freshwater wetlands.

DO NO HARM

In this assessment, restoration is defined as "return of an ecosystem to a close approximation of its condition prior to disturbance. Restoration is ... a holistic process not achieved through the isolated manipulation of individual elements" (National Research Council 1992). 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 hinder recovery of the original site hydrology with its 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; a few others include freshwater input, sediment and detritus deposition, and tectonic uplift and subsidence. 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. Such sites lack the natural processes that normally create tidal wetlands, so a much higher level of engineering 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). Tidal wetland creation (making a new tidal wetland where tidal flow never existed previously) may cause unexpected problems for other nearby tidal wetlands by altering the natural patterns of tidal flows.

INCORPORATE SALMON LIFE HISTORY

Current research is rapidly expanding our knowledge of how salmon use Oregon's tidal wetlands. However, our knowledge base is still very limited. To restore tidal wetlands for salmon habitat functions, we need to take a landscape approach, focusing on connectivity of habitats and restoration of the full continuum of habitats needed by rearing and migrating juveniles. Some studies have suggested that the slightly brackish (oligohaline) zone of the estuary, characterized by tidal swamp vegetation, may be particularly important for osmotic transition, and may need to be strategically targeted for restoration (Simenstad and Bottom, undated).

DEVELOP A COMPREHENSIVE RESTORATION PLAN USING LANDSCAPE ECOLOGY CONCEPTS TO RE-ESTABLISH ECOSYSTEM CONNECTIVITY AND COMPLEXITY

This assessment 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. The assessment establishes an ecosystem context 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 example of a strategic approach is combining tidal and nontidal wetland conservation and restoration actions. Tidal wetlands identified in this assessment that have adjacent nontidal wetlands may offer valuable opportunities for protecting or restoring habitat connections and linkages. Planning for tidal wetland conservation and restoration should include adjacent nontidal wetlands (and adjacent uplands) whenever possible.

USE HISTORY AS A GUIDE, BUT RECOGNIZE IRREVERSIBLE CHANGE

This assessment identifies all historic tidal wetlands. While most of these sites can probably be restored, some sites may be difficult to restore due to current conditions. Subsidence (sinking of the soil surface) can mean that former high marsh and tidal swamp sites restore to mud flats or low marsh rather than their original habitat types. Human land uses in the estuaries and their 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.

The fieldwork in Step 1 of this assessment will help determine which areas still have adequate tidal flows for restoration of tidal wetlands. This fieldwork is particularly important in the upper estuary, where tidal velocities and volumes may have been low even prior to disturbance. Additional onsite studies may be needed, including elevation surveys, water level (tidal range) measurements, plant community analysis, and other measurements to determine the feasibility of restoring tidal influence and tidal wetland habitats at a particular site. Freshwater inflow to restoration sites should also be evaluated, because freshwater 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, Niedowski 2000). 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 is also needed to help guide future restoration efforts, because tidal wetland restoration is still very much a developing science.

Monitoring needs for tidal wetland restoration sites are discussed in the **Monitoring** section of this module.

TAKE ADVANTAGE OF BEST, INTERDISCIPLINARY SCIENCE AND TECHNICAL KNOWLEDGE AND EMPLOY A SCIENTIFIC PEER-REVIEW PROCESS

When you are ready to design a restoration project, get technical assistance. Restoration design will benefit from expertise 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. The team can help you evaluate the biological soundness and feasibility of your restoration goals, and can advise on baseline and followup monitoring and design. Early consultation with your team to establish baseline monitoring protocols is important; details on monitoring are provided in this module.

As you implement restoration and do followup monitoring, your team can continue to help you evaluate your success in achieving your restoration goals, and spread the word about your experiences to other restoration practitioners.