Oregon Coastal Management Program

PACIFIC STATES MARINE FISHERIES COMMISSION

CORE CMECS GIS PROCESSING METHODS FOR THE COLUMBIA RIVER ESTUARY

The goal of this effort was to produce estuary habitat information for the Columbia River Estuary, using the federally adopted Coastal and Marine Ecological Classification Standard (CMECS) version 4.0. This project is an extension of previous efforts by the Oregon Coastal Management Program (Lanier et al., 2014). While no new geospatial information was collected as part of this project, many recently collected or published data sets were utilized to derive CMECS habitat products. This document describes the methods and datasets used by the project team in the generation of the Columbia River Estuary CMECS habitat products.

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January 2022

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Acknowledgements

Funding for this project provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration.

Thank you to all of the data contributors who provided technical guidance and recommendations.

Project Summary

This project supports the Oregon Coastal Management Program (OCMP)'s efforts to expand their spatial data framework within the Oregon Coastal Zone. OCMP and PSMFC GIS staff will collaborate to fill an important remaining data gap and create spatial data for the CMECS aquatic, substrate and geoform components in the portion of the Columbia River Estuary within the Oregon coastal zone.

Project Objectives

1. PSMFC GIS staff will use existing best available regional and nationally standard datasets as inputs to the project. Staff will follow GIS processing methods established by OCMP to create CMECS data products for the Columbia River Estuary compatible with those previously created for estuaries along the Oregon coast.
2. Develop and deliver/publish GIS data for the substrate, aquatic and geoform CMECS elements of the Columbia River Estuary within Oregon's Coastal Zone.
3. PSMFC will deliver final published datasets along with metadata to OCMP for integration into the program's broader spatial data framework.

Guiding Principles and Methods

The project team used a set of guiding principles, developed by the Oregon Coastal Management Program as part of Phase I of their Oregon Estuary Project of Special Merit (Lanier et al., 2014) and Phase II (Lanier et al., 2018).

Operational Procedure #1 – Vector Polygons

> A vector-based data file type approach was used. While we used raster GIS information in the development of our information products, all products generated from our work are in the vector data format.

Operational Procedure #2 – Source data screening

> Source data from partners and other data providers were evaluated for quality, consistency, and spatial extent to assess suitability for inclusion and to determine appropriate data synthesis approach(es). For example, if the source data were collected as point locations, the data could be interpolated into a surface that would become a set of polygons depicting the extent of the resource of interest. If the source data points did not have enough spatial coverage to create a high quality surface, the source data would not be integrated into the final map layers.

Operational Procedure #3 - Anchor Layer

> A Project Anchor Layer is a GIS layer which form the boundaries of the project analysis layers and are carried through all subsequent GIS processing steps. It enforces key geometry features within the layers (components) for the estuary project. This line is often used in multiple instances in the CMECS hierarchy. For this project, the Pacific Marine & Estuarine Fish Habitat Partnership's (PMEP) Current and Historic Extent of Tidal Wetlands for the Columbia River was used as the project anchor layer. The methods for delineating this layer were developed for the state of Oregon by the Oregon Coastal Management Program in 2014, and expanded in PMEP's

layer to include estuaries in California and Washington. For details on this layer and methods used to develop it, please see the PLOS One article, "Insights into estuary habitat loss in the western United States using a new method for mapping maximum extent of tidal wetlands" (Brophy et al, 2019).

Operational Procedure #4 – Retain Source Geometry

The original source geometry was used for component layer transformations (from the source data into CMECS). Source geometries were altered when polygons with identical attributes were merged.

Operational Procedure #5 – Cartographic Smoothing

Data that was vectorized from raster surfaces were smoothed before being integrated into existing surrounding data, for cartographic and computational reasons.

CMECS Settings and Components

Aquatic Setting (AS)

The Estuarine System

The Estuarine System is defined by salinity and geomorphology. This System includes tidally influenced waters that (a) have an open-surface connection to the sea, (b) are regularly diluted by freshwater runoff from land, and (c) exhibit some degree of land enclosure. In CMECS the Estuarine System has four subsystems: Coastal, Open Water, Tidal Riverine Coastal, and Tidal Riverine Open Water.

2.1 Estuarine Coastal

The Estuarine Coastal Subsystem extends from the supratidal zone at the land margin up to the 4 meter depth contour in waters that have salinity greater than .5 (maximum bottom salinity during the average annual low flow, September). CMECS calls for mean higher high water (MHHW) to differentiate tidal/non-tidal zones within this zone; however, the Approximate Maximum Extent of Tidal Wetlands boundary (described above) was used to represent this boundary in this project, as the MHHW elevation datum does not capture the full extent of habitats influenced by the tides (see Appendix A). The upper bounds of "Coastal" was differentiated from non-coastal, or terrestrial, as it is captured in areas above the approximate maximum extent of tidal wetland boundary but still within the project boundary. Everything below the approximate maximum extent of tidal wetland boundary but above the 4m depth line is classified as "Estuarine Coastal."

2.1.A107 Estuarine Coastal (Diked)

Same as 2.1, but those areas that fell within one of LCEP's tidally restricted polygons attributed as "mostly restricted" or "fully restricted" by man-made structures were given a "Diked" modifier. In CMECS, this modifier is called "Impounded/Diverted", but in Oregon, the term "diked" is more commonly used.

2.1.A108 Estuarine Coastal (Restored)

Same as 2.1, but those areas that fell within one of LCEP or PMEP's "restored areas" were attributed with a "Restored" modifier.

2.2 Estuarine Open Water

The -4m depth line separates the Coastal aquatic from the Open Water aquatic and is dependent on the quality of the bathymetry in each system. This line does not exist in many smaller estuaries, as their maximum depth may be less than 4m. Areas deeper than -4m are considered "Open Water," calculated using -4m below the mean lower low water (MLLW) tidal datum.

The data digital terrain model raster datasets were merged into a single coastwide data set and converted to the appropriate MLLW elevation datum using VDATUM (NAVD 88 to MLLW). The -4m contour was then extracted using the Contour Tool in ArcGIS Pro and converted to a polygon file type using the Feature to Polygon Tool. Visual inspection of polygons was conducted to ensure only polygons representing water deeper than -4m were included in the Open Water classification.

2.3 Estuarine Tidal Riverine Coastal

Same method as "Estuarine Coastal" except with the addition of salinity considerations (salinity has to be less than 0.5 practical salinity units (PSU) to be considered Tidal Riverine). In our case we gathered salinity observation values from the CMOP Climatological Atlas data set for points within our project boundary. The point observations were summarized to determine the maximum PSU for the bottom salinity during observations in the month of September. To assign salinity values to the aquatic polygons, a point half-way between the values indicating a change from below to above 0.5 was used to divide the polygon (applied to the full width of the polygon at that point) into areas of high a low salinity.

2.3.AI07 - Estuarine Tidal Riverine Coastal (Diked)

Same as 2.3, but those areas that fell within one of LCEP's tidally restricted polygons attributed as "mostly restricted" or "fully restricted" by man-made structures were given a "Diked" modifier. In CMECS, this modifier is called "Impounded/Diverted", but in Oregon, the term "diked" is most commonly used.

2.3.AI08 - Estuarine Tidal Riverine Coastal (Restored)

Same as 2.3, but those areas that fell within one of LCEP or PMEP's "restored areas" were attributed with a "Restored" modifier.

2.4 Estuarine Tidal Riverine Open Water

Same method as 2.2 except with the addition of salinity considerations (salinity has to be less than 0.5 psu to be considered Tidal Riverine).

Aquatic Setting Datasets

- Estuary extent: West Coast USA Current and Historical Estuary Extent, PMEP, 2018
- Shoreline: Continually Updated Shoreline Product (NOAA, 2019)
- Impounded/diverted (diked): Tidally restricted areas, (LCEP, 2011); Indirect Assessment of Tidal Wetland Loss, (PMEP, 2020)

- Restored areas: LCEP Columbia Habitat Restoration Inventory (LCEP, 2020); Indirect Assessment of Tidal Wetland Loss, (PMEP, 2020)
- Bathymetry: Lower Columbia Digital Terrain Model, TopoBathy DEM (LCEP, 2011)
- Salinity: CMOP Climatological Atlas (CMOP, 2021)

Water Column Component

The WC represents a new approach to the ecological classification of open water settings. The component describes the water column in terms of vertical layering, water temperature and salinity conditions, hydroforms, and biogeochemical features. Modifiers allow users to further subdivide water column units. Representative units include “cold, oligohaline estuarine open water surface layer” and “warm marine offshore western boundary current oceanic epipelagic upper layer.”

For this project, the Water Column Component was not mapped because no comprehensive data were available.

Geoform Component

The GC describes the major geomorphic and structural characteristics of the coast and seafloor. This component is divided into four subcomponents that describe tectonic and physiographic settings and two levels of geoform elements (based upon the scale of the features) that include geological, biogenic, and anthropogenic geoform features. Representative units include lagoon, ledge, tidal channel/creek, and moraine.

Tectonic Setting

At the largest scales, the GC is divided in eight planetary features that reflect global tectonic processes. Generally, these features are thousands of square kilometers or larger in size. Northern Oregon and Southern Washington are located within a Convergent Active Continental Margin, which is defined by intense areas of active magmatism, where the oceanic lithosphere is subducted beneath the continental lithosphere.

Physiographic Setting

Spatially nested within the tectonic settings, physiographic settings describe landscape-level geomorphological features from the coast to mid-ocean spreading centers. The Columbia River is classified as a Riverine Estuary. This class of estuary tends to be linear and seasonally turbid (especially in upper reaches), and it can be subjected to high current speeds (FGDC, 2012). These estuaries are sedimentary and depositional, so they may be associated with a delta, bar, barrier island and other depositional features. These estuaries also tend to be highly flushed (with a wide and variable salinity range) and seasonally stratified. Riverine estuaries have moderate surface-to-volume ratios with a high watershed-to-water-area ratio—and they can have very high wetland-to-water-area ratios. These estuaries are often characterized by a V-shaped channel configuration and a salt wedge.

High inputs of land drainage can promote increased primary productivity, which may be confined to the water column in the upper reach, due to low transparency in the water column. Surrounding wetlands may be extensive and healthy, given the sediment supply and nutrient input. This marsh perimeter may be important in taking up the excess nutrients that are introduced to the system. Physically, the system may tend to be stratified during periods of high riverine input, and the input of marine waters may be enhanced by countercurrent flow.

Level 1 and 2 Geoform

Geoforms are physical, coastal, and seafloor structures that are generally no larger than hundreds of square kilometers in size. The size determination may be an areal extent or a linear distance. Larger geoforms (Level 1) are generally larger than one square kilometer, and correspond to Megahabitats in the Greene et al. classification system (2007). Smaller geoforms (Level 2) are generally less than one square kilometer in size, and correspond to meso and macro scale habitats in the Greene et al. classification scheme. Level 1 and Level 2 geoforms are arranged as two separate subcomponents so that they can be used in tandem to describe complex spatial patterns of geoform structures. Geoforms of both Level 1 and Level 2 are broken out into Geologic, Biogenic, and Anthropogenic.

Where present, anthropogenic geoform classes replaced any geologic geoforms. Within the geologic geoform, marsh platforms took priority over channels or sloughs and flats, beaches, shores and islands. Minor sloughs and channels took priority over flats, beaches shores and islands. Flats, beaches, and shores were prioritized over islands. Lastly, islands replaced channels, sloughs and open water. See Figure 1 for diagram of data processing priority.

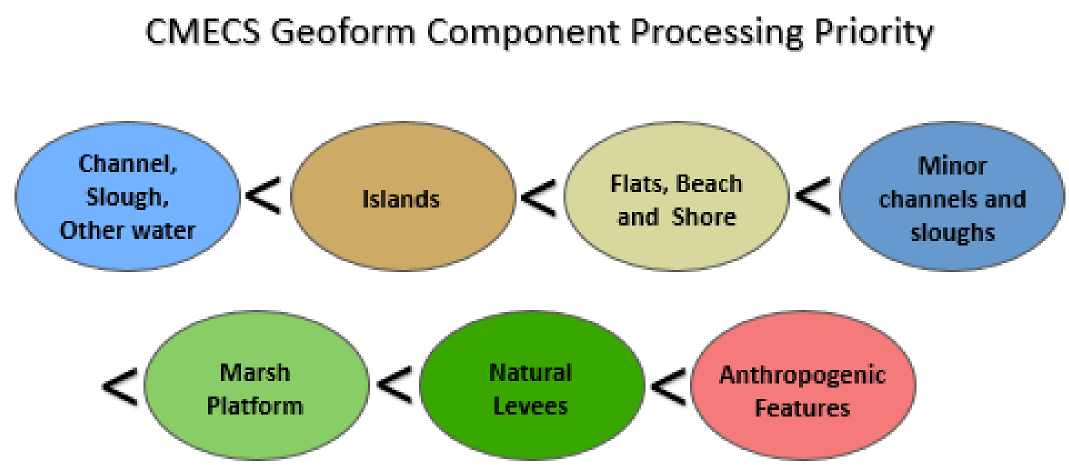

Figure 1: CMECS Geoform data processing priority by feature classification category. Anthropogenic features take priority and replace all other features.

Geologic Geoforms

Geologic Geoforms are formed by the abiotic processes of uplift, erosion, volcanism, deposition, fluid seepage, and material movement. Waves, currents, wind, chemical dissolution, seismic motion, and chemical precipitation all contribute to these geoforms and give them their distinctive qualities.

g105 – Beach

A beach is defined as a gently sloping zone formed by unconsolidated material at the shoreline, typically with a concave profile. NWI data was used to select those polygons that contain AB (Aquatic Bed) and US (Unconsolidated Substrate) in all systems (Estuarine, Palustrine, and Marine) except Lacustrine (Marine was included because some M polygons came into the mouth of the Project Boundary). Polygons were classified as “beach” based on the polygon’s shape and their name. Beaches were identified by selecting points with the attribute “beach” in the Oregon Geographic Names Information System (GNIS) data layer.

g109 – Channel

A channel is a general term for a linear or sinuous depression on an otherwise more flat area (for example, a valley- or groove-like feature through which water flows). Columbia River Estuary Ecosystem Classification Geomorphic Catena (USGS, 2012) was queried to identify areas of the Columbia River classified as channels (Either the complex or catena were classified as a channel). These areas were used to clip PMEP’s estuary extent to generate a new feature class of Channels.

g10903 – Slough

“Slough” is a geoform type under “channel” defined as: (a) a sluggish body of water in a tidal flat, bottomland, or coastal marshland, or (b) a sluggish channel of water in which water flows slowly through either low, swampy ground or a section of an abandoned river channel. Sloughs were found by selecting points with the attribute “slough” in the Oregon Geographic Names Information System (GNIS) data layer. Then, using the newly generated Channels feature class, the polygons for each slough were attributed in the feature class as “Sloughs.”

g122 - Flat

Flats are various shapes that represent a nearly level surface often composed of unconsolidated sediments and most commonly found in the intertidal or shallow subtidal zones. NWI data was used to select those polygons that contain AB (Aquatic Bed) and US (Unconsolidated Substrate) in all systems (Estuarine, Palustrine, and Marine) except Lacustrine (Marine was included because some M polygons came into the mouth of the Project Boundary). Polygons were classified as “Flat” based on the polygon’s shape and their flood exposure. Features that were irregularly exposed, flooded, or subtidal were classified as flats.

g12205 - Tidal Flat

A tidal flat is an extensive, nearly horizontal, barren (or sparsely vegetated) tract of land that is alternately covered and uncovered by the tide. Tidal flats consist of unconsolidated sediment (mostly clays, silts and/or sand, and organic materials). Two data sources were used to identify tidal flats, NWI and polygons created by areas between tidal datum contours. NWI data was used to select those polygons that contain AB (Aquatic Bed) and US (Unconsolidated Substrate) in all systems (Estuarine, Palustrine, and Marine) except Lacustrine (Marine was included because some M polygons came into the mouth of the Project Boundary). NWI features that are “regularly flooded” were also classified as tidal flats. Data from datum contours were developed by identifying the area between Mean Lower Low water (MLLW) contour line and the Mean High Water (MHW) line to create polygons representing “tidal flats.”

g129 – Island

Islands are defined as an area of land completely surrounded by water – or an elevated area of land surrounded by swamp or marsh, which is isolated at high water or during floods. The NOAA CUSP shoreline was used to delineate island areas greater than 1 acre in size and classified as “islands.”

g136 – Marsh Platform

Marsh platforms are described as the flat, often thick, accumulation of peat that supports emergent marsh vegetation. Marsh Platforms are commonly dissected by tidal creeks. Two data sources were used. CREEC Geomorphic Catena were used to select polygons where Catena classified as ’Wetlands.’ Additionally, PMEP’s biotic habitat dataset was used to select all biotic features that represent tidal marsh (this includes Emergent Tidal Marsh, Tidal Scrub-Shrub Wetland, Emergent Tidal Marsh, Emergent Wetland, Scrub-Shrub Wetland, Tidal Scrub-Shrub Wetland, Tidal Forest/Woodland' or Forested Wetlands. The layers were unioned, and resulting polygons were classified as “marsh platform.”

g141 – Natural Levees

Natural Levees are defined as an embankment of sediment, bordering on one or both sides of a river (or other feature). The LCEP Levees dataset was used for the CMECS “Natural Levees” classification. Lines classified as “Natural levee” in the inventory were turned into polygons by buffering the line features (based on an average width of observed random samples) by 20ft.

g161 – Shore

A shore is defined as the intersection of a specified plane of water with a beach that migrates with changes of the tide or of the water level. NWI was used to pull out those polygons that contain AB (Aquatic Bed) and US (Unconsolidated Substrate) in all NWI systems (Estuarine, Palustrine, and Marine) except Lacustrine (Marine was included because some M polygons came into the mouth of the Project Boundary). Polygons were classified as “Shore”, based on the polygon’s shape (determined using aerial photographic imagery).

Other Water

Water features in the estuary did not fall within one of the established geoform Level 1 or Level 2 classes (the closest would be a depression). To keep the coverage of water features in our estuary habitat classification complete, we (the project team) generated an “other water” category to capture the lower, open water, landform of the estuary system.

Datasets (Geologic)

- GNIS Oregon data layer (2021)
- Columbia River Estuary Ecosystem Classification (CREEC) Level IV Ecosystem Complexes (USGS, 2011)
- Columbia River Estuary Ecosystem Classification (CREEC) Level V Geomorphic Catena (USGS, 2011)
- Continually Updated Shoreline Product (CUSP) (NOAA)
- MLLW and MHW contours developed using VDatum with the LCEP Digital Terrain Model as the input raster dataset (LCEP, 2011)
- National Wetlands Inventory (USFWS, 2012)
- PMEP's West Coast Estuarine Biotic Habitat V1.2 (PMEP, 2019)
- Lower Columbia River Levees (LCEP, 2011) * buffer by 20 feet

Geoprocessing Reference Datasets

- ESRI Aerial Imagery
- World Imagery Wayback (ESRI, 2021)
- DOGAMI LIDAR (Digital Terrain Model)
-

Biogenic Geoforms

Biogenic Geoforms are physical features and landforms that were created by the action of living organisms. These primarily consist of different types of reefs. As with all geoforms the characteristic of concern in this component is the physical shape of these reef features, not the living biology that may have participated in their genesis.

For this project, no Biogenic Geoforms were mapped, because no comprehensive data were available.

Anthropogenic Geoforms

In many estuarine and coastal areas artificial structures (such as piers, jettys, dams, and fill) are a significant part of the environment. The same relationship between Level 1 and Level 2 geoforms prevails in this origin type as in the geologic and biogenic categories; however, due to the complexity of some of the anthropogenic structures, many more Level 2 units may be present in a single Level 1 geoform. Besides physical structures, features that are the result of human activity (such as scars and trawl marks) are included among the anthropogenic geoforms.

g312 – Dam

Dam is defined as an obstruction across a flow that produces a lake, pond, or other widening. The Columbia River Estuary Ecosystem Classification (CREEC) Cultural Features data from 2011 were used as the source for dams.

g30201 – Artificial Levee

Artificial Levees are defined as either: (a) dike along the side of a river channel erected to prevent overflow during floods, usually running along the channel direction and near the natural levee crests of streams; or (b) an artificial embankment constructed along the bank of a watercourse or an arm of the sea to protect land from inundation. LCEP

Levees dataset was used to identify features for the “Artificial Levee” classification. Levee line features were buffered by 20ft and incorporated as “Artificial Levees.”

Note: some of the artificial levees identified in LCEP’s levee dataset were classified as “fill” or “Jetty/Groin” in the CREEC dataset. These features were classified in the CMECS dataset as CREEC classification that was the closest crosswalk to the data sources, in these cases either “fill area” or “breakwater/jetty.”

g30202 - Artificial Levee (breached) *new code*

The LCEP’s levee dataset was used to classify “Breached Dikes” as a new CMECS code “Breached Dike”. The lines classified as “Breached Dike” in the Levees Inventory were turned into polygons using a 20ft buffer and incorporated as “Artificial Levees (breached).”

g313 - Dock/Pier

A dock or pier is defined as a landing place for vessels normally oriented perpendicular to the shore with a flat surface for off-loading materials. Our project team used several input data sources to identify fill areas; they are listed below by source.

- The DLCD Public Access Inventory was used to identify piers. Aerial imagery and LiDAR was then used to Heads-Up-Digitize these areas into polygon features and classify them as CMECS categories “Dock/Pier”.
- The USGS GNIS dataset was used to identify docks, piers, marinas, and ports (where docks and piers may exist). Aerial imagery and LiDAR was then used to Heads-Up-Digitize these areas into polygon features and classify them as CMECS categories “Dock/Pier.”
- (DSL)’s Wetland Impacted Area layer (from the Land Administration System (LAS) Database) was used to identify areas where there have been removal/fill projects associated with marinas in order to identify potential Docks and Piers for inclusion in this category. Aerial imagery and LiDAR was then used to Heads-Up-Digitize these areas into polygon features and classify them as CMECS categories “Dock/Pier.”
- In Washington, the Overwater Structure Inventory by WA Department of Natural Resources was used to identify dock/pier structures.

g315 - Dredge Deposit

Dredge Deposit is defined as an accumulation on the land surface (or seafloor) where spoil materials from a dredging operation are placed. They often exhibit some topographic expression and can support biological communities that are different than the surrounding area. The CREEC Level V Geomorphic Catena where material is equal to dredge spoils were used to identify dredge deposits.

g319 - Fill Area

A Fill Area is defined as a topographically low area into which unconsolidated material has been placed in order to raise the ground level as part of development or expansion of coastal infrastructure. Our project team used several input data sources to identify fill areas; they are listed below by source.

- The Columbia River Estuary Ecosystem Classification (CREEC) Cultural Features classified as “Fill area.”
- The Columbia River Estuary Ecosystem Classification (CREEC) Geomorphic Catena classified as “Filled area.
- Washington Department of Natural Resources Overwater Structures in Rivers where “Structure” is classified as “Fill area.”
- The Federal Aviation Administration (FAA) Airports data layer was used to identify areas of fill associated with airports. The LiDAR DEM was used to Heads-Up-Digitize those “Fill Areas”.
- Primary, secondary, tertiary, residential and unclassified roads from Open Street Map in Washington and Oregon (Geofabrik, 2021) were used to identify the road centerlines. Line features were turned into polygon features by the creation of a buffer based on an average width of a random sample (based upon a classification of each road type provided by Geofabrik, 2021).
- The Open Street Map (Geofabrik, 2021) railroads features were classified as “Fill Areas.” Line features were turned into polygon features by the creation of a buffer based on an average width of a sample of railroads in Oregon and Washington.
- The Open Street Map land use data layer was used to identify areas of “industrial,” “retail,” or “residential” use and were classified as “Fill Areas.”
- Coastal Building Footprints (DOGAMI, 2015) were used to identify buildings within the project area and classified as “Fill Areas.”

g320 – Harbor

A Harbor is defined as a small bay or a sheltered part of a body of water, usually well protected against high waves and strong currents that serves as a safe anchorage for ships and where port facilities are present. Harbors were found by selecting points with the attribute of “Harbor” or with feature name “Port” in the Oregon Geographic Names Information System (GNIS) data layer. Aerial imagery was used to visually inspect and Heads-Up-Digitize these areas into polygon features and classify them.

g324 - Marina/Boat Ramp

The Marina/Boat ramp class is defined as a series of docks, walkways, slips, and support infrastructure for in-water storage of yachts and boats. Marinas and boat ramps in Oregon were found by selecting points with the word “marina” or “boat ramp” in the Feature Name field of the Oregon Geographic Names Information System (GNIS) data layer. Aerial imagery was used to visually inspect and the LiDAR DEM was used to Heads-Up-Digitize these areas into polygon features and classify them. In Washington,

g307 – Breakwater/Jetty

Structures extending more or less perpendicularly from the shore into a body of water, which are designed to direct and confine the current or tide, to protect a harbor, or to prevent shoaling of a navigable inlet by littoral materials.

g305 – Artificial Scar

A gouge or deformation of the bottom, or an area where the surface of the substrate, vegetation, or other colonizing organisms have been removed by abrasion or impact. These may be temporary or permanent features. These features were identified as "Excavations" or "Cuts" in the CREEC Cultural Features dataset.

g302601 – Ditch *new code*

Ditches are excavated linear channels, generally about ten meters wide, and may only be seasonally wet. These features were identified in the CREEC Cultural Features dataset.

Datasets (Anthropogenic)

- Columbia River Estuary Ecosystem Classification (CREEC) Cultural Features (USGS, 2011)
- Lower Columbia River Levees (LCEP, 2011) * buffer by 20 feet
- Public Access Inventory (DLCD, 2021)
- GNIS Names (USGS, 2021)
- Wetland Impacted Area layer (from the Land Administration System (LAS) Database) (DSL, 2021)
- Overwater Structure Inventory (WA DNR, 2017)
- Columbia River Estuary Ecosystem Classification (CREEC) Level V Geomorphic Catena (USGS, 2011)
- Airports (Federal Aviation Administration/FAA, 2021)
- Open Street Map Railroads WA, OR (Geofabrik, 2021)
- Open Street Map Roads WA, OR (Geofabrik, 2021) *buffered based on road classification
- Open Street Map industrial, residential, and retail areas WA, OR (Geofabrik, 2021)
- Open Street Map Buildings WA, OR (Geofabrik, 2021)
- Building footprints, Oregon (DOGAMI, 2015)

Geoprocessing Reference Datasets

- ESRI Aerial Imagery
- World Imagery Wayback (ESRI, 2021)
- DOGAMI LIDAR (Digital Terrain Model)

Substrate Component

Substrate is defined in CMECS as "the non-living materials that form an aquatic bottom or seafloor, or that provide a surface (e.g., floating objects, buoys) for growth of attached biota. Substrate may be composed of any substance, natural or manmade".

There are three primary CMECS substrate types: Biogenic, Geologic, and Anthropogenic. ***Where present, biogenic substrate classes replaced any geologic substrates, and any anthropogenic substrate replaced any underlying geologic or biogenic soils.***

We used many primary region-wide inputs in our CMECS substrate component classification:

- US Department of Agriculture Natural, Resources Conservation Service Soil Survey Geographic Database (NRCS SSURGO) soils contributed Geologic and Biogenic substrate information.
- US Fish and Wildlife Service National Wetland Inventory contributed Geologic substrate information where NRCS was unavailable (sub-aqueous areas).
- Anthropogenic substrate was derived from an assortment of sources: roads, railroads, dikes, dredge deposits, boat ramps and various other sources of "fill" information.
- NRCS gSSURGO soils database consists of map unit geometry, with many related tables containing information about soil properties. A single map unit polygon may be composed of many soil components (horizontal), each of which will have many soil horizons (vertical). Figure 2 below shows the inherent complexity of the Soils data product (excerpted from (Dylan Beaudette, NRCS)).

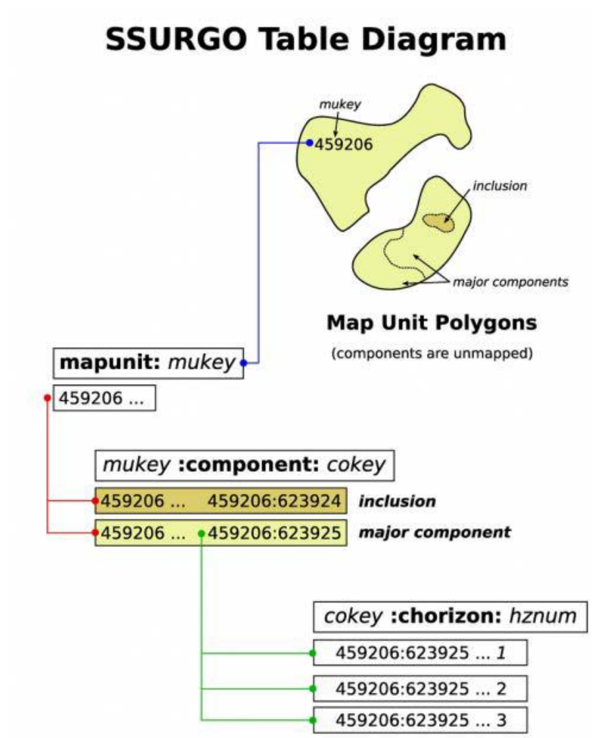

Figure 2: Relationship classes in NRCS's gSSURGO database.

The NRCS diagram above shows how map units in the database are structured so that they are related to soil horizons through the Mapunit Key. For the purposes of this project, the CMECS classification of any NRCS SSURGO substrate map unit was determined using the physical characteristics of that surface soil horizon's dominant component. For map units where there was not a dominant soil component, the top two subdominant components were used together. In the vast majority of cases, the final CMECS substrate classification of a map unit was not impacted by the use of two subdominant soil components as inputs (i.e. the subcomponent crosswalk results did not disagree). In the rare situation where CMECS classification of each soil subdominant component would have led to conflicting CMECS crosswalk results, the CMECS class was "rolled-up" to the point of agreement in a more generalized CMECS class.

Crosswalking data from NRCS SSURGO data into CMECS followed methods outlined in the EPSM Core GIS Methods document (Lanier et al., 2014) and is described below.

Geologic Substrate

Geologic Substrate had the following inputs for the CMECS classification:

- NRCS soils from the gSSURGO database in Washington and Oregon. NRCS soils data was interpreted for the entire tidal area and provides virtually seamless coverage.
- NWI. NRCS does not contain data for sub-aqueous areas. These areas were filled using NWI substrate information.
- LCEP Geomorphic Catena material were used to identify areas with bedrock material or anthropogenic substrates, such as road fill, railroad fill, or other fill.
- Estuary Plan Book (EPB) is older than these other sources, but in many places has more detailed information on substrates than NWI.

Within the geologic substrate, dataset prioritization was identified based on the level of detail available in the dataset. NRCS soils data were given priority over all other datasets. LCEP data were given priority over EPB and NWI. And lastly, EPB data (which provided more detail on substrates, despite being an older dataset) was given priority over NWI.

1.1 - Rock Substrate – This class is defined as igneous, metamorphic, or sedimentary rock with particle sizes greater than or equal to 4.0 meters (4,096 millimeters) in any dimension that cover 50% or greater of the Geologic Substrate surface.

1.2 – Unconsolidated Mineral Substrate - Geologic Substrates with less than 50% cover of Rock Substrate. This CMECS class uses Folk (1954) terminology to describe any mix of loose mineral substrate that occurs at any range of sizes—from Boulders to Clay. In the sections below, we describe how the NRCS sieve size information was translated into the CMECS substrate classifications. Many use the percentage ratios shown in figure 4 to differentiate between subclasses of course of fine sediments.

1.2.1 - Coarse Unconsolidated Substrate - If more than 95% of the sample is held by sieve 10 (2mm), the sample is Coarse Unconsolidated Substrate. These substrates correspond to the top three levels of the Folk Gravel-Sand-Mud pyramid diagram.

1.2.1.2.1 - Sandy Gravel - If 70-20% of the sample passes sieve 10, and less than 10% of the sample passes sieve 200 (.0625mm), then the sample is Sandy Gravel.

1.2.1.2.2 - Muddy Sandy Gravel - If 70-20% of the sample passes sieve 10, and less than 10% of the sample passes sieve 200, then the sample is Muddy Sandy Gravel.

1.2.1.2.3 - Muddy Gravel - If 70-20% of the sample passes sieve 10, and 50-100% of the sample passes sieve 200, then the sample is Muddy Gravel.

1.2.1.3.2 - Gravelly Muddy Sand - If 95-75% of the sample passes sieve 10, and 10-50% of the sample passes sieve 200, then the sample is Gravelly Muddy Sand.

1.2.1.3.3 - Gravelly Mud - If 95-75% of the sample passes by sieve 10, and 50-100% of the sample passes sieve 200, then the sample is Gravelly Mud.

1.2.2 - **Fine Unconsolidated Substrate** - Geologic Substrate surface layer contains less than 5% gravel (particles 2 millimeters to < 4,096 millimeters in diameter). These sediments are classified using the bottom two rows of the Folk (1954) Gravel-Sand-Mud diagram, (figure 4 above), and the entire Folk (1954) Sand-Silt-Clay pyramid diagram. In using the NRCS soils data, if less than 95% of the sample is held by sieve 10, the sample is Fine Unconsolidated Substrate.

1.2.2.1.1 - Slightly Gravelly Sand - If more than 95% of the sample passes sieve 10, and less than 10% of the sample passes sieve 200, then the sample is Slightly Gravelly Sand.

1.2.2.1.2 - Slightly Gravelly Muddy Sand - If more than 95% of the sample passes sieve 10, and 10-50% of the sample passes sieve 200, then the sample is Slightly Gravelly Muddy Sand.

1.2.2.1.3 - Slightly Gravelly Sandy Mud - If more than 95% of the sample passes sieve 10, and 50-90% of the sample passes sieve 200, then the sample is Slightly Gravelly Sandy Mud.

1.2.2.1.4 - Slightly Gravelly Mud - If more than 95% of the sample passes sieve 10, and 90-100% of the sample passes sieve 200, then the sample is Slightly Gravelly Mud.

1.2.2.3 - Muddy Sand - If 100% of the sample passes sieve 10, and 10-50% of the sample passes sieve 200, then the sample is Muddy Sand.

1.2.2.4 - Sandy Mud - If 100% of the sample passes sieve 10, and 50-90% of the sample passes sieve 200, then the sample is Sandy Mud.

1.2.2.5 – Mud - If 100% of the sample passes sieve 10, and 90-100% of the sample passes sieve 200, then the sample is Mud.

Datasets

- gSSURGO database (Washington and Oregon), Natural Resource Conservation Service (NRCS)
- National Wetlands Inventory (Washington and Oregon), U.S. Fish and Wildlife Service (USFWS)
- Geomorphic Catena, Lower Columbia Estuary Partnership (LCEP)
- Estuary Plan Book (EPB), Department of Land Conservation and Development (DLCD)

Biogenic Substrate

Biogenic Substrates are classified as areas where the percent cover of non-living Biogenic Substrate exceeds percent cover of both Geologic Substrate and Anthropogenic Substrates, when all are considered separately. Biogenic substrates are classified at the higher levels by taxonomy and at the lower levels by median particle size.

Our project team classified organic soils (taxonomic order of histosols and other histic taxonomic subgroups) as Biogenic Substrates. Soils with minor components of histosols were not mapped. The following NRCS soil mapping units (shown in Table 1) were mapped as Biogenic Substrates, based on expert guidance (Thor Thorson, Jericho Winter, and Steve Campbell of NRCS). Only those soils whose major components are predominantly organic are included. Soil mapping units that had only minor components of organic soils were not included.

County	Clastop	Columbia	Clark	Cowlitz	Pacific
Expert	*Thor Thorson, 2014*	*Jericho Winter, 2022*	*Steve Campbell, 2022*	*Steve Campbell, 2022*	*Steve Campbell, 2022*
Soil Map Units (map unit	5A - Bergsvick	15 - Crims silt loam, protected	Sr - Semiahmoo muck	195 - Semiahmoo much, 0 to 1 percent slopes	108 - Orcas peat

	6A-Brallier		Su - Semiahmoo much, shallow variant		132 - Seastrand mucky peat
	11A-Coquille-Clatsop				
	12A-Coquille-Clatsop				

Biogenic Substrate Datasets

- gSSURGO database (expert input Washington and Oregon), Natural Resource Conservation Service (NRCS)

Anthropogenic Substrate

Substrates where percent cover of Anthropogenic Substrate exceeds percent cover of both Geologic Substrate and Biogenic Substrates, considered separately. Anthropogenic Substrates are classified at the higher levels by composition and at the lower levels by median particle size.

In general, sources that could supply better spatial resolution or higher specificity of substrate material type were given preference over sources of lower spatial resolution or substrate material type. Where multiple sources contributed potential conflicting classifications, the final CMECS class was determined by "rolling up" to the level where the more specific classes no longer disagreed.

3.0 - Anthropogenic Substrate -

- The FAA Airport layer was used to identify airport fill, and LiDAR was used to Heads-Up-Digitize those areas and classify them as "Anthropogenic Rock" in CMECS.
- The Columbia River Estuary Ecosystem Classification (CREEC) Cultural Features identified "Fill areas" and were classified as "Anthropogenic Substrate."
- Washington Department of Natural Resources Overwater Structures in Rivers where "Structure" is classified as "Fill area."
- The Federal Aviation Administration (FAA) Airports data layer was used to identify areas of fill associated with airports.
- Primary, secondary, tertiary, residential and unclassified roads from Open Street Map in Washington and Oregon (Geofabrik, 2021) were used to identify the road centerlines. Line features were turned into polygon features by the creation of a buffer based on an average width of a random sample (based upon a classification of each road type provided by Geofabrik, 2021).
- The Open Street Map (Geofabrik, 2021) railroads features were classified as "Anthropogenic Substrate." Line features were turned into polygon features by the creation of a buffer based on an average width of a sample of railroads in Oregon and Washington.
- The Open Street Map land use data layer was used to identify areas of "industrial," "retail," or "residential" use and were classified as "Anthropogenic Substrate."
- Coastal Building Footprints (DOGAMI, 2015) were used to identify buildings within the project area. Only structures on land were included, and any of the building footprints that

were overwater structures (within areas classified as “Channel” in the Geoform setting) were not included since they are overwater structures and are not necessarily modifying the underlying substrate as they do on land.

3.1 - Anthropogenic Rock - Anthropogenic Substrate that is primarily composed of natural mineral materials that were purposefully or accidentally deposited by humans. This includes breakwaters made of natural stone, dredge material, artificial reefs made of natural stone, as well as beach nourishment and beach fill. Shape for this substrate class is covered in the GC (e.g., Groin, Breakwater, and Dredge Deposit). If the origin of a feature cannot be determined, it is assumed to be of natural origin and classified in the Geologic or Biogenic Substrate Origin.

- LCEP Levees dataset was used to classify “Man-Made Levees” made of earth or fill as “Anthropogenic Rock” in CMECS.
- The CREEC Level V Geomorphic Catena where material is equal to dredge spoils were used and classified as “Anthropogenic Rock” in CMECS.

3.1.2 - Anthropogenic Rock Rubble - Substrate that is dominated by Anthropogenic Rock with a median particle size of 64 millimeters to < 4,096 millimeters (Cobbles and Boulders).

- The Levees Inventory (Mattison, 2011) “Rip Rap” class (jetties were classified as “Rip Rap” in the Levees Inventory) was used to identify “Anthropogenic Rock Rubble” in CMECS. Those “Rip Rap” features were converted to polygon features using the buffer tool (20ft).

3.1.3 - Anthropogenic Rock Hash - Substrate that is dominated by Anthropogenic Rock with a median particle size of 2 millimeters to < 64 millimeters (Granules and Pebbles).

- The Levees Inventory (Mattison, 2011) was used to classify road beds or railroad bed levees as “Anthropogenic Rock Hash” in CMECS. Those features classified as roads or railroads in the Levees Inventory were converted to polygon features using the buffer tool (20ft).
- Open street map roads were classified as “Fill Area” and given a substrate class of Anthropogenic Rock Hash. Open street map feature types were used to identify the road centerlines. Line features were turned into polygon features by the creation of a buffer (based on an average width of a random sample by Geofabrik, 2021).
- Railroads (Open Street Map, 2021) were used to identify railroad centerlines. Railroad features were turned into polygon features by the creation of a buffer (based on an average width of a random sample by Geofabrik, 2021).

3.3 - Construction Materials - Anthropogenic Substrate that is composed of any single construction material or combination of construction materials (concrete, brick, rebar, pipe, porcelain, fiberglass, rubber, plastic, < 50% wood, < 50% metal, etc.) that were manufactured by humans.

- NCRS SSURGO database map units were used to classify dams as “Construction Materials”
- The Columbia River Estuary Ecosystem Classification (CREEC) Cultural Features data from 2012 was used to classify dams as “Construction Materials.”

Anthropogenic Substrate Datasets

- Columbia River Estuary Ecosystem Classification (CREEC) Cultural Features (USGS, 2011)
- Lower Columbia River Levees (LCEP, 2011) * buffer by 20 feet

- Public Access Inventory (DLCD, 2021)
- GNIS Names (USGS, 2021)
- Wetland Impacted Area layer (from the Land Administration System (LAS) Database) (DSL, 2021)
- Overwater Structure Inventory (WA DNR, 2017)
- Columbia River Estuary Ecosystem Classification (CREEC) Level V Geomorphic Catena (USGS, 2011)
- Airports (Federal Aviation Administration/FAA, 2021)
- Open Street Map Railroads WA, OR (Geofabrik, 2021)
- Open Street Map Roads WA, OR (Geofabrik, 2021) *buffered based on road classification
- Open Street Map industrial, residential, and retail areas WA, OR (Geofabrik, 2021)
- Open Street Map Buildings WA, OR (Geofabrik, 2021)
- Building footprints, Oregon (DOGAMI, 2015)

Geoprocessing Reference Datasets

- ESRI Aerial Imagery
- World Imagery Wayback (ESRI, 2021)
- DOGAMI LIDAR (Digital Terrain Model)

Modifiers

Modifiers are physicochemical, spatial, geological, biological, anthropogenic, and temporal variables with defined categorical values and ranges that are used to describe CMECS units. Modifiers can be applied when additional information is needed to further characterize an identified unit for individual applications. Modifiers provide additional environmental, structural, or biological information about the ecosystem; modifiers are useful for description and application but are not required for classification according to the CMECS schema. Modifiers are a dynamic component of the CMECS in the sense that users are free to apply additional local modifiers for their project needs as long as these are reported and do not conflict with the established definition of modifiers in the CMECS document.

Anthropogenic Impact Modifiers

Dredged (A104): Landscape that is mechanically altered by the removal of sediments or other materials (e.g., shell) in order to deepen or widen channels (e.g., for navigation or alteration to hydrology). Dredged channels were identified through the “Coastal Maintained Channels in US waters” dataset from NOAA. Channels that are “regularly maintained” were included and given the “dredge” modifier in the Aquatic Setting.

Impounded/diverted (A107): Areas where artificial construction impedes, redirects, or retains hydrological flow by building or placing barriers (e.g., dams, levees, dikes, berms, seawalls, or piers); these structures are designed to either retain water or to prevent inundation. To identify areas affected by dikes and other artificial barriers, we used a GIS layer of tidally restricted areas by LCEP. Another layer, PMEP’s tidal wetland loss layer, was used as a reference to identify additional areas “lost” to tidal inundation in areas beyond the extent of LCEP’s dataset and as a second validating source for the diked area classification.

The LCEP tidally restricted areas layer was created to show the approximate degree of tidal/fluvial inundation of the lower Columbia River floodplain wetlands, relative to historical times prior to anglo-European settlement (Keith Marco, 2021. Initial tidal/fluvial delineation (inundated vs. upland) was done by comparing 2010 LiDAR elevation data to a localized estimated benchmark elevation to identify areas which would flood based on elevation. Benchmark elevation varies with distance upstream, and incorporates both the MHHW level as well as effects of river discharge, which become increasingly dominant with distance upstream from the river mouth. Final correction factors were also applied based on water surface elevation data collected in 2009-2010 for 23 off channel sites. Once initial delineation of upland vs. wetland was completed, wetland areas were classified based on hydrologic access, using the following relative degrees of tidal restriction:

> 1. Fully inundated/unrestricted: areas which receive full or mostly full inundation relative to the historical period. Generally includes wetlands which have not been blocked by a man-made structure, or have been fully restored by an action such as a complete levee removal.
>
> 2. Partially inundated: areas which receive regular tidal inundation, but to a somewhat lesser degree than full historical inundation. Generally includes areas which have been partially restored by an action such as a levee breach, where much of the levee is still present and impeding inundation.
>
> 3. Mostly restricted: areas which receive little regular tidal inundation, due to the presence of a man-made structure. Generally includes areas with a structure such as a levee in combination with one or more culverts or partially functioning tidegates.
>
> 4. Fully restricted: areas which receive no tidal/fluvial inundation, due to the presence of a man-mad structure. Generally includes areas that are completely blocked by a levee, or channels with a one way tidegate which allows drainage but no inundation.

In our project, we intersected the “full restricted” and “mostly restricted” areas with maps for the CMECS Aquatic Setting. Polygons were assigned the Anthropogenic Impact modifier “Impounded/diverted” (which includes diked areas). The results were reviewed by our Estuary Habitat Specialist and Technical Advisory Committee, and revisions to diked status were made based on their input.

Restored (A108): Areas where restoration activities have been conducted; may include planted areas. To identify restored areas, we used two datasets: (1) LCEP’s Columbia Habitat Restoration Inventory (LCEP, 2020) and (2) PMEP’s Indirect Assessment of Tidal Wetland Loss (PMEP, 2020).

The LCEP dataset includes an Inventory of completed and in-construction habitat restoration projects throughout the lower Columbia River floodplain and it's lower tributary reaches, that have been executed from 1999-2020. Included are projects that have been sponsored by the Estuary Partnership and its partner organizations. In the LCEP dataset, polygons associated with “levee breach/removal” or “point barrier removal or modification” for tidegate modification or removals identified.

PMEP’s Indirect assessment of tidal wetland loss dataset provides an indirect estimate of emergent, scrub-shrub and forested tidal wetland losses for 55 non-lagoonal estuaries spanning the contiguous United States West Coast, including the Columbia River. Losses are defined as those areas that were tidal wetlands prior to European settlement, but are no longer tidal wetlands today. Losses were estimated by comparing the National Wetland Inventory's mapping of current tidal wetlands to the Pacific Marine and Estuarine Fish Habitat Partnership (PMEP)'s West Coast Estuary Extent mapping. The estuary extent layer represents the likely historical extent of tidal wetlands, so areas not identified as current tidal wetlands in the National Wetlands Inventory (NWI) are considered "lost" in this analysis. This dataset has also removed from the "loss" calculation, those areas that are known to have been restored. Polygons attributed as "Restored" in PMEP's tidal wetland loss dataset were queried. Features from both of these datasets representing restored areas were overlaid with the CMECS Aquatic Setting an attributed with "Restored" modifiers.

Modifier Datasets

- Restored areas: LCEP Columbia Habitat Restoration Inventory (LCEP, 2020)
- Tidally Restricted Areas (LCEP, 2020)
- Indirect Assessment of Tidal Wetland Loss (PMEP, 2020)
- Coastal maintained channels (NOAA, 2015)

References

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