



Prepared in cooperation with Green Point Consulting and the U.S. Environmental Protection Agency

Tidal Wetlands of the Yaquina and Alsea River Estuaries, Oregon: Geographic Information Systems Layer Development and Recommendations for National Wetlands Inventory Revisions



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U.S. Department of the Interior
U.S. Geological Survey

Cover. Photograph of Drift Creek and adjoining tidal marshes in the Alsea estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, November 2010.

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By Laura S. Brophy, Green Point Consulting; with contributions from: Deborah A. Reusser, U.S. Geological Survey;
and Christopher N. Janousek, U. S. Environmental Protection Agency

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m ²)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm ²)
acre	0.004047	square kilometer (km ²)

Salinity is unitless.

Datums

UTM Zone 10N NAD83 HARN uses the NAD83(HARN) geographic 2D CRS as its base CRS and the UTM zone 10N (Transverse Mercator) as its projection.

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the Oregon Lambert HARN (international feet).

Elevation, as used in this report, refers to distance above the vertical datum.

Acronyms and Abbreviations

BLM	U.S. Bureau of Land Management
DLCD	Department of Land Conservation and Development
EPA	U.S. Environmental Protection Agency
FTW	Former Tidal Wetland
GIS	Geographic Information Systems
HARN	High Accuracy Reference Network
LiDAR	Light Detection and Ranging
NAIP	National Agricultural Imagery Program
NOAA	National Oceanic and Atmospheric Administration
NWI	National Wetlands Inventory
USFS	U.S. Forest Service
MLLW	Mean Lower Low Water
MHHW	Mean Higher High Water
HMT	Highest Measured Tide

Definitions

National Wetlands Inventory Wetland

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

US Army Corps of Engineers and Oregon Department of State Lands Wetland

“Wetlands” means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

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Abstract

Geographic Information Systems (GIS) layers of current, and likely former, tidal wetlands in two Oregon estuaries were generated by enhancing the 2010 National Wetlands Inventory (NWI) data with expert local field knowledge, Light Detection and Ranging-derived elevations, and 2009 aerial orthophotographs. Data were generated for two purposes: First, to enhance the NWI by recommending revised Cowardin et al. (1979) classifications for certain NWI wetlands within the study area; and second, to generate GIS data for the 1999 Yaquina and Alsea River Basins Estuarine Wetland Site Prioritization study. Two sets of GIS products were generated: (1) enhanced NWI shapefiles; and (2) shapefiles of prioritization sites. The enhanced NWI shapefiles contain recommended changes to the Cowardin et al. classification (system, subsystem, class, and/or modifiers) for 286 NWI polygons in the Yaquina estuary (1,133 acres) and 83 NWI polygons in the Alsea estuary (322 acres). These enhanced NWI shapefiles also identify likely former tidal wetlands that are classified as upland in the current NWI (64 NWI polygons totaling 441 acres in the Yaquina estuary; 16 NWI polygons totaling 51 acres in the Alsea estuary). The former tidal wetlands were identified to assist strategic planning for tidal wetland restoration. Cowardin et al. classifications for the former tidal wetlands were not provided, because their current hydrology is complex owing to dikes, tide gates, and drainage ditches. The scope of this project did not include the field evaluation that would be needed to determine whether the former tidal wetlands are currently wetlands, and if so, determine their correct Cowardin et al. classification. The prioritization site shapefiles contain 49 prioritization sites totaling 2,177 acres in the Yaquina estuary, and 39 prioritization sites totaling 1,045 acres in the Alsea estuary. The prioritization sites include current and former (for example, diked) tidal wetlands, and provide landscape units appropriate for basin-scale wetland restoration and conservation action planning. Several new prioritization sites (not included in the 1999 prioritization) were identified in each estuary, consisting of NWI polygons formerly classified as nontidal wetland or upland. The GIS products of this project improve the accuracy and utility of the NWI data, and provide useful tools for estuarine resource management.

Introduction

Wetlands in Oregon estuaries have been altered by past human land uses and will continue to undergo changes owing to future human land use decisions and climate change effects, such as sea-level

rise, increased storm frequency and intensity, and changing temperature and precipitation patterns. Human alterations to tidal wetlands in several Oregon estuaries have been well documented through field surveys, aerial photograph interpretation of high resolution imagery, and Light Detection and Ranging (LiDAR) analyses (Brophy, 1999, 2005, 2012). However, some of these data were published as reports (for example, Brophy, 1999) and were not available in a format that could be used for modeling future changes in coastal habitats because of sea-level rise (SLR). In addition, although the National Wetlands Inventory (NWI) data layers had been updated by the U.S. Fish and Wildlife Service in 2010, for the Yaquina and Alsea estuaries, preliminary SLR model runs for the Yaquina estuary by U.S. Geological Survey (USGS) indicated that some important wetlands were possibly miscoded. To improve SLR modeling results and enhance the accuracy and utility of the NWI for resource managers, the USGS provided funding to Green Point Consulting in 2010 to develop enhanced Geographic Information Systems (GIS) products for the Yaquina and Alsea drainage basins with recommended NWI (Cowardin et al. 1979) classification revisions using information from previous studies and expert field knowledge. This report describes the methods used to enhance the NWI data layers and to develop the other GIS products, and summarizes the results of these changes. This report also includes photographs of wetland types and plant species that are common in these estuaries. Links to download the data are located in the data section of this document.

Study Areas

The Yaquina estuary is on the central Oregon coast adjacent to the town of Newport at latitude 44.62°N, longitude 124.02°W. The Alsea estuary is approximately 16 mi south of the Yaquina estuary adjacent to the town of Waldport, Oregon (fig. 1). The project study areas include the entire Yaquina River estuary and the entire Alsea River estuary, from the Pacific Ocean to the upstream limit of tidal influence. Instead of the mapped head of tide, as published by the Oregon Department of State Lands (OR DSL) (2007), the study area included all land surfaces within tidal range (based on LiDAR-derived elevations), as described in section, “LiDAR Analysis”, even if those land surfaces were upstream of mapped head of tide. This was necessary because field experience has shown that the DSL head of tide mapping is sometimes inaccurate (for example, Brophy, 2012), and because this study included former tidal wetlands behind the tide gates and barriers that constitute the current head of tide in some water bodies.

The Yaquina and Alsea estuaries are drowned river mouths with expansive intertidal mud flats near their mouths (fig. 2). Upslope and upstream of the mud flats are the three types of tidal wetlands addressed in this study: emergent tidal wetlands (tidal marsh), scrub-shrub tidal wetlands, and forested tidal wetlands. All three types can occur as either saline or freshwater wetlands. Their corresponding Cowardin et al. classes are shown in table 1. Woody-dominated (scrub-shrub and forested) tidal wetlands are collectively referred to as “tidal swamp”. The estuarine and tidally influenced palustrine wetland vegetation in both of these estuaries is species-rich and includes grasses such as *Deschampsia cespitosa* (fig. A1), *Agrostis stolonifera* (fig. A2), *Hordeum jubatum* (fig. A3), and *Distichlis spicata*; rushes (*Juncus* spp., figs. A4–A5); sedges such as *Carex lyngbyei* (fig. A6) and *Carex obnupta* (fig. A7); and succulent halophytes (*Triglochin maritimum*, fig. A8). Trees and shrubs found in Yaquina and Alsea tidal wetlands include Sitka spruce (*Picea sitchensis*) (fig. A9) and black twinberry (*Lonicera involucrata*) (figs. A10–A11). Additional representative landscapes and vegetation present across the study areas can be seen in figures A12–A32. Further information on Oregon tidal wetland habitats and vegetation can be found in Akins and Jefferson (1973), Jefferson (1975), Eilers (1975), Adamus and others (2005), and Brophy (2007a).



Figure 1. Map of the Central Oregon Coast showing locations of the Yaquina and Alsea estuaries and associated drainage basins. Oregon boundaries from the Nationalatlas.gov in geographic projection. Watershed boundaries and water polygons from U.S. Environmental Protection Agency classification project (Lee and Brown, unpublished data, 2009).



Figure 2. Aerial image showing extensive intertidal area near the mouth of the estuary, Alsea Bay, Oregon. (Photograph by Laura Brophy, Green Point Consulting, September 2007).

Table 1. Common names for tidal wetland types frequently found in the Yaquina and Alsea estuaries, and their corresponding Cowardin et al. (1979) classifications.

[Table does not include all possible wetland types]

Common names – coarse scale	Common names – fine scale	Cowardin et al. classification
Tidal marsh, salt marsh	Low marsh, low salt marsh	E2EMN
	High marsh, high salt marsh, high brackish marsh	E2EMP
Tidal swamp	Brackish scrub-shrub tidal wetland	E2SSP
	Brackish forested tidal wetland	E2FOP
	Freshwater scrub-shrub tidal wetland	PSSR
	Freshwater forested tidal wetland	PFOR
Freshwater tidal marsh	Freshwater tidal marsh	PEMR

Like other Oregon estuaries, the Yaquina and Alsea estuaries are subjected to dry summers, during which river influence is low and ocean influence is high; and wet winters, where river influence increases (Brown and Ozretich, 2009). During the summer months, strong upwelling events provide nutrient rich waters to Pacific coast estuaries. Estuaries contribute to coastal ecosystem services by cycling nutrients and providing critical habitat for native plants and animals including marine, anadromous, and resident fish, birds, and invertebrates (Adamus, 2006).

Project Goals and Objectives

The goals of this project were to enhance the NWI data with expert local and regional knowledge for the Alsea and Yaquina estuaries, to improve the accuracy and utility of these GIS layers for resource management and to improve model results, for potential future wetland habitat distributions due to sea-level rise. To accomplish these goals, the following specific objectives were established:

1. Educate USGS and Environmental Protection Agency (EPA) personnel on field identification of Oregon tidal wetland plants in the emergent, scrub-shrub and forested classes.
2. Generate enhanced NWI shapefiles containing recommended revisions to the Cowardin et al. classification for tidal wetlands within the study area (emergent, scrub-shrub, and forested classes).
3. Generate GIS datasets (shapefiles) for the tidal wetland prioritization sites identified in the 1999 tidal wetland prioritization for the Yaquina and Alsea estuaries (Brophy, 1999), and characterize major changes at these prioritization sites since 1999.

Methods

Plant Identification Workshop

To improve and standardize knowledge of the local tidal wetland flora for USGS and EPA personnel, a 1-day workshop taught by Laura Brophy was held in May 2010. USGS and EPA staff visited three tidal wetlands in the Yaquina estuary, representing a range of salinity regimes. Workshop training provided the foundation for subsequent large-scale estuarine vegetation surveys conducted by the USGS and EPA during 2010 in four coastal estuaries in Oregon.

Data Processing Steps

In February 2010, NWI shapefiles for the Yaquina drainage basin were downloaded from the NWI website (U.S. Fish and Wildlife Service, 2010) and merged into one data layer by EPA. In April 2010, NWI shapefiles for the Alsea Bay drainage basin were downloaded from the NWI website and merged into one data layer by Green Point Consulting. Metadata for these NWI data list the date of the source imagery as “1977 to present”. The NWI data layers were then processed in the following ways:

1. **LiDAR Analysis:** LiDAR-derived elevation data (Watershed Sciences, Inc., 2009) were used to select NWI polygons within tidal range. Details on this process are provided in section, “LiDAR Analysis”.
2. **NWI Wetland Classification:** The Cowardin et al. classification for each NWI polygon within tidal range was reviewed and revised where necessary, based on the LiDAR-derived elevation, 2009 aerial photography, salinity data provided by EPA, and field knowledge of the Yaquina and Alsea estuaries. Recommended revisions cover the Cowardin et al. system, subsystem, and class levels, hydrologic modifiers, and special modifiers. Details on this process are provided in section, “NWI Wetland Classification”.
3. **Creation of GIS data for 1999 tidal wetland prioritization:** NWI polygons were merged to form a GIS layer of the prioritization sites defined in Brophy (1999). The wetland characteristics determined in 1999 were attributed to these prioritization sites. The LiDAR Digital Elevation Model (DEM), 2005 aerial photography, and field knowledge were used to identify any major changes that had occurred since 1999; these changes were attributed to the prioritization sites in the GIS data. Through the use of the new LiDAR data and 2009 aerial photography, several new prioritization sites were identified and attributed. Details on this process are provided in section, “Creation of GIS Data for 1999 Tidal Wetland Prioritization”.

LiDAR Analysis

LiDAR-derived elevations were obtained from the “bare earth” digital elevation model developed for the Oregon LiDAR Consortium by Watershed Sciences, Inc. (Watershed Sciences, Inc., 2009; Oregon Department of Geology and Mineral Industries, 2012). Standard (not water-penetrating) airborne LiDAR equipment was used. Data acquisition was not timed for low tide, but for this study area, all ground surfaces critical to the analysis (that is, surfaces above Mean Higher High Water) were above water in the LiDAR data. The vertical accuracy of the LiDAR data was 0.11 ft, determined through Real Time Kinematic ground survey on road surfaces, compared to the closest laser point (Watershed Sciences, Inc., 2009). Average laser pulse density was 0.80 per ft² (Watershed Sciences, Inc., 2009).

The LiDAR analysis focused on the upper limit of tidal influence, since NWI mapping of habitat classes lower in the tidal range (that is, low marsh, mud flat, aquatic bed) appeared to be accurate. To determine the upper limit of tidal influence, LiDAR derived elevations were analyzed to determine the percentage of each NWI polygon that occurred within three elevation zones (table 2).

Table 2. Elevation zones used for LiDAR analysis (elevations in feet (ft) NAVD88), Yaquina and Alsea estuaries, Oregon.

Elevation zone	Yaquina estuary	Alsea estuary
1. Tidally inundated year-round	<9 ft	<8 ft
2. Seasonally inundated by combined tidal and fluvial flows	9–11 ft	8–11 ft
3. Potential tidal wetland	11–13 ft	11–13 ft

These elevation ranges were developed by reviewing tidal datums for the two estuaries (table 3) and comparing those datums to field knowledge of the Yaquina and Alsea estuaries gained during multiple projects (Brophy, 1999, 2003, 2004, 2006, 2009; Brophy and Christy, 2008, 2009, 2010; Brophy and others, 2011).

Table 3. Tidal datums for the Yaquina and Alsea estuaries, Oregon.

[MLLW= Mean Lower Low Water; MHHW= Mean Higher High Water; HMT=Highest Measured Tide.]

Source	Yaquina estuary			Alsea estuary		
	MLLW	MHHW	HMT	MLLW	MHHW	HMT
National Oceanographic Atmospheric Administration (2012)	-0.7	7.6	11.5	n/a	n/a	n/a
Brew and others (2007)	-0.7	7.6	n/a	-0.22	7.5	n/a
Buckley (2006)	-0.8	8.2–8.8 ¹	12.3	n/a	6.5	10.7
Hamilton (1984) ²	-0.6	7.7	11.7	0.0	7.7	12.0

¹ Where a range of values is provided, the range includes all locations within the specified estuary, as provided by the source at left. The entry “n/a” indicates the value was not provided relative to the NAVD88 geodetic datum.

² Hamilton (1984) provides elevations relative to the NGVD29 or NGVD29(47) datum. Elevations relative to the NAVD88 datum were determined by applying the elevation adjustments at http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl.

The elevation zones defined in table 2 were deliberately broad to reflect the range of published values in table 3 and the limited number of field studies of inundation regimes in the Yaquina and Alsea estuaries. Because this analysis focused on the upper limits of tidal influence, the elevation zones in table 2 did not subdivide elevations below Mean Higher High Water (MHHW).

The elevation zones in table 2 extended well above MHHW for several reasons: First, studies have documented that brackish high marsh and brackish to freshwater tidal swamps (scrub-shrub and forested tidal wetlands) in Oregon generally are found at elevations well above MHHW. For example, at the Bandon Marsh National Wildlife Refuge in the Coquille River estuary, the elevation of a forested tidal wetland in the lower estuary (bay fringe) was 8.2 ft NAVD88, which is 1.2 ft above MHHW

(Brophy and van de Wetering, 2012). At a strongly fluvial site in the Siuslaw River estuary, the elevation of a freshwater tidal wetland was 8.6 ft NAVD88 (1.5 ft above MHHW); model simulations showed that this site is tidally inundated about 2 percent of the time during typical months of December and January (Brophy, 2009). Second, inundation at these high tidal wetlands is the product of both tidal forces and river flows (fluvial forces). As indicated in table 2, inundation in elevation zone 2 is primarily seasonal. Combined tidal and fluvial inundation occurs more often in winter when river flows are high (Brophy, 2009; Brophy and others, 2011). The contribution of river flow to tidal amplitude is particularly strong in the middle and upper estuary where river valleys are more confined (Brophy, 2009; Brophy and others, 2011; Huang and others, 2011). Model simulations have not yet fully explored the highest potential elevations of this combined fluvial-tidal inundation.

Finally, dense vegetation may interfere with the LiDAR signal, resulting in “bare earth” elevations that are higher than the actual ground surface elevation (Gopfert and Heipke, 2006). This effect is particularly pronounced in the freshwater tidal zone (upper estuary) in dense monotypic stands of slough sedge (*Carex obnupta*) and reed canarygrass (*Phalaris arundinacea*) (Brophy and van de Wetering, 2012).

Land surfaces within the lowest elevation zone (<8 ft for the Alsea estuary, <9 ft for the Yaquina) are clearly tidal wetlands, based on information from previous studies (Brophy, 2009; Brophy and others, 2011), tidal datums (table 3), and data provided by EPA. For example, EPA analysis of National Oceanic and Atmospheric Administration (NOAA) tidal height records from 2004 to 2008 show that in the lower Yaquina estuary, wetlands at 9.0 ft NAVD88 (1.4 ft above MHHW) are submerged by tidal waters at least once per month year-round (J. Stecher and C. Janousek, unpub, data, 2011). The next elevation range (8–11 ft for the Alsea, 9–11 ft for the Yaquina) includes land surfaces likely to experience tidal inundation during winter, or in spring and fall during spring tide cycles or high river flows. The top elevation range (11–13 ft) covers the range of NOAA values for HMT (Highest Measured Tide) recorded at NOAA’s local tidal stations and therefore includes potential waters of the State, as either Tidal Waters (*OAR 141–085–0515(2)*) or wetlands (*OAR 141–085–0510(97)*), as described in Oregon administrative rules. However, this higher range was not used in our final analysis, as tidal wetlands in the Yaquina and Alsea estuaries generally occurred below this elevation range.

To determine the percentage of each NWI polygon that occurred within the elevation zones in table 2, the NWI data were first reprojected to Oregon Statewide Lambert NAD83 HARN to match the projection of the LiDAR-derived elevation datasets. The LiDAR raster dataset (DEM) for each estuary was then reclassified using Environmental Systems Research Institute (ESRI) Spatial Analyst to create two new discrete raster datasets: Dataset 1: Value of 1 = <9 ft (Yaquina) or <8 ft (Alsea), value of 0 = other elevation; Dataset 2: Value of 1 = 9–11 ft NAVD88 (Yaquina) or 8–11 ft (Alsea), value of 0 = other elevation. The NWI polygons were then intersected with these two discrete raster datasets using the “Isectpolyrst” command with proportion = TRUE in the ArcMap Geospatial Modeling Environment. This created a new attribute in the NWI layer showing the percent of each NWI polygon with a value of 1 or 0 for each of the two elevation classes (<8 ft *versus* 8–11 ft for the Alsea; <9 ft *versus* 9–11 ft for the Yaquina).

NWI polygons with more than 25 percent of their area in these two elevation zones were compared to aerial photographs, field knowledge of the estuaries, and data from other studies (Brophy, 2003, 2004, 2007b, 2007c, 2009; Brophy and Christy, 2008, 2009; Brophy and others, 2011). The 25 percent threshold was based on these studies and data from other Oregon estuaries (Brophy and van de Wetering, 2012), and allowed for potential vegetation interference with the LiDAR signal as well as the fluvial contribution to water levels previously described. NWI polygons, which were considered very likely to be current or former tidal wetlands (based on aerial photograph interpretation, field knowledge,

and other data), were selected and the appropriate Cowardin et al. classification was assigned (see section, “Wetland Classification”). The selected NWI polygons were then merged (Editor/Merge tool in ESRI ArcMap) to form the Prioritization Sites identified in the 1999 Yaquina and Alsea River Basins Estuarine Wetland Site Prioritization (Brophy, 2009) (see section, “Creation of GIS Data for 1999 Tidal Wetland Prioritization”).

For extensive tide gated lands like Boone Slough, Nute Slough, Depot Slough, and Olalla Slough in the Yaquina estuary, few visual indicators remain of former tidal status. Substantial portions of these tide gated lands are within the <9 ft and 9–11 ft elevation zones, but are classified in the NWI as upland; however, these were very likely tidal wetlands prior to construction of the tidal flow barriers. A separate procedure to map these likely former tidal wetlands was developed to assist planning for future restoration projects (see section, “Likely Former Tidal Wetlands Classified as Upland in the NWT”).

As in the 1999 prioritization (Brophy, 1999), lands that have been filled and converted to developed uses were excluded from this study, even if they were within tidal range. Examples include the former log storage yard at the Siletz Tribes mill just downstream of Mill Creek, on the northern bank of the Yaquina River, and industrial lands on the banks of the Yaquina in the city of Toledo.

Wetland Classification

Expert knowledge of the Yaquina and Alsea estuaries, LiDAR-derived elevations, salinity data provided by EPA, and recent aerial photographs were used to determine the correct Cowardin et al. system, subsystem, class, hydrologic modifiers, and special modifiers for each NWI polygon identified as a tidal wetland using the methods described in the “LiDAR Analysis” Section. For consistency, these revisions followed the same definitions of wetland systems, subsystems, and classes used in the NWI (Cowardin et al. 1979). The elevation zones in table 1 were not used to classify the wetlands; they were used only for the previously described LiDAR analysis.

The highest-resolution aerial photographs available at the time of this study were color infrared photographs acquired jointly by Department of Land Conservation and Development (DLCD) and EPA during 2004–06 (Oregon Department of Land Conservation and Development and others, 2007a, 2007b). These images had 0.25 m ground pixel resolution. The DLCD-EPA imagery was supplemented by 2005 true color NAIP imagery (digital ortho quarter-quads, 0.5 m ground pixel resolution). Photograph interpretation was used to identify tidal channels, brackish *versus* freshwater vegetation, topographic transitions, developed lands, dikes, restrictive culverts, and tide gates, and other features that helped distinguish between tidal wetlands and nontidal wetlands or uplands, and to provide other information needed for wetland classification. Recommended classifications also drew on other field studies of tidal wetlands in the Yaquina, Alsea, and other Oregon estuaries (Brophy, 2003, 2004, 2007b, 2007c, 2009, 2012; Brophy and Christy, 2008, 2009, 2010; Brophy and others, 2011), and salinity data provided by EPA (C. Brown and C. Janousek, written commun, 2011).

Estuarine versus Palustrine System (salinity regime)

Wetlands with salinity equal to or greater than 0.5 (originating from marine salts) during low flow (summer and early fall) are classified in the Cowardin et al. system as estuarine wetlands (Cowardin et al. 1979). Tidal wetlands with salinities less than 0.5 (freshwater tidal wetlands) are classified as palustrine wetlands, and are assigned a “water regime modifier” to indicate tidal influence.

Cheryl Brown of EPA provided a shapefile containing salinity data for the Yaquina estuary originating from many sources (more than 8,000 data points originating from EPA and the Oregon Department of Environmental Quality). Almost all measurements were on the main stem river, but

sampling depth was variable (Cheryl Brown, written commun., 2011). Despite the NWI's classification of tidal wetlands as palustrine upstream of river mile 14, these data showed late summer and early fall salinities in the range of 5–10 as far upstream as river mile 19.5, near the upstream limit of tidal wetlands in the estuary. Therefore, only very limited areas were classified as palustrine, tidally influenced wetlands. Additional data from upper Poole Slough on the Yaquina likewise revealed that other wetlands designated as palustrine tidal in the NWI are actually brackish habitats (C. Janousek and C. Folger, unpub. data, 2011).

For the Alsea estuary, data from previous field studies (Brophy, 2003, 2006; Brophy and Christy, 2008, 2009, 2010) were used to determine which wetlands should be classified in the estuarine system *versus* the palustrine system. Field observations of vegetation were the primary means for this classification; dominance by brackish-tolerant species (based on field knowledge and Adamus, 2005) indicated wetlands that should be placed in the estuarine system.

Salinity in a tidal wetland may differ from salinity in the adjacent tidal water body. For example, a forested tidal wetland near the hillslope base may have much lower salinity than the nearby tidal river because of freshwater drainage from the nearby uplands (Brophy, 2009; Brophy and van de Wetering, 2012). Where specific field data were not available, the aerial photographs (previously described) were used to help determine estuarine versus palustrine classification. Reed canarygrass (*Phalaris arundinacea*) (fig. A14) and red alder (*Alnus rubra*) (figs. A15–A16) are two species that are identifiable in aerial photographs and do not tolerate much salinity, based on our field experience and Adamus (2005). Aerial photographs were used to identify tidal wetlands that were dominated by these species, and these areas were classified as tidally influenced palustrine wetlands.

Cowardin et al. (1979) Classification Modifiers

Water regime (hydrologic) modifiers and special modifiers were included in our recommended Cowardin et al. classifications. Although the mapping standard used by the NWI does not require special modifiers for estuarine habitats (Federal Geographic Data Committee, 2009), the special modifiers we have provided in our mapping contain crucial information and should therefore be retained. Modifiers were used according to the definitions provided in Cowardin et al. (1979).

Water Regime Modifiers

When the Cowardin et al. classification is applied to Oregon estuaries, low salt marsh generally is assigned the “N” modifier, which is defined as “regularly flooded” (“tidal water alternately floods and exposes the land surface at least once daily”) (Cowardin et al. 1979, p. 21), and high estuarine marsh is generally assigned the “P” modifier, which is defined as “irregularly flooded” (“tidal water floods the land surface less often than daily”) (Cowardin et al. 1979, p. 21). In general, the water regime modifiers for wetlands already classified as estuarine in the NWI were not revised, because they were fairly accurate. However, “irregularly flooded” is not an accurate description of the high marsh inundation regime. Field measurements and model simulations indicate that high marsh is in fact regularly flooded, although much less often than low marsh. The typical pattern is inundation during higher high tides on spring tide cycles, once or twice a month (Brophy, 2009; Brophy and others, 2011). For NWI polygons that were classified as palustrine but the correct classification was estuarine (based on salinity data, as previously described), the “N” and “P” modifiers were applied as appropriate, based on elevation and our knowledge of the specific location. Estuarine scrub-shrub and estuarine forested wetlands (E2SS and E2FO) were assigned the “P” modifier, because in our study area these wetland types generally do not flood daily.

For tidally influenced palustrine wetlands, the Cowardin et al. classification offers the same hydrologic regime modifiers used in nontidal systems, but with the word “tidal” added: R = seasonally flooded (tidal), S = temporarily flooded (tidal), T = semipermanently flooded (tidal), and V = permanently flooded (tidal). These modifiers are not well-suited to the observed flooding regimes in freshwater tidal wetlands of Oregon. Regular flooding of tidally influenced palustrine wetlands has been documented during spring tide cycles throughout the year, with more frequent flooding during high winter flow periods (Brophy, 2007b, 2009; Brophy and others, 2011). Given limited classification options, the best-suited hydrologic modifier from the Cowardin et al. system (seasonally flooded (tidal)) was used for all tidally influenced palustrine wetlands in our study areas.

Special Modifiers

Special modifiers generally describe wetland alterations. These modifiers were applied based on local knowledge and aerial photograph interpretation. As previously described, these modifiers contain crucial information and should not be viewed as optional in the revised NWI classification, although the NWI mapping standard does not require their use (Federal Geographic Data Committee, 2009).

Former tidal wetlands behind dikes, tide gates, and restrictive culverts should be classified in the NWI as diked wetlands (modifier “h”). However, many of these areas lack the “h” modifier in existing NWI mapping. In some cases, this may be because of the NWI’s reliance on remote data. Field work is often needed to identify hydrologic alterations, especially restrictive culverts and tide gates.

Identifying lands protected by dikes was of critical importance for the USGS climate change project modeling efforts targeted at identifying potential estuarine habitats at risk to sea-level rise. In an analysis of elevation ranges for NWI classes, lands behind dikes without the “diked” modifier created an artificially low elevation range for some wetland classes (D. Reusser and R. Loiselle, unpub. data, 2012).

The diked modifier was added to all NWI polygons which were considered likely to be former tidal wetlands with hydrology affected by dikes, tide gates, or restrictive culverts (identified using LiDAR-derived elevations, aerial photographs, and expert local knowledge of the estuaries). The polygons to which the diked modifier was applied were at low elevations (usually below 8 or 9 ft relative to MLLW), and were located behind (landward of) the dikes, tide gates, and restrictive culverts. In major tributary and slough systems like Boone Slough, Nute Slough, Depot Slough, and Olalla Slough, some of these polygons were located at a considerable distance from the dike or tidal restriction. Nevertheless, use of the diked modifier seemed appropriate because elevations generally were low, and these large slough systems were likely to have had strong tidal forcing prior to alteration.

Likely Former Tidal Wetlands Classified as Upland in the NWI

In the major diked tributaries of the Yaquina estuary—Boone Slough, Nute Slough, Depot Slough, and Olalla Slough—low-elevation land surfaces were extensive and were classified as upland in the NWI. These lands generally were less than 9 ft NAVD88. Similar low-elevation lands classified as upland in the NWI were identified in the middle and upper Alsea estuary. It seems likely that these were once tidal wetlands. However, the hydrology is currently altered by tide gates and extensive ditching and diking, so field investigation would be needed to determine whether these low-elevations lands are currently wetlands, and if so, their correct Cowardin et al. classification. We added these low-lying former tidal wetlands to the Enhanced NWI maps by cutting the upland polygon at an elevation of 11 ft NAVD88 based on the LiDAR data, using Editor/Split in ArcMap. An 11 ft elevation cutoff was used for consistency with the previously described LiDAR analysis (table 2). In lieu of a Cowardin et al. classification, the code FTW (Former tidal wetland) was assigned to these polygons, with the note

“likely former tidal wetland/tidal waters of the State.” The former tidal wetland polygons also were added to the Prioritization Sites by merging them with the adjacent NWI polygons, as described in section, “Creation of GIS Data for 1999 Tidal Wetland Prioritization Sites”.

Creation of GIS Data for 1999 Tidal Wetland Prioritization Sites

As described in section, “Project Goals and Objectives”, one goal of this study was to generate GIS data (shapefiles) for the prioritization sites defined in the 1999 tidal wetland prioritization for the Yaquina and Alsea estuaries (Brophy, 1999) and characterize any major changes at the prioritization sites since 1999. The 1999 study identified and characterized current and likely former tidal wetlands in the Yaquina and Alsea estuaries, and divided the wetlands into 78 sites suitable for action planning purposes (43 in Yaquina, 35 in Alsea). These sites are referred to as prioritization sites in this report. The 1999 study then used ecological criteria to prioritize these 78 sites for conservation and restoration activities. Paper maps of the approximate locations of the 78 prioritization sites were provided with the 1999 report, but no GIS data were produced. The current project updated the 1999 study by providing GIS layers of the prioritization sites. The 1999 project and the current study are intended for use in strategic planning of voluntary conservation and restoration efforts; note however, that these products are not intended for regulatory use (Brophy, 1999). Consistent with the Oregon Estuary Assessment method (Brophy, 2007a), the 1999 study and the current study included emergent, scrub-shrub, and forested wetlands, but algal beds, seagrass beds, and mudflats were not included.

GIS mapping and characterization of prioritization sites for the current study drew upon many data sources. Primary data sources were the LiDAR-derived elevations, NWI maps, and aerial photographs previously described. Other data included mapping of tidal wetlands and potential tidal wetlands provided by Scranton (2004), historical vegetation data, other GIS and tabular data sources, and expert local knowledge of the two estuaries derived from previous field studies ((Brophy, 2003, 2004, 2007b, 2007c, 2009; Brophy and Christy 2008, 2009; Brophy and others, 2011).

The Oregon Watershed Assessment Manual, Estuary Assessment module (Brophy, 2007a) describes in detail how prioritization sites are created. Because individual NWI polygons are too small and numerous, they were merged to form larger analysis units based on hydrology, alterations, and land use history (fig. 3). These units (prioritization sites) are suitable for planning wetland restoration and conservation actions at the basin scale. In some cases, a prioritization site consisted of a single NWI polygon. However, in a few cases NWI polygons were split because of differences in the level of habitat alteration within a single polygon. Details on methods for defining prioritization sites are described in Brophy (2007a). The availability of LiDAR-derived elevations and recent aerial photography enabled identification of several new prioritization sites that had not been identified in the 1999 study (see section, “New Prioritization Sites Added to 1999 Study”). New prioritization sites were created only if the underlying NWI polygons totaled more than 1 acre.

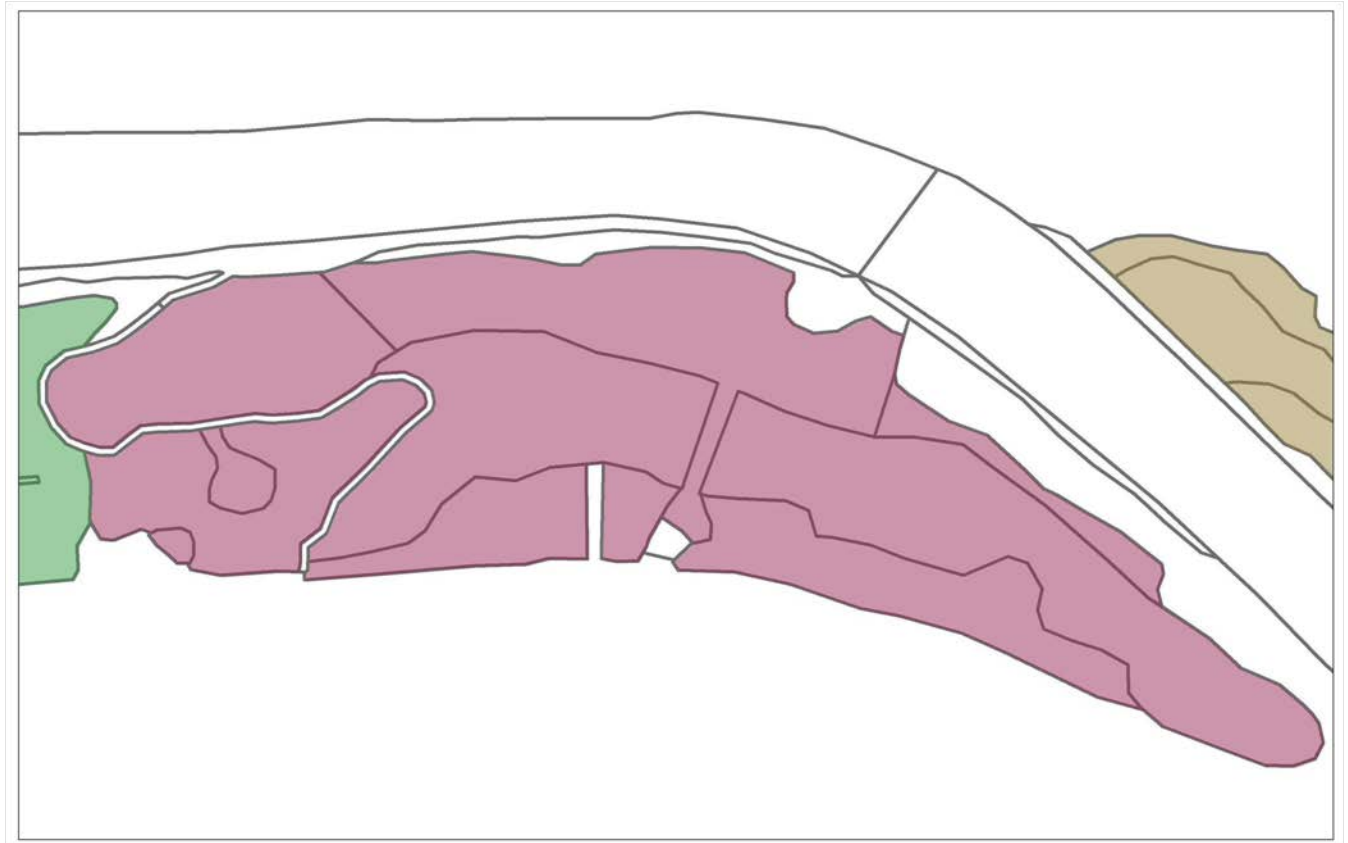


Figure 3. Illustration of the relationship between prioritization site designation and National Wetland Inventory polygons. In this example from the Alsea estuary, Oregon, the pink shaded area is a single prioritization site (Site A21 in fig.7) composed of 12 underlying NWI polygons (dark pink outlines). The NWI polygons were merged to form the prioritization site, based on their similar alteration level, land use history, and hydrologic connectivity. NWI polygons outside the pink prioritization site are non-tidal wetlands or wetlands in tidal wetland classes not included in this study (brown and green shaded areas plus the white river channel); or uplands (white areas at edges of figure).

Action planning for wetland restoration and conservation requires knowledge of conditions such as habitat alterations, dominant vegetation, land use, and potential restoration actions. The 1999 prioritization for the Yaquina and Alsea estuaries (Brophy, 1999) provided this information for each prioritization site in spreadsheet format. These prioritization site characteristics (table 2) were transferred as attributes to the GIS data generated in this project. In addition, major changes in prioritization site conditions since 1999 were identified through interpretation of the LiDAR data and aerial photographs, and by incorporating expert local knowledge, as previously described. These changes were listed as attributes in the prioritization site GIS shapefiles (attributes 8, 11, 13, 16, 18, 20, and 22 in table 4).

Table 4. Table of attributes for GIS layer of prioritization sites to accompany 1999 tidal wetland prioritization.

[Note: the value “n/a” for any attribute indicates that field was not used in the 1999 report.]

Attribute number	Attribute name	Description
1	FID	Feature ID (generated by ArcMap)
2	Shape	Feature type (generated by ArcMap)
3	GPC_site	GPC site number
4	Area_acres	Site size (acres)
5	Site_name	Name of site (if any)
6	TRS	TRS location (Township, Range, Section)
7	Descrip99	General description of wetland conditions and location (1999 data)
8	Descr2010	General description of wetland conditions and location in 2010 (if different from 1999)
9	Own_num99	Approximate number of landowners (1999 data)
10	Veg_typ99	Vegetation description, using classification from Oregon Estuary Plan Book (Cortright and others 1987) (1999 data). Dominant species listed where possible, based on field observation.
11	Veg_2010	Vegetation description in 2010 (if different from 1999), using classification from Oregon Estuary Plan Book (Cortright and others 1987). Dominant species listed where possible, based on field observation.
12	Alter99	Alteration type(s) (1999 data)
13	Alt2010	Alteration type(s) in 2010, if different from 1999
14	Altdate99	Date of alteration, determined from historic aerial photographs (1999 data)
15	Action99	Possible restoration actions (1999 data)
16	Actn2010	Possible restoration actions in 2010 (if different from 1999)
17	LandUse99	Current land use (1999 data)
18	LndUs2010	Current land use in 2010 (if different from 1999 data)
19	LandAdj99	Adjacent land use (1999 data)
20	LndAdj10	Adjacent land use in 2010 (if different from 1999)
21	Stream99	Connections to streams (1999 data)

Attribute number	Attribute name	Description
22	Strm2010	Connections to streams (2010, if different from 1999 data)
23	Expert991	Comments from experts, part 1 (1999 data)
24	Expert992	Comments from experts, part 2 (1999 data)
25	Nxtstp991	Recommended next steps for action planning for wetland restoration/conservation, part 1 (1999 data)
26	Nxtstp992	Recommended next steps for action planning for wetland restoration/conservation, part 2 (1999 data)
27	Reprts991	Other reports that mention the site, part 1 (1999 data) – see full report (Brophy, 1999) for key to abbreviations
28	Reprts992	Other reports that mention the site, part 2 (1999 data) – see full report (Brophy, 1999) for key to abbreviations
29	GIS_2010	Notes on creation of GIS layer in 2010

Results

Recommended Revisions to Cowardin et al. (1979) Classification

The enhanced NWI shapefiles contain recommended revisions to the Cowardin et al. classification (system, subsystem, class, and/or modifiers) for 286 NWI polygons in the Yaquina estuary (1,133 acres) and 83 NWI polygons in the Alsea basin (322 acres) (figs. 4 and 5). Many of the changes consisted of adding the “diked” modifier to diked former tidal wetlands that are currently palustrine wetlands. For example, PEMC was changed to PEMCh for 514 acres in the Yaquina estuary, and PEMA was changed to PEMAh for 32 acres in the Alsea estuary (tables 5 and 6). Other common changes were the addition of a tidally influenced hydrologic modifier to palustrine wetlands, and a change from the palustrine to the estuarine class based on field measurements of salinity data. Substantial acreages of likely former tidal wetland were identified that are currently classified as upland in the NWI (tables 5 and 6; see section, “Likely Former Tidal Wetlands Classified as Upland in the NWI”)

Likely Former Tidal Wetlands Classified as Upland in the NWI

Analysis of LiDAR data revealed many likely former tidal wetlands that were classified as upland in the National Wetlands Inventory (64 NWI polygons totaling 441 acres in the Yaquina estuary, and 16 NWI polygons totaling 51 acres in the Alsea estuary) (figs. 4 and 5; tables 5 and 6). Cowardin et al. classification of these former tidal wetlands was beyond the scope of this project because field evaluation would have been needed to determine the hydrologic status of these areas.

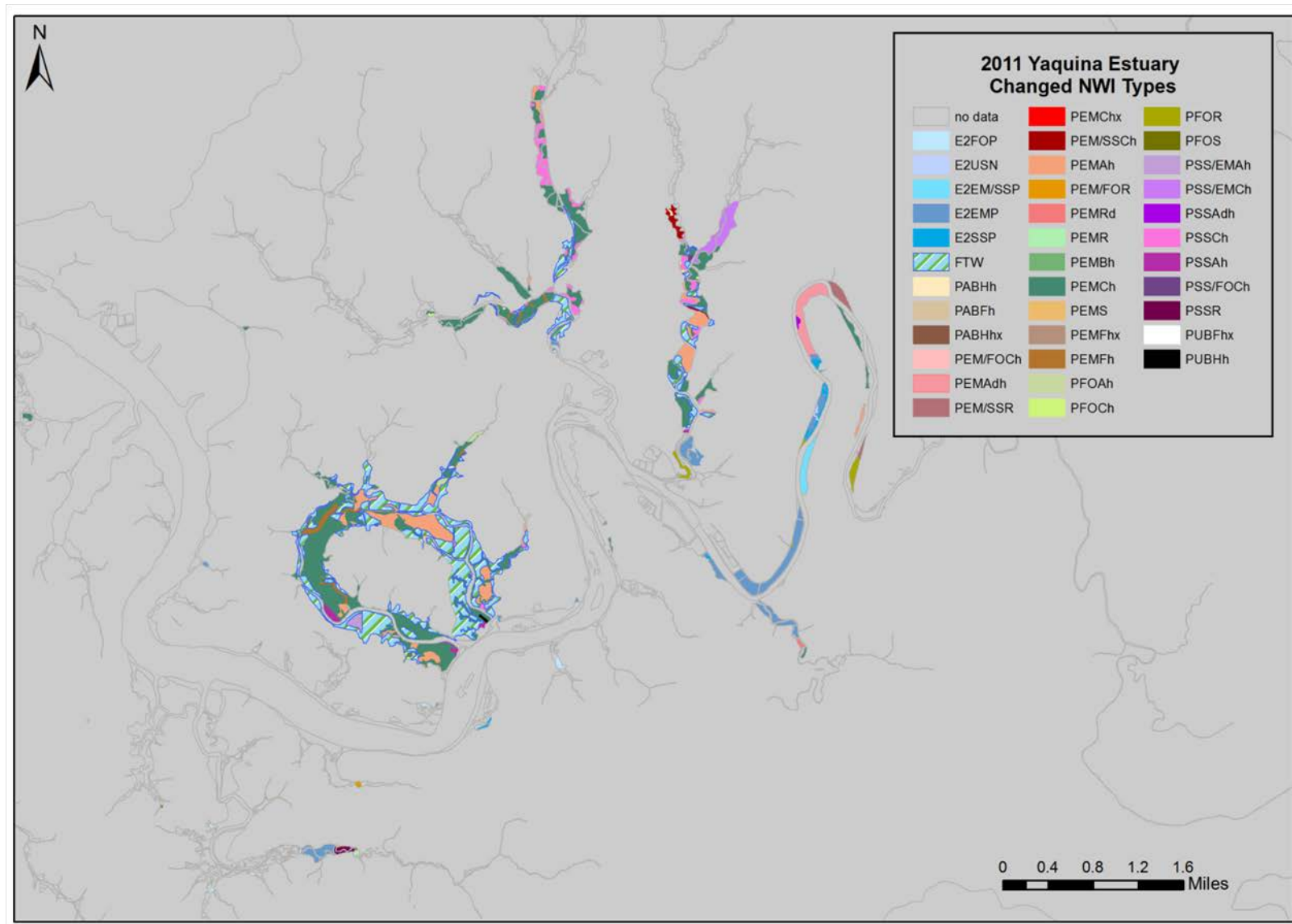


Figure 4. Map of recommended National Wetland Inventory Cowardin et al. (1979) classification revisions resulting from this project for the Yaquina estuary, Oregon, including areas identified as likely former tidal wetlands ("FTW"). NWI polygons without recommended revisions are shown as outlines only (fill=background color). Source data: Table 7-Yaquina_tidal_NWI_2011. Projection: UTM Zone 10N NAD83.

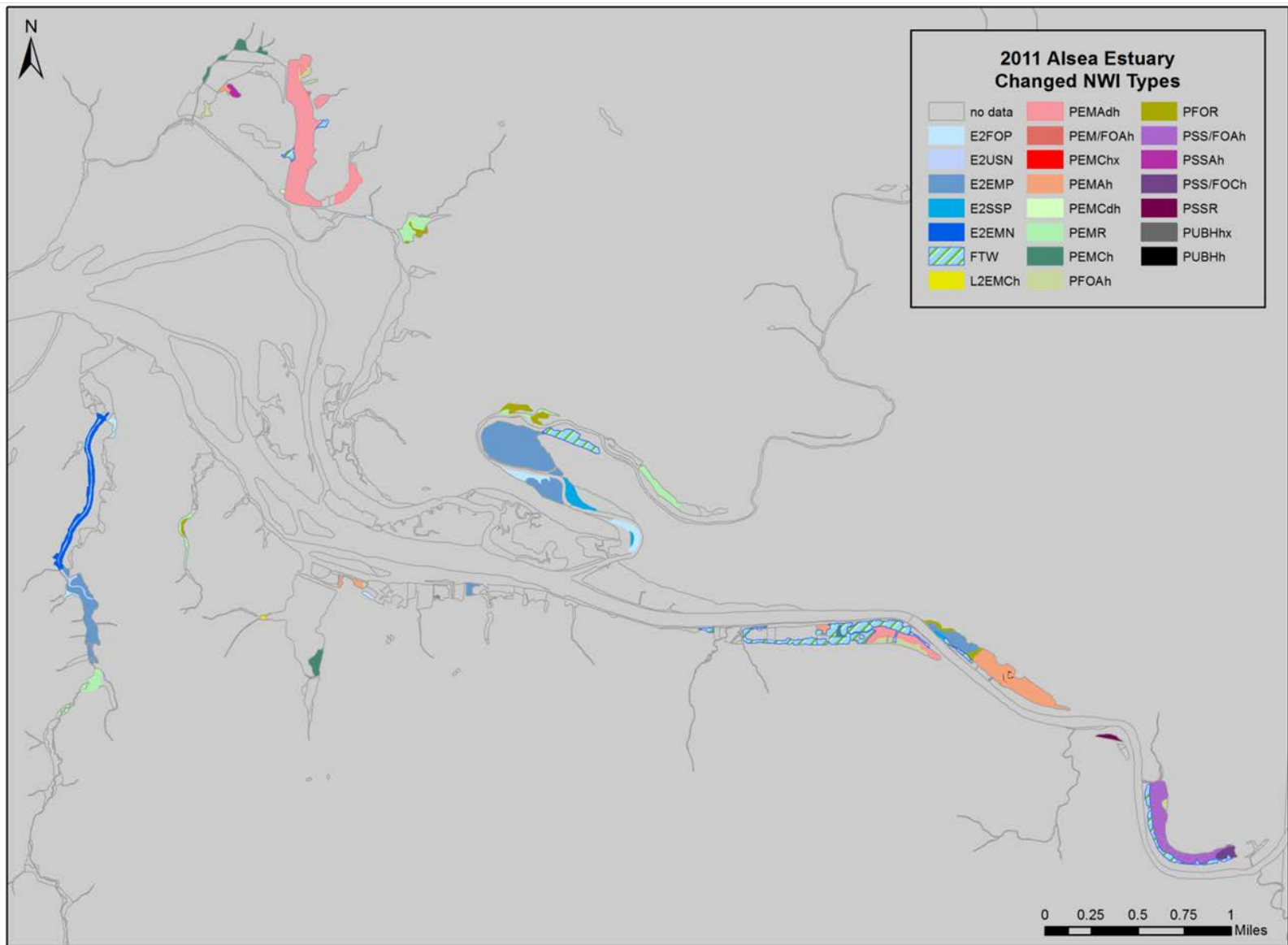


Figure 5. Map of recommended National Wetlands Inventory Cowardin et al. (1979) classification revisions resulting from this project for the Alsea estuary, Oregon, including areas identified as likely former tidal wetlands (“FTW”). NWI polygons without recommended revisions are shown as outlines only (fill=background color). Source data: Table 7-Alsea_tidal_NWI_2011. Projection: UTM Zone 10N NAD83.

Table 5. Total area (acres) of recommended changes to NWI Cowardin et al. classification, by original NWI classification. Yaquina estuary, Oregon.

[Table includes only those original and revised classifications that totaled more than 1 acre]

		Recommended revised Cowardin et al. classification (or other designation*): area in acres																				
		E2EM/SSP	E2EMP	E2FOP	E2SSP	FTW ¹	PABF	PEM/SSch	PEM/SSR	PEMAdh	PEMAh	PEMCh	PEMFh	PFOAh	PFOR	PSS/EMAh	PSS/EMCh	PSSAh	PSSCh	PSSR	Total	
Original NWI classification	PABF						5.8														5.8	
	PEM/SSA								15.9												15.9	
	PEM/SSC	18.1						14.3													32.4	
	PEMA		4.0							38.9	170.1	10.1									227.4	
	PEMAh		19.5																		19.5	
	PEMC		3.3									514.3									518.0	
	PEMCd		46.3																		46.3	
	PEMF												21.3								21.3	
	PEMR		49.3									1.1									51.2	
	PFOA			1.8										6.4	16.1						24.6	
	PFOC			2.4											0.4						5.7	
	PSS/EMA															8.8					8.8	
	PSS/EMC																36.6				36.6	
	PSSA				9.0														10.9		6.1	27.8
	PSSC																			60.3	60.3	
	PSSR				3.8															2.9		6.7
	U		1.8			441.0																442.8
		Total	18.1	128.2	5.5	13.5	441.0	5.8	14.3	15.9	38.9	170.1	525.5	21.3	6.4	16.8	8.8	36.6	10.9	63.2	6.1	1574.4

¹FTW is not a Cowardin et al. classification, but a designation indicating a likely Former Tidal Wetland, currently disconnected from tidal flow but with land surfaces at elevations within tidal range.

Table 6. Total area (acres) of recommended changes to NWI Cowardin et al. classification, by original NWI classification. Alsea estuary, Oregon.

[Table includes only those original and revised classifications that totaled more than 1 acre]

		Recommended revised Cowardin et al. classification (or other designation*): area in acres																
		E2EMN	E2EMP	E2FOP	E2SSP	E2USN	FTW ¹	PEMAdh	PEMAh	PEMCh	PEMR	PFOAh	PFOR	PSS/ FOAh	PSS/ FOCh	PSSAh	PSSR	Total
Original NWI classification	PEMA		21.8						31.8		13.2							66.8
	PEMAd							75.3										75.3
	PEMC		2.7							9.9	4.5							17.1
	PEMCh										7.3							7.3
	PEMR		51.3															51.3
	PEMS		8.3															8.3
	PFOA			1.5								10.5						12.0
	PFOB			1.7														1.7
	PFOCh												2.4					2.4
	PFOR			4.4														4.4
	PSS/FOA													24.3				24.3
	PSS/FOC														3.2			3.2
	PSSA												1.5			1.8	1.9	5.2
	PSSR				6.6													6.6
	R1UBV					2.2												2.2
	R1UBVh					5.9												5.9
	U	12.5		4.5	0.6			51.0						6.3				
	Total	12.5	84.1	12.9	7.2	8.0	51.0	75.3	31.8	9.9	24.9	10.5	11.0	24.3	3.2	1.8	1.9	373.0

¹FTW is not a Cowardin et al. classification, but a designation indicating a likely Former Tidal Wetland, currently disconnected from tidal flow but with land surfaces at elevations within tidal range.

GIS Data for 1999 Prioritization Sites

GIS datasets were created for the 1999 prioritization sites as well as for several new prioritization sites in each estuary (figs. 6 and 7). The GIS datasets contain 49 prioritization sites totaling 2,177 acres in the Yaquina estuary, and 39 prioritization sites totaling 1,045 acres in the Alsea estuary. The prioritization sites consisted of 494 and 192 underlying NWI polygons in the Yaquina and Alsea estuaries, respectively.

New Prioritization Sites

Previously described LiDAR-derived elevations and NWI classification analysis allowed us to identify tidal wetlands (or former tidal wetlands) that had not been described in the 1999 study. In most cases, these tidal wetlands were already classified as wetlands in the NWI, but they were not previously classified as tidal wetlands nor did they have special modifiers suggesting hydrologic alterations that would restrict tidal flows. In two cases, new sites were identified that were classified as upland in the NWI, but which were at elevations within tidal range. These two cases were prioritization sites A38 and A40, on land owned by U.S. Forest Service (USFS) and U.S. Bureau of Land Management (BLM), near the Drift Creek tidal wetland restoration project (prioritization site A26) (fig. 7). LiDAR data were used to digitize new prioritization site boundaries using the methods described in section, “Likely Former Tidal Wetlands Classified as Upland in the NWI”.

The new prioritization sites in each estuary are listed, with approximate acreages. *Field visits by a knowledgeable wetland scientist are recommended to determine the state and federal regulatory status of these areas.*

- Yaquina estuary: New prioritization sites (fig. 6)
 - Site Y44 (7 acres): Partially filled forested tidal wetland at the mouth of Olalla Slough.
 - Site Y45 (13 acres): Diked pasture in the upper estuary, probably former tidal swamp.
 - Site Y46 (4 acres): Diked pasture in the upper estuary, probably former tidal swamp.
 - Site Y47 (12 acres): Undiked tidal swamp (forested and scrub-shrub tidal wetland) in the upper estuary.
 - Site Y48 (2 acres): Fringing marsh on south bank of the Yaquina River, just upstream of site Y3.
 - Site Y49 (3 acres): Undiked tidal marsh just outside the tide gates on Depot Slough.
- Alsea estuary: New prioritization sites (fig. 7)
 - Site A38 (8 acres): Tidal marsh and tidal swamp (forested tidal wetland) on the northern bank of Drift Creek at river mile 2. This is a USFS restoration site.
 - Site A39 (6 acres): Freshwater tidal marsh (probably former tidal swamp) at river mile 3 on Drift Creek.
 - Site A40 (9 acres): Forested tidal wetland or former tidal wetland, immediately east of the large USFS tidal marsh restoration area on Drift Creek. A site visit or information from USFS is needed to determine the current hydrologic status.
 - Site A41 (2 acres): Small possible tidal swamp opposite mouth of Risley Creek and Bain Slough.

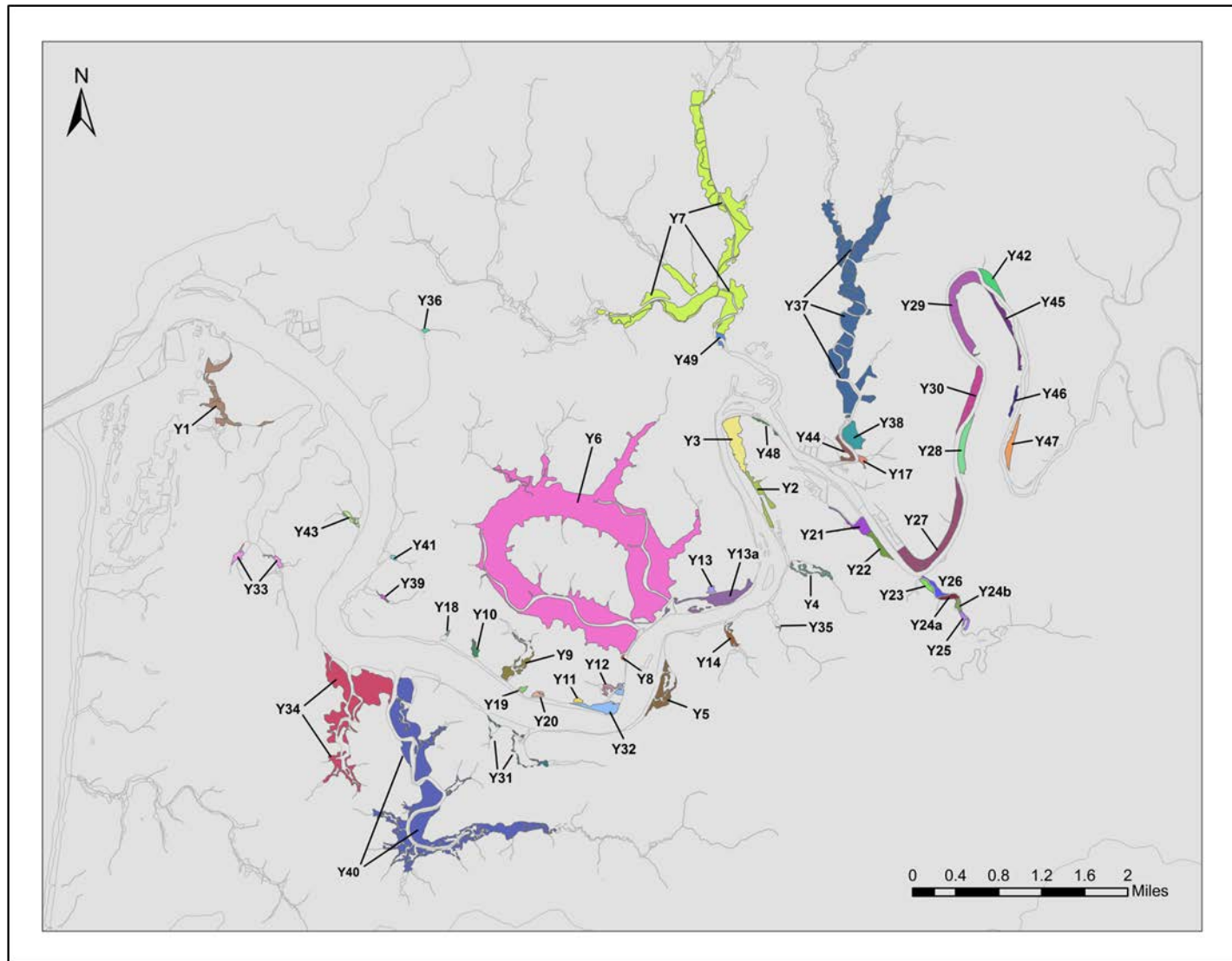


Figure 6. Map of tidal wetlands and likely former tidal wetlands of the Yaquina River estuary, Oregon: prioritization sites from the 1999 tidal wetland prioritization (Brophy 1999), plus new sites identified in the current study (sites Y44 through Y49). Prioritization sites, created by merging NWI polygons, provide analysis units suitable for action planning for tidal wetland restoration and conservation. Colored areas are prioritization sites; each site is colored separately, and labels indicate site numbers. Background is NWI mapping (gray lines). Projection: UTM Zone 10N NAD83.

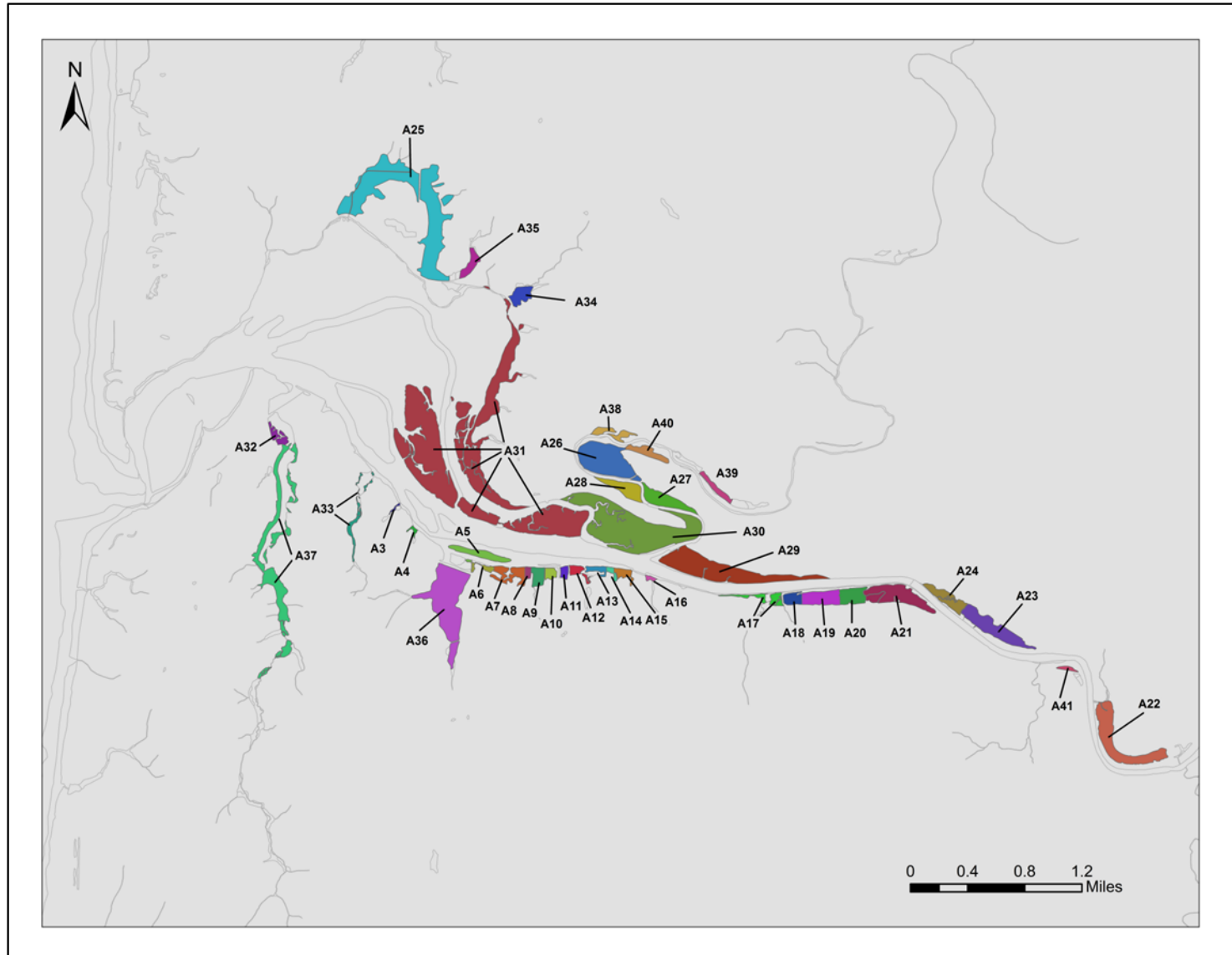


Figure 7. Map of tidal wetlands and likely former tidal wetlands of the Alsea River estuary, Oregon: Prioritization sites from the 1999 tidal wetland prioritization (Brophy 1999), plus new sites identified in the current study (sites A38 through A41). Prioritization sites, created by merging NWI polygons, provide analysis units suitable for action planning for tidal wetland restoration and conservation. Colored areas are prioritization sites; each site is colored separately, and labels indicate site numbers. Background is NWI mapping (gray lines). Projection: UTM Zone 10N NAD83.

Revisions to Prioritization Site Attributes

New information on prioritization site characteristics (changes since 1999, or information not provided in 1999) was generated for 15 of 49 prioritization sites in the Yaquina estuary and 8 of 39 prioritization sites in the Alsea estuary. The new information can be found in the attribute tables of the prioritization site shapefiles (see section, “Downloadable Wetland Shapefiles”). Most of the new information relates to restoration activities or field observations since 1999.

Recommendations

Time limitations prevented digitization of all likely former tidal wetlands. For example, many narrow bands of floodplain were classified as upland in the NWI, but had elevations within our defined 9–11 or 11–13 ft elevation zones. These floodplains also are likely tidal wetlands, former tidal wetlands, and/or tidal waters potentially subject to State and Federal regulations, but these areas were not added to the NWI shapefile. Despite their narrow width, tidal floodplains provide important ecosystem services for aquatic organisms using the main stem rivers. We recommend using LiDAR to map tidal floodplains so they can be included in planning for coastal resource conservation and restoration.

This analysis relied heavily on interpretation of high-resolution aerial photographs acquired in 2005 by Oregon Department of Land Conservation and Development (DLCD) and EPA (Oregon Department of Land Conservation and Development and others, 2007a, 2007b). Field observations in 2010 indicated that changes have occurred at some prioritization sites since production of these 2005 photographs. NAIP (National Agricultural Imagery Program) orthophotographs were flown in 2009, but were not yet available as of the writing of this report. Regular review of field conditions is recommended to update the information provided in this report. Field visits by knowledgeable wetland scientists (after obtaining landowner permission for access) would be particularly useful.

Since completion of the data layers in 2010, GIS inventories of dikes and tide gates in Oregon estuaries have become available (Mattison, 2011a, 2011b). The information in these GIS inventories generally is consistent with this project’s products; additional detail is provided for some dikes and tide gates. Review of the dike and tide gate inventories is recommended when updating this project’s shapefiles, and when planning site-specific actions.

LiDAR data constitute a powerful new tool for studies like this one, with potential utility beyond the present report. For example, the LiDAR data could be used to digitize new boundaries for NWI polygons, provided on-site validation of wetland conditions is conducted. Additional effort is recommended to fully utilize the LiDAR data to assist strategic planning for tidal wetland conservation and restoration.

In some parts of the estuary, particularly the freshwater tidal zone, it is likely that the LiDAR signal did not successfully penetrate dense herbaceous vegetation, resulting in “bare earth” elevations that are higher than the actual land surface. Vegetation interference with the LiDAR signal has been documented (Gopfert and Heipke, 2006). In Oregon, LiDAR-derived elevations are sometimes 1–2 ft higher than actual ground surfaces in areas of dense slough sedge and reed canary grass (Brophy, 2012; Brophy and van de Wetering 2012). Because of this potential inaccuracy, ground-truthing of the LiDAR bare earth model is recommended, particularly for site-specific planning and restoration design.

Intended Uses and Limitations of Mapping

These data are intended to be used for planning purposes only and are non-regulatory in nature. The recommended revisions should be included in the NWI to improve its accuracy, but our methods

and suggested wetland classification revisions should be reviewed by NWI staff to ensure they meet NWI standards. As is always the case with NWI mapping, users should be aware that there may be upland areas within mapped wetlands, and there may be unmapped wetlands and tidal waters that are subject to State and/or Federal regulation per State Removal-Fill Law, Federal Clean Water Act or Federal Rivers and Harbors Act. Furthermore, because the NWI uses the Cowardin et al. definition of a wetland, which differs from the definition of a regulatory wetland subject to State and Federal regulations, not all NWI wetlands are necessarily subject to regulation.

Downloadable Wetland Shapefiles

This report contains Geographic Information System (GIS) data in georeferenced vector (polygon) format. The vector (polygon) data are available as Environmental Systems Research Institute (ESRI) shapefile files. Shapefiles generally include *.shp, *.shx, *.xml, and *.dbf files at a minimum. All these data also include *.prj files which contain the dataset projection information. The GIS shapefiles have been bundled with their corresponding Federal Geographic Data Committee (FGDC)-compliant metadata into compressed zip files.

To download the data, right-click on the appropriate filename hotlink below. Then select 'Save Target As...' to save the file to your local hard drive.

The following products were created in the course of this study:

1. GIS datasets (shapefile format) of NWI polygons in the Yaquina and Alsea estuaries, containing recommended revisions to the NWI classification (**Yaquina_tidal_NWI_2011.shp** and **Alsea_tidal_NWI_2011.shp**, respectively). Datasets include metadata, based on the metadata provided by EPA for the original Yaquina NWI layer.
2. GIS datasets (shapefile format) of the prioritization sites identified in the 1999 prioritization of tidal wetlands in the Yaquina and Alsea estuaries (Brophy, 1999): **Yaquina_tidal_wetlands_2011.shp** for the Yaquina estuary, and **Alsea_tidal_wetlands_2011.shp** for the Alsea estuary. Attribute tables contain all publicly available data in the original site information tables, as well as updates from this project. Metadata are included with the shapefiles.

Table 7. Downloadable Wetland Shapefiles

[The projection for all GIS products is Oregon Lambert HARN (international feet), matching the projection of the LiDAR datasets used in the analysis.]

File Name	Description	Size	Download Link
Yaquina_tidal_NWI_2011.zip	Shapefile containing recommended revisions to the NWI classifications for Yaquina estuary.	1,658 KB	http://pubs.usgs.gov/of/2012/1038/data/Yaquina_tidal_NWI_2011.zip
Alsea_tidal_NWI_2011.zip	Shapefile containing recommended revisions to the NWI classifications for Alsea estuary.	631 KB	http://pubs.usgs.gov/of/2012/1038/data/Alsea_tidal_NWI_2011.zip
Yaquina_tidal_wetlands_2011.zip	Shapefile containing prioritization sites identified in the 1999 prioritization of tidal wetlands in the Yaquina estuary and updates from this project.	213 KB	http://pubs.usgs.gov/of/2012/1038/data/Yaquina_tidal_wetlands_2011.zip
Alsea_tidal_wetlands_2011.zip	Shapefile containing prioritization sites identified in the 1999 prioritization of tidal wetlands in the Alsea estuary and updates from this project.	104 KB	http://pubs.usgs.gov/of/2012/1038/data/Alsea_tidal_wetlands_2011.zip

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Appendix A: Landscapes and vegetation present across study areas in Yaquina and Alsea estuaries, Oregon.



Figure A1. Photograph of tidal marsh dominated by *Deschampsia cespitosa* (tufted hairgrass) at prioritization site A5, fig. 7 at Eckman Island in the Alsea estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, September 2010.



Figure A2. Photograph of *Agrostis stolonifera* (creeping bentgrass) at prioritization site A31 in figure 7 in the Alsea estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, September 2010.



Figure A3. Photograph of *Hordeum jubatum* (foxtail barley) at prioritization site Y1, fig. 6 in the Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, August 2010.



Figure A4. Photograph of *Juncus effusus* (common rush) at prioritization site A24 in fig. 7 in the Alsea estuary, Oregon. This species tends to be found at high elevations in lower salinity tidal marshes. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, November 2010.



Figure A5. Photograph of *Juncus balticus* ssp. *ater* (Baltic rush) at prioritization site Y1 in fig. 6 in the Yaquina estuary, Oregon. Several species of rushes are found in Oregon tidal wetlands. Baltic rush is the most frequently encountered species in high marsh. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, May 2010.



Figure A6. Photograph of *Carex lyngbyei* (Lyngbye's sedge) at prioritization site Y40 in fig. 6 in Poole Slough, Yaquina estuary, Oregon. One of the most common tidal marsh species in the Pacific Northwest, Lyngbye's sedge grows in both low and high marsh. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, April 2011.



Figure A7. Photograph of *Carex obnupta* (slough sedge) at prioritization site A17 in fig. 7 in the Alsea estuary, Oregon. Slough sedge grows in the upper marsh in less saline regions of the estuaries and can also be found in freshwater wetlands. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, September 2010.



Figure A8. Photograph of *Triglochin maritimum* (seaside arrowgrass) at prioritization site Y40 in fig. 6 in Poole Slough, Yaquina estuary, Oregon. Seaside arrowgrass is a succulent perennial forb commonly found in low tidal marsh. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, May 2010.



Figure A9. Photograph of *Picea sitchensis* (Sitka spruce) at the edge of a marsh along Drift Creek at prioritization site A28 in fig. 7 in the Alsea estuary, Oregon. Sitka spruce is the principal foundation species of brackish tidal swamps in Oregon. It can also be found growing on nurse logs in estuarine marshes. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, December 2011.



Figure A10. Photograph of black twinberry (*Lonicera involucrata*) growing on the bank of a tidal channel in tidal swamp at prioritization site Y28 in fig. 6 in the Yaquina estuary, Oregon. Trees in the background are Sitka spruce, also growing on the tidal channel banks. Summer surface water salinity at this site is in the mesohaline range (8–9). Photograph by Laura Brophy, Green Point Consulting, September 2006.



Figure A11. Photograph of salt-stressed black twinberry (*Lonicera involucrata*) with epiphytic lichens and mosses in emergent tidal marsh along the main stem of the Alsea River, Oregon at prioritization site A17 in fig. 7. The stressed condition of the specimen may be due to high salinity. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, September 2010.



Figure A12. Photograph of scrub shrub tidal wetland at prioritization site Y40 in fig. 6 in upper Poole Slough, Yaquina estuary, Oregon. Dominant shrubs are black twinberry (*Lonicera involucrata*) and Pacific crabapple (*Malus fusca*). Photograph by Christopher Janousek, U.S. Environmental Protection Agency, September 2010.



Figure A13. Photograph of low marsh and algal-dominated mudflats at prioritization site Y34 in fig. 6 near the mouth of McCaffery Slough in the Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, August 2010.



Figure A14. Photograph of tidal marsh at prioritization site Y30 in fig. 6 in the upper Yaquina estuary with *Phalaris arundinacea* (reed canarygrass) growing above other emergent vegetation (e.g., *Carex*, *Potentilla*). Photograph by Christopher Janousek, U.S. Environmental Protection Agency, July 2010.



Figure A15. Photograph of red alder (*Alnus rubra*) on the margin of tidal marsh at prioritization site A27 in fig. 7 in the Alsea River estuary, Oregon. Grass in the foreground is Pacific reedgrass (*Calamagrostis nutkaensis*), typical of the ecotone between brackish tidal marsh and brackish tidal swamp. Photograph by Laura Brophy, Green Point Consulting, July 2005.



Figure A16. Photograph of red alder (*Alnus rubra*) growing from a nurse log at prioritization site Y1 in fig. 6 in the lower Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, November 2010.



Figure A17. Photograph of low marsh vegetation in a saline marsh at prioritization site Y1 in fig. 6 in the lower Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, August 2010.



Figure A18. Photograph of *Achillea millefolium* (common yarrow) flowers in foreground with *Symphyotrichum subspicatum* (Douglas aster) and *Grindelia stricta* (coastal gumweed) in background found at prioritization site Y1 in fig. 6 in the Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, August 2010.



Figure A19. Photograph of high marsh dominated by *Carex lyngbyei* and *Agrostis stolonifera* at prioritization site Y30 in fig. 6 in the Yaquina estuary, Oregon. Photograph by Laura Brophy, Green Point Consulting, September 2006.

a.



b.



Figure A20. Photographs of *Potentilla anserina* (Pacific silverweed) at (a) prioritization site Y13a in fig. 6 Critesers Marsh in the Yaquina estuary, Oregon and (b) prioritization site A30 in fig. 7 in the Alsea estuary, Oregon. A member of the rose family, Pacific silverweed is a common species in high tidal marsh from Alaska to California. Photographs by Christopher Janousek, U.S. Environmental Protection Agency, (a) taken in April 2010 and (b) taken in October 2010.



Figure A21. Photograph of *Heracleum lanatum* (cow parsnip) at prioritization site Y13a in fig. 6 in Critesers Marsh in the Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, May 2010.



Figure A22. Photograph of a small tributary in estuarine emergent marsh at prioritization site Y40 in fig. 6 in upper Poole Slough in the Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, August 2010.



Figure A23. Photograph of estuarine emergent marsh, including a small patch of tall *Schoenoplectus* sp(p)., at prioritization site Y26 in fig. 6 at Mill Creek in the Yaquina estuary, Oregon. This wetland was formerly designated by the National Wetlands Inventory as palustrine marsh. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, August 2010.



Figure A24. Photograph of cattail (*Typha latifolia*) marsh at prioritization site Y27 in fig. 6 in the upper Yaquina River, Oregon. This is a restored tidal wetland, formerly diked; it was previously classified in the National Wetlands Inventory as a seasonally-flooded palustrine marsh with no diking modifier. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, September 2010.



Figure A25. Photograph of *Oenanthe sarmentosa* (water parsley) submerged at high tide at prioritization site Y28 in fig. 6 in the Yaquina estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, November 2010.



Figure A26. Photograph of *Eleocharis palustris* (common spike rush) near prioritization site Y29 in fig. 6 growing at the edge of the river in the upper part of the Yaquina estuary, Oregon. This species is found in lower salinity wetlands. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, August 2010.



Figure A27. Photograph of low marsh at prioritization site A32 in fig. 7 in the saline portion of the Alsea estuary, Oregon (mouth of Lint Slough). Photograph by Laura Brophy, Green Point Consulting, September 2003.



Figure A28. Photograph of *Sarcocornia perennis* (pickleweed) at prioritization site A30 in fig. 7 in the Alsea estuary, Oregon. Pickleweed is commonly found in saline low marsh habitat but can also occur at higher tidal elevations in brackish parts of Oregon's estuaries. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, October 2010.



Figure A29. Photograph of tidal marsh and channel banks covered with diatoms and green algae at prioritization site A31 in fig. 7 in the Alsea estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, September 2010.



Figure A30. Photograph of tidal freshwater zone near prioritization site A39 in fig. 7 in Drift Creek, a tidally-influenced palustrine system in the Alsea River Estuary, Oregon. Photograph by Laura Brophy, Green Point Consulting, August 2005.



Figure A31. Photograph of Drift Creek and adjoining tidal marshes at prioritization site A26 in fig. 7 in the Alsea estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, November 2010.



Figure A32. Photograph of *Angelica lucida* (seawatch angelica) at prioritization site A36 in fig. 7 close to Eckman Lake in the Alsea estuary, Oregon. Photograph by Christopher Janousek, U.S. Environmental Protection Agency, October 2010.