ShoreZone Coastal Imaging & Habitat Mapping Protocol

December 2017

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ShoreZone

Photos on Previous Page:
Helm Point, Coronation Island, Alaska
Bangookbit Dunes, Nunivak Island, Alaska
Coos Bay, Oregon
Prince Rupert, British Columbia

ShoreZone Coastal Imaging and Habitat Mapping Protocol

December 2017

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Summary

ShoreZone is an aerial imaging, coastal habitat classification and mapping system used to inventory alongshore and across-shore geomorphological and biological attributes of the shoreline. The georeferenced, oblique, low altitude aerial imagery is acquired during the lowest tides of the year and then used to classify habitat attributes into a searchable database. This data is used for coastal planning, identification of vulnerable resources, oil spill response planning, habitat modeling, recreational planning and scientific research.

The conceptual framework for the ShoreZone habitat mapping and classification system was developed and tested on shorelines near Victoria, British Columbia in the summer of 1979. The standardized protocols for both the imagery collection and habitat classification, which were developed shortly thereafter, have been updated as throughout the years. Improvements in technology has allowed for the collection of more detailed data from the high resolution digital imagery, although the basic attributes have remained consistent for ShoreZone mapping, which now covers over 120,000 km of the west coast of North America and into the Arctic. The imagery and habitat data, including previous protocols and summery reports for Alaska, Oregon and Washington State, are accessible from either the NOAA ShoreZone or ShoreZone.org websites. Some of the British Columbia imagery is available through the Coastal and Ocean Resources ArcGIS site while the habitat mapping data can be obtained by contacting Coastal and Ocean Resources or GeoBC.

This current version of the ShoreZone protocol builds on the 2014 protocol document and details several additions and revisions including:

- Use of Structure from Motion software to process ShoreZone video captures to render orthophotos and allow better estimation of zone widths,
- Revised Bioband classification and codes and new metrics including percent cover estimates,
- Estimation of wave energy dissipation in the intertidal area (Iribarren category),
- Revised coastal Flood Zone and Stability Indices,
- And the development of new comprehensive Coastal Vulnerability Index to estimate the vulnerability of a unit to sea level rise.

This protocol is not meant to be specific to any geographic region but is applicable to all ShoreZone mapping done from January 1, 2016 until the next revision of the protocol is published. For mapping completed previous to January 1, 2016, please consult the 2014 ShoreZone protocol (Harper and Morris, 2014).

Table of Contents

List of Tables

List of Figures

Section 1.0
Introduction to ShoreZone

1.1 The ShoreZone System

Coastal habitats serve a number of important ecological functions including nesting, breeding or refuge areas for wildlife, fisheries, food web support, sediment trapping, and nutrient cycling (Beck *et al*. 2001). Information regarding the distribution and type of coastal biota is critical for making sound management decisions. Local, state, and federal regulatory agencies require this information for planning, zoning, leasing, and permitting. The current management focus on marine habitat conservation is a response to the general degradation of coastal ecosystems brought on by ocean margin development, overutilization of marine organisms, the lack of knowledge about coastal ecosystems and how to manage them (Crowder *et al*. 2006). In order for conservation measures to be effective, coastal habitats and the biological communities associated with them need to be defined (Costello 2009). The spatial distributions of characteristics, unique, and at-risk habitats, and the current ecological status of each need to be defined as well (Groves *et al*. 2002). However, this level of detail is often absent over the relevant spatial scales of conservation planning (Lourie and Vincent 2004). ShoreZone is a coastal imaging and habitat mapping system developed to describe the complexity of the supratidal, intertidal, and nearshore subtidal zones that comprise the coastal margin and address some of those identified knowledge gaps.

ShoreZone uses aerial imagery of the coastline (Section 2.0) to partition a digital representation of the shoreline into relatively homogenous segments, as defined by a suite of environmental attributes. ShoreZone then describes the physical and biological attributes of each unit (Section 3.0). This protocol describes the data standard that is the heart of the ShoreZone program, both in terms of the collection of imagery and the classification of the unit attributes. Such a standard enables queries of data over large geographic regions. This is especially important now that ShoreZone has been implemented along ~120,000 km of the coast of the Pacific Northwest from Oregon to the Arctic in Alaska (Figure 1). Section 1.2 provides background information about the development of ShoreZone since its initiation in British Columbia in 1979.

ShoreZone data (imagery and habitat mapping) from Alaska, Oregon and Washington State is accessible from the NOAA ShoreZone site and from ShoreZone.org which has been maintained by The Nature Conservancy in the past. The Alaska dataset is also part of the Alaska Ocean Observing System data portal (search for ShoreZone under the available data layers). The full mapping geodatabase can also be downloaded and queried for information. The ShoreZone coastal mapping data and imagery have been used for a multitude of purposes over time. Some of these applications are detailed in Section 1.3.

This protocol document serves to detail the methods used to classify each attribute of the ShoreZone geodatabase for ShoreZone mapping done after January 1, 2016, although it is also broadly applicable the rest of the dataset. This document is therefore meant to be for users of that geodatabase, which is available for download from the NOAA ShoreZone site. Please see Table 1 below for a list of previous ShoreZone protocols with links to those documents and Figure 3 for the geographic areas they were applied to. Summary reports for the habitat mapping done in each survey completed in Alaska, Oregon and Washington State are also available through the NOAA ShoreZone website and provide specific details about each survey area with summary maps and statistics.

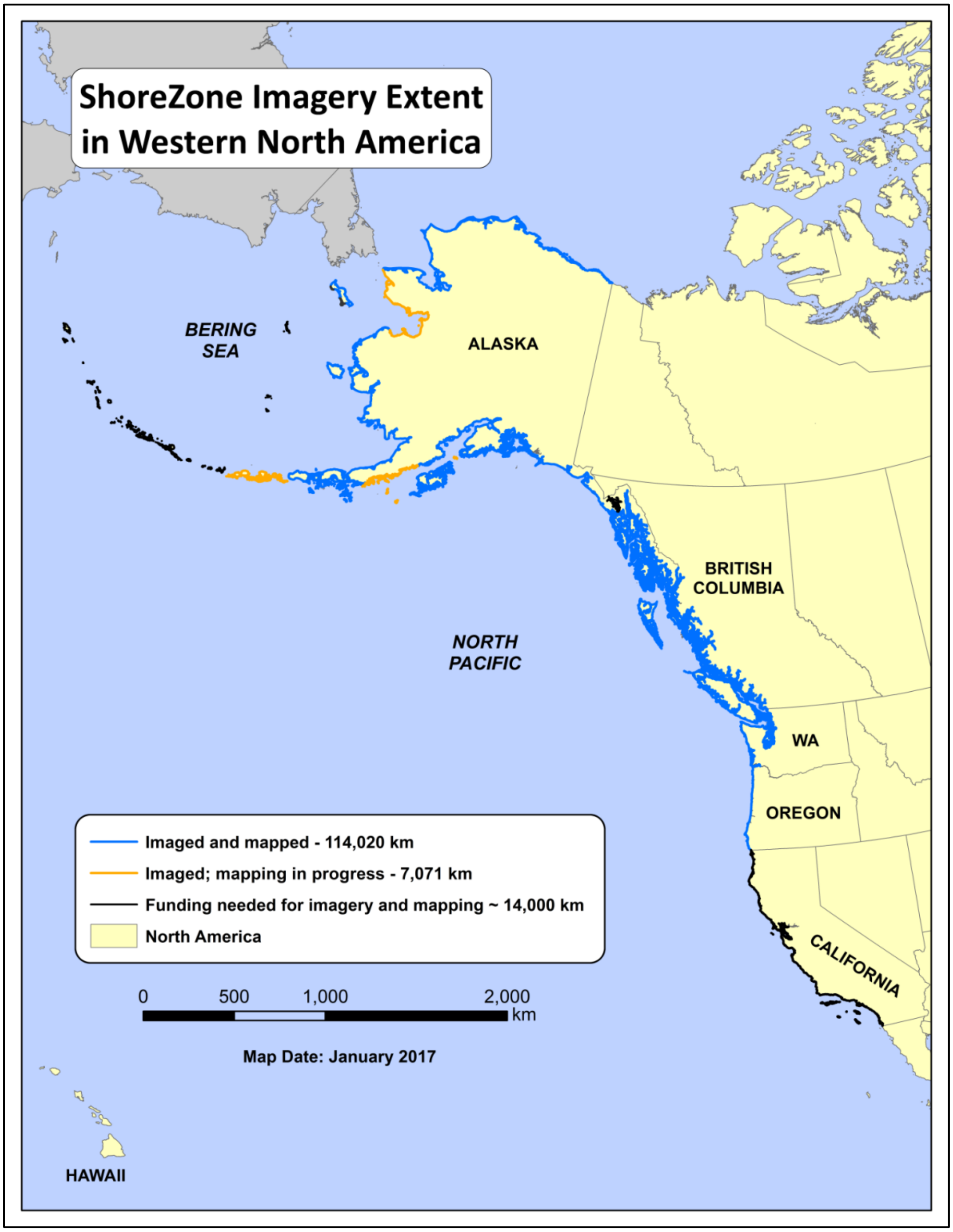


Figure 1. The extent of ShoreZone imagery and habitat mapping as of March 2017.

1.2 History of ShoreZone Development

The conceptual framework and coding system of the Physical ShoreZone Mapping System was first developed in 1979 for the British Columbia Ministry of Environment. This initial imaging and mapping system was originally tested on the shoreline of Saltspring Island near Victoria in the summer of 1979. It was during these pilot projects that the use of oblique video imagery for mapping the shoreline was tested. This technique has become an integral component in the process of ShoreZone mapping. A decade of further development resulted in the first physical mapping protocol being published by the British Columbia Ministry of Environment (Howes *et al*. 1994), with a companion biological classification published shortly after (Searing and Frith 1995). The fully integrated biophysical mapping system was first applied to Gwaii Haanas National Park with the remainder of British Columbia being completed from 1991 to 2007. The State of Washington was imaged and mapped between 1994 and 2002, with the coast of Oregon imaged in 2011 and mapped in 2013. The first Alaska ShoreZone mapping occurred in 2001 and is ongoing today. The protocols have continued to be updated to reflect improvements in imaging technology and the consequent refinement of attributes that can be classified from that imagery. Figure 2 shows a map of the sequence of imagery acquisition over the history of ShoreZone while Table 1 lists the various protocols published and Figure 3 shows where each protocol was implemented for mapping.

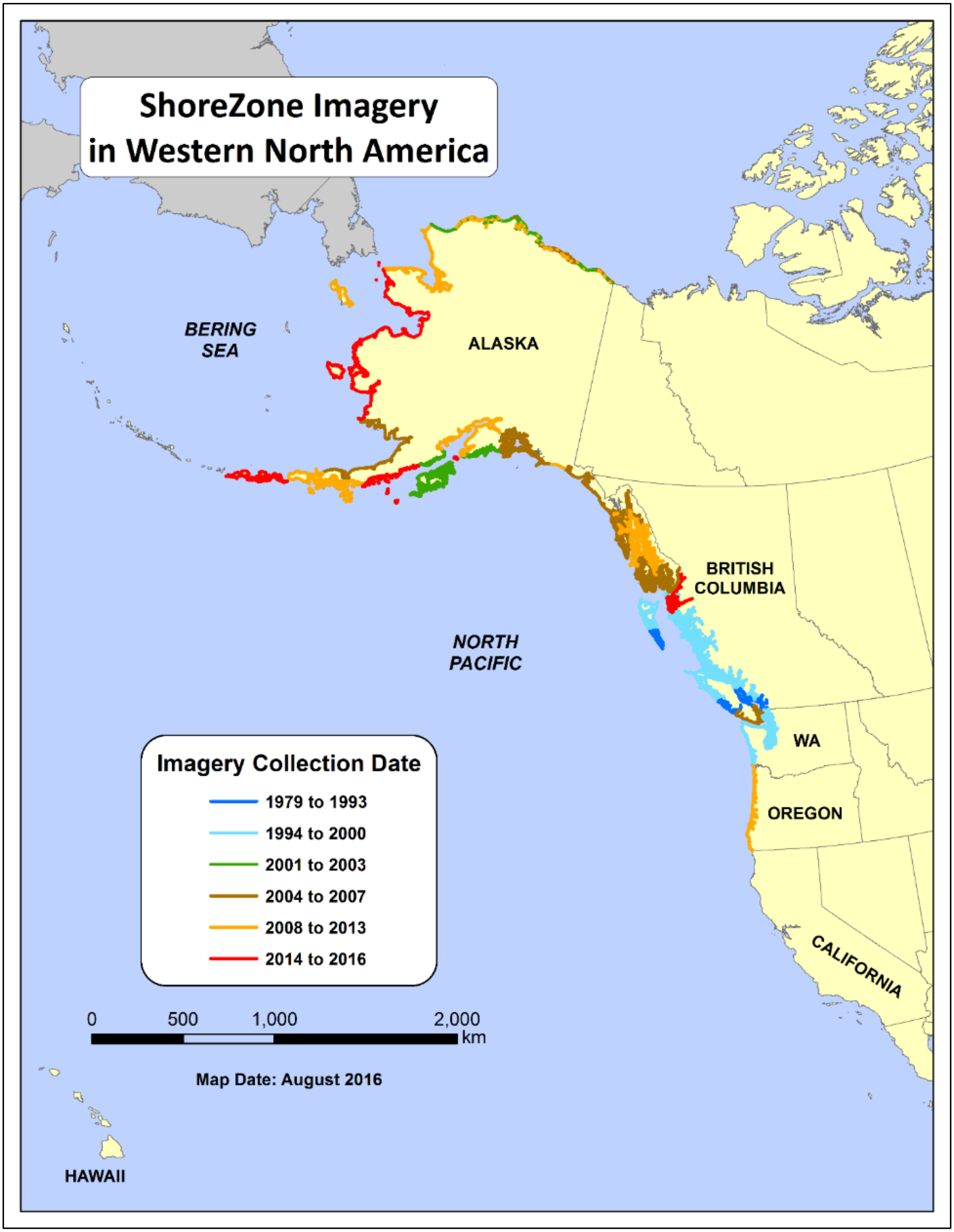


Figure 2. Chronology of ShoreZone imagery acquisition.

Table 1. Chronology of ShoreZone protocol revisions. See Figure 3 for map of where each protocol was used for habitat mapping.

Year	Authors	Protocol document title	Revisions
1980	Owens	Physical shore-zone analysis, Saltspring Island, B.C.	Original pilot project using aerial video, habitat classification using standardized codes
1994	Howes, Harper, Owens	Physical shore-zone mapping system for British Columbia	Documentation of standardized methods
1995	Searing and Frith	British Columbia biological shore-zone mapping system	Documentation of standardized methods
2004	Berry, Harper, Bookheim, Sewell, and Tamayo	Washington State ShoreZone Inventory User's Manual	Same as 1994 protocol but with anthropogenic features added
2004	Harper and Morris	ShoreZone Mapping Protocol for the Gulf of Alaska	Same as 2000 protocol but with procedures modified for the Gulf of Alaska
2008	Harney, Morris, and Harper	ShoreZone Coastal Habitat Mapping Protocol for the Gulf of Alaska	Same as 2004 protocol but updated with an illustrated data dictionary
2013	Harper, Morris, and Daley	ShoreZone Coastal Habitat Mapping Protocol for Oregon	Same as the 2008 protocol but with new wetlands forms and Biobands, and maps and an illustrated data dictionary for Oregon
2014	Harper and Morris	Alaska ShoreZone Coastal Habitat Mapping Protocol	Same as 2013 protocol but with maps and images from Alaska and updated to include periglacial landforms, wetland forms and Biobands, and assessments of coastal flooding and erosion although those assessments were not applied to the North Slope mapping project
2017	Cook, Daley, Morrow and Ward	ShoreZone Coastal Imaging and Habitat Mapping Protocol (this document)	Revised to include Structure from Motion orthophoto processing in the mapping workflow, estimation of shoreline Aspect, the introduction of categories for Intertidal Zone Slope, quantitative estimates for the Biobands, Enhanced mapping protocols, physical ESI mapping to full NOAA standards, revision of criteria for Flooding Index and Stability Index in the Coastal Vulnerability Module, the addition of a Coastal Vulnerability Index and qualitative wave energy dissipation categories.

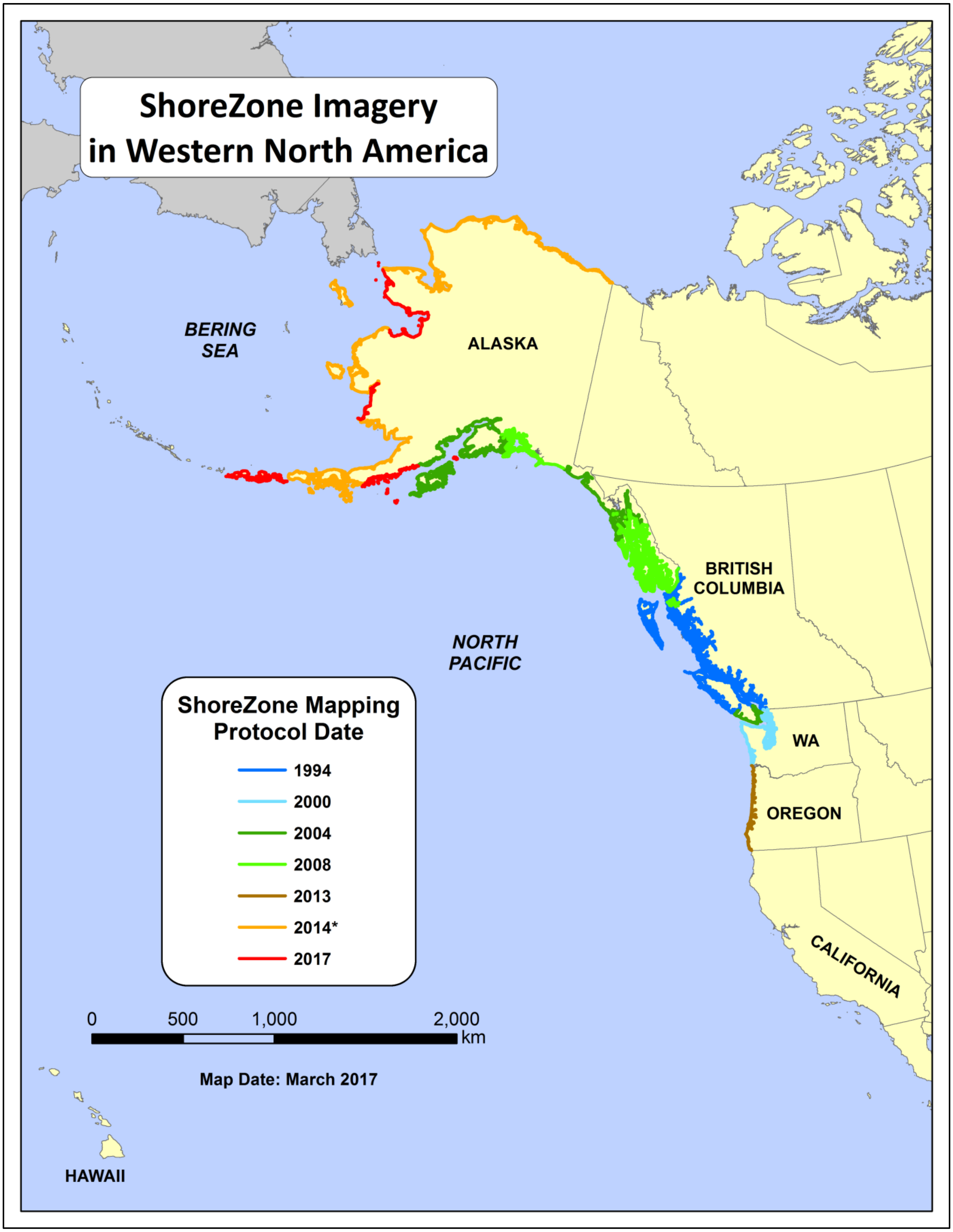


Figure 3. ShoreZone mapping associated with each protocol listed in Table 1.
*The 2014 protocol was applied to the North Slope (Chukchi and Beaufort Seas) without the Coastal Vulnerability Module described as part of that protocol.

1.3 Applications for ShoreZone Data

The ShoreZone database has broad utility for oil spill planning and response, research, habitat and species modelling, shoreline planning, habitat conservation, emergency and risk management, and potentially detecting change over time. Below are some projects that utilized ShoreZone imagery or mapping as well as some uses currently in development. This is not meant to be an exhaustive list of all projects that have utilized ShoreZone but illustrate a few examples of past potential uses.

Emergency and Risk Management
The utility of the ShoreZone data in an emergency was highlighted prior to the grounding of the Kulluk drill rig that was adrift in the Gulf of Alaska in late December 2012. ShoreZone imagery was used by the Incident Command Team along with modelled drift trajectory forecasts to rapidly assess remote shorelines near Kodiak Alaska (http://www.nytimes.com/2015/01/04/magazine/the-wreck-of-the-kulluk.html). The data and imagery revealed reefs and offshore pinnacles in the drift path which would have seriously damaged or sunk the rig. Instead, based in part on the information provided by ShoreZone, efforts were made to divert the rig further south to Ocean Beach where it grounded with relatively little environmental damage.

Habitat and Species Modelling
A habitat suitability model was constructed for the European green crab (*Carcinus maenas*) to identify potentially suitable habitats for this invasive species in coastal Alaska, British Columbia, and Washington using ShoreZone habitat mapping attributes (Harney 2007). A literature review and expert surveys were conducted to determine which ShoreZone attributes were considered critical to green crab colonization and should be included in the model. The ShoreZone database was then queried to rank shoreline units possessing those attributes with respect to habitat suitability for the green crab based on the number of critical habitat attributes that co-occurred within that unit. The modelled results were then compared to 15 known green crab occurrence sites on the west coast of Vancouver Island with a high level of positive correlation found between the model and the known sites. The model was intended to be used to design a monitoring program to look for green crab incursion in more northerly locations.

Marine Spatial Planning
There is a growing body of research demonstrating that marine zoning has a positive effect on resident communities of fish, mammals, birds, invertebrates, algae and plants. Zoning plans are intended to reduce present and potential conflicts among users and activities, provide business and user groups with regulatory guidelines, improve efficiency in permitting decisions, and provide general management directions for resource managers. Coastal and Ocean Resources conducted an ecological assessment for the Marine Planning Partnership for the North Pacific Coast (MaPP) program which used ShoreZone coastal habitat attributes as data layers in its spatial analysis. The MaPP partnership used a collaborative process for developing a coastal and marine zoning plan for the coast of British Columbia. More information can be found online at http://mappocean.org/. ShoreZone has also been used by The Nature Conservancy in its ecoregional conservation assessments in the Pacific Northwest and provides coastal habitat data that readily integrates into the Marxan spatial planning program for computed conservation scenarios.

Public Outreach/Education

Alaska's coastlines are remote and logistically inaccessible to most residents and visitors, but are a national treasure in terms of diverse natural history and scenery. In the process of mapping the coast's biological and geological habitats for ShoreZone, an archive of hundreds of thousands of high resolution digital images was created. This archive was used to create an exhibit of prints called '*Coastal Impressions: A Photographic Journey along Alaska's Gulf Coast'.* The exhibit was also published as a hard copy and a digital online booklet with annotated descriptions of the natural history, ecology, and/or coastal processes shaping the coastline within each image. The exhibit and booklet has reached thousands of Alaskans and visitors since its debut showing at the Alaska Marine Science Symposium in Anchorage in January 2012. The exhibit was sponsored by the Cook Inlet Regional Citizens Advisory Council (CIRCAC) and developed in partnership with NOAA Fisheries, Alaska Fisheries Science Center Auke Bay Laboratories, and the Alaska ShoreZone program. The exhibit was so well received that several agencies (BOEM, NPS, NOAA, Arctic LCC and CIRCAC) developed a second exhibit titled *Arctic Impressions: A Photographic Journey along Alaska's Arctic Coast* featuring photos from the Bering, Chukchi and Beaufort Seas. That exhibit was unveiled at the Alaska Marine Science Symposium in January 2014 and an interactive online photo booklet was produced.

Change Detection

Coastal habitats are constantly in flux, but natural and anthropogenic factors can cause change to occur more rapidly (i.e. more severe storm activity due to sea-level rise, isostatic rebound, climate change). These changes can affect coastal communities and their resources. Recent technological developments could allow ShoreZone imagery to be used to monitor change over time. This is especially valuable because all the Pacific Northwest has been imaged in the last 30 years, and some areas are now starting to be re-imaged. Figure 4 shows an example of imagery acquired in 2001 and again in 2009 in Cook Inlet, Alaska. The supratidal cliff in the example had eroded significantly during the 8-year interval. Erosional coastlines like this are especially vulnerable to sea-level rise and increased storm intensity associated with climate change.

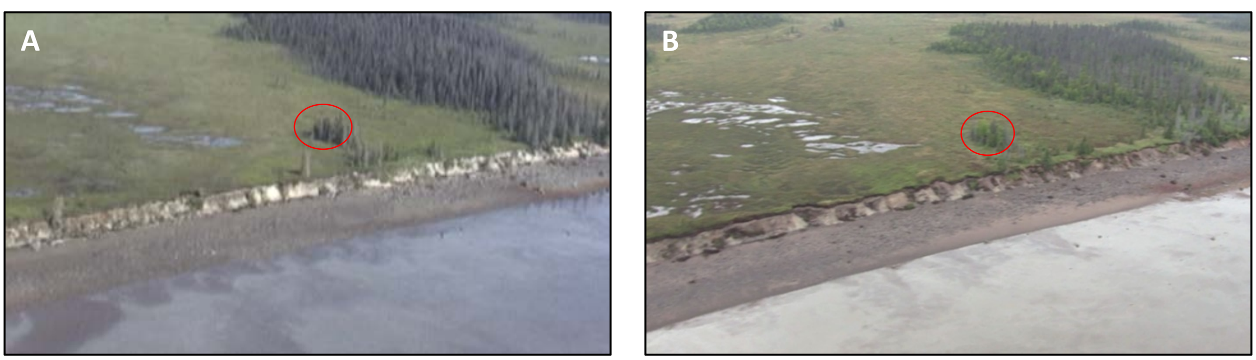


Figure 4. A) Video image taken during a ShoreZone survey in 2001 near Polly Creek in Cook Inlet. B) The same section of coast imaged during a ShoreZone survey in 2009. The red circles indicate a point of reference between the photos. It can clearly be seen that the supratidal cliff eroded in the 8 years between the surveys due to the loss of trees that were at the edge of the cliff in 2001.

Section 2.0
ShoreZone Imaging Protocols

ShoreZone imaging surveys are meticulously planned to ensure the capture of oblique coastal aerial imagery suitable for classification with the ShoreZone habitat mapping protocols. Logistical challenges that need to be planned for include tides, weather, marine mammals, fuel positioning and travel to and from the survey area. Imaging surveys are generally conducted during the lowest tide windows of the year when tidal elevations will be lower than zero feet (mean low water) in the U.S. and below 1 m in Canada. These tide windows range from 2 to 4 hours in duration each day of the tide window, although in some regions where astronomical tidal ranges are small (e.g. Beaufort Sea) and surges driven by meteorological conditions dominate water level changes, survey windows are less sensitive to tides and can be considerably longer.

Helicopters are the preferred aircraft for an imaging survey as it gives the maximum maneuverability, especially when imaging complex shorelines. The ShoreZone imaging team consists of three to four people, depending on the capabilities and size on the helicopter (see Figure 5). The videographer/geomorphological commentator sits in the rear left seat and takes continuous high resolution (HD) video of the shoreline and provides a verbal description of the physical characteristics of the shoreline. The video is captured as a digital file on flash cards with an external, simultaneous hard-drive backup. The photographer/biological commentator sits in the front left seat and takes high resolution still images, with one photo being taken every three to five seconds depending on the speed of the helicopter and complexity of the shoreline. The current photo resolution standard is 13.5 megapixels with photos saved as digital files on flash cards. A digital backup of the photos is created at the end of each day. The photographer also provides commentary regarding the biological communities present on the shoreline with particular focus on biota less easily identified in the imagery, such as subtidal kelps. The pilot is responsible for keeping the helicopter at a consistent distance from the waterline (100 m), at a consistent elevation (100 m) (see Figure 6) and at a consistent speed (60 knots). The distance from the waterline, elevation and speed can all vary depending on the morphology of the shoreline (wide tidal flats or platforms require higher elevation for proper imaging and complex shorelines require slower speeds) or weather (poor visibility often requires slower speeds for proper imaging). If there is room, a navigator sits in the rear right hand seat and gives direction to the pilot and ensures the smooth and continuous running of the GPS system which takes a positional fix every second. The time on the GPS is synced to the video and still camera each morning immediately before lift-off to ensure accuracy in the spatial positioning of the imagery. If there is not room for a navigator, the GPS recording is run by the videographer.

Figure 5. The ShoreZone team imaging the coast around Prince Rupert, BC in June 2015, consisting of the pilot, photographer/biologist, navigator and geomorphologist/videographer (from left to right).

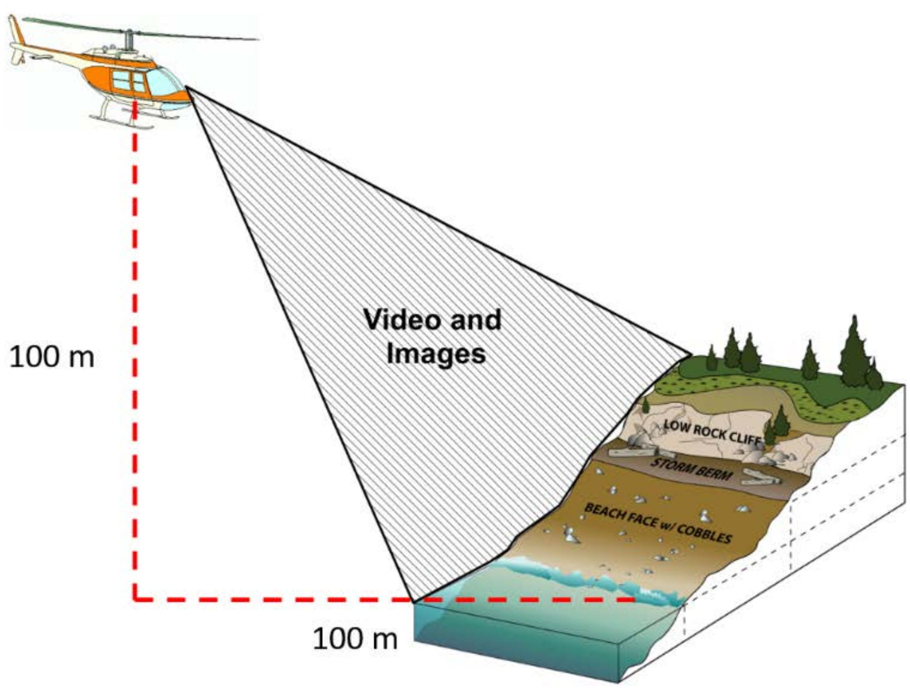


Figure 6. Oblique aerial images are acquired at 100 m altitude and 100 m offset from the shoreline leading to imagery at a 45^{o} angle to the intertidal.

The desired end products of these imaging surveys are oblique (45° angle to the beach), continuous video and photos of the intertidal zone at extreme low tide levels. The imagery is a critical part of the ShoreZone dataset. The Alaska, Oregon and Washington State imagery is accessible online through the NOAA ShoreZone site or ShoreZone.org, along with many of the survey flight logs that detail the area of the coast covered each day and any challenges encountered. Metadata (date, time, positional information, resolution, file size etc.) is attached to each video file and still image. The imagery from British Columbia is not currently part of that dataset although the long-term plan is to have the entire catalogue available online. However, a smaller subset of the more recent BC ShoreZone imagery is available through the Coastal and Ocean Resources ArcGIS site. All the imagery on these websites is georeferenced and attached to the helicopter flight line (see Figure 7).

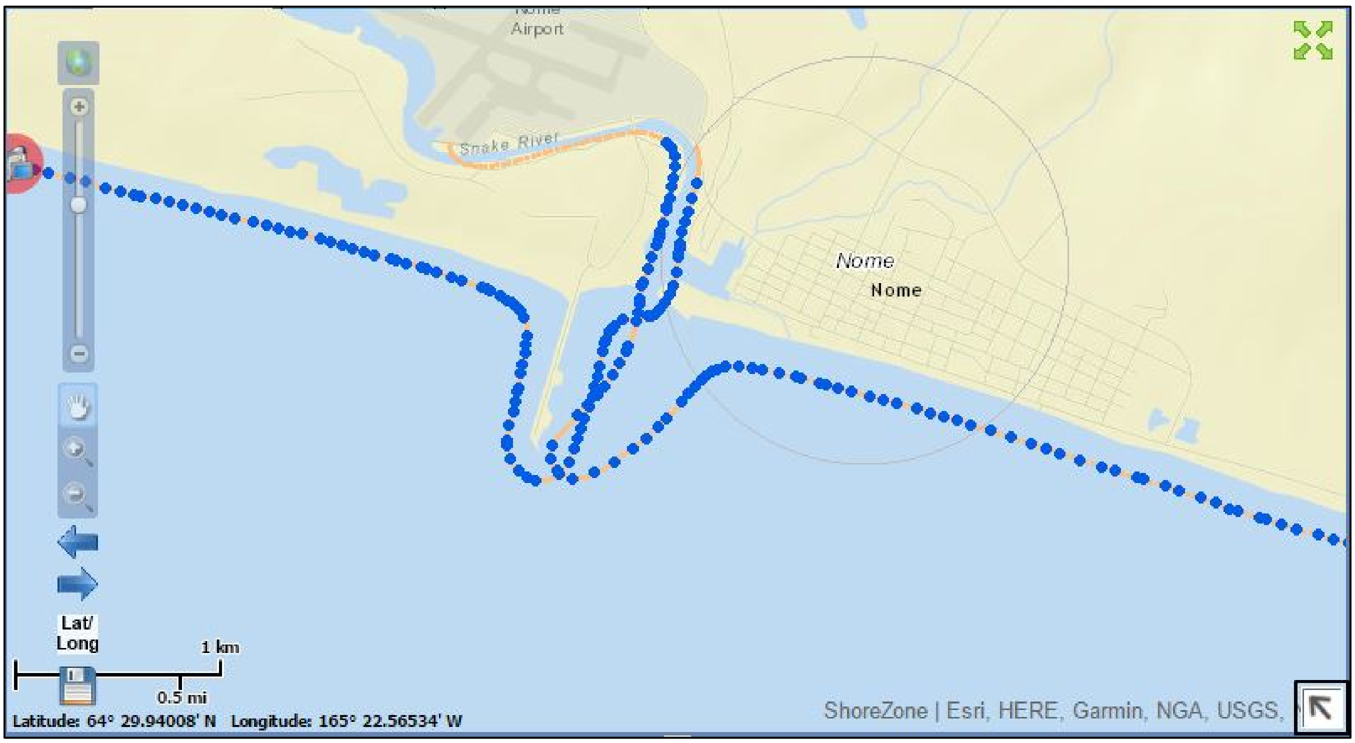


Figure 7. A screen capture of the imagery viewing interface on the NOAA ShoreZone website. This section is from Nome in Norton Sound which was imaged in summer 2015. The light red dots are the 1-second positional fixes for the video and the blue dots are the geo-referenced photo points. Clicking on any of those points allows the user to view the imagery (video and photo) at that point. Thematic layers are also available for the physical and biological attributes mapped as part of the ShoreZone habitat classification.

Section 3.0
ShoreZone Habitat Mapping Protocols

ShoreZone habitat mapping is done through interpretation of the oblique aerial ShoreZone imagery. The final format of that mapping is as a geodatabase which includes spatial referencing information for each ShoreZone unit. The following sections describe the attributes found in that geodatabase, starting with the spatial framework ShoreZone uses to link those attributes to a specific section of the coast (Section 3.1) and followed by detailed descriptions of the main physical (Section 3.2) and biological (Section 3.3) attributes that comprise the dataset. A data dictionary that defines the fields in the geodatabase maintained by NOAA for Alaska, Oregon and Washington State habitat mapping can be found in Appendix A. This geodatabase can be downloaded from the NOAA ShoreZone website. That downloadable geodatabase has slightly different field names to those described in Appendix A although the definitions for the attributes are the same. A data dictionary for the NOAA ShoreZone geodatabase is also found on the NOAA ShoreZone website, although it is in the process of being updated. A guide to querying out data from the ShoreZone database in ArcGIS and MS Access is also available. The British Columbia ShoreZone geodatabase can be requested from either Coastal and Ocean Resources or GeoBC.

3.1 Spatial Framework for ShoreZone Mapping

The first step in ShoreZone mapping is the delineation of a digital shoreline into linear segments. These segments are the main spatial feature of the ShoreZone dataset and are called **Units**. All the physical and biological attributes of the Unit are attached to that linear segment of the digital shoreline so they are spatially explicit. A Unit is defined in ShoreZone as “a relatively homogenous stretch of the coast in terms of substrate composition, slope, width and wave exposure, as interpreted from ShoreZone oblique, low altitude, aerial imagery”. If any of those attributes change significantly a new Unit will be broken out on the digital shoreline. Small features that differ somewhat from the composition of the overall unit are described in the database attributes as forms within the larger Unit but are not spatially explicit within the Unit. There are also point features in the ShoreZone dataset, called **Variants**. These Variants are the mouths of rivers and streams that flow into the main Unit, although in older mapping point features may capture other anomalous features such as shipwrecks, marine mammal carcasses, etc. (see Table 1 and Figure 3 for the protocol used to map each section of the coast). The Variant is attached to the Unit at the point where the feature crosses the digital shoreline (which is usually the digital representation of the Mean High Water line). A small subset of physical and biological attributes is classified for each Variant.

To link the digital unit or variant to the attributes in the geodatabase, each is given a unique identifier. This identifier is made of a **Region Code**, **Area Code** (with multiple Areas nesting in each larger geographic Region), **Unit Number** and **Subunit Number** with each separated by a slash (ex. 10/03/0001/0). This is collectively called the **Physical Identifier**, or 'Phy Ident'. The Subunit Number is only applicable to point features so it always has a value of '0' for linear Units. Variants will be numbered according to their occurrence in the Unit (ex. 10/03/0001/4 would be the fourth stream mouth in unit 10/03/0001/0). See Figure 8 for an example of how ShoreZone Units are displayed on a digital shoreline.

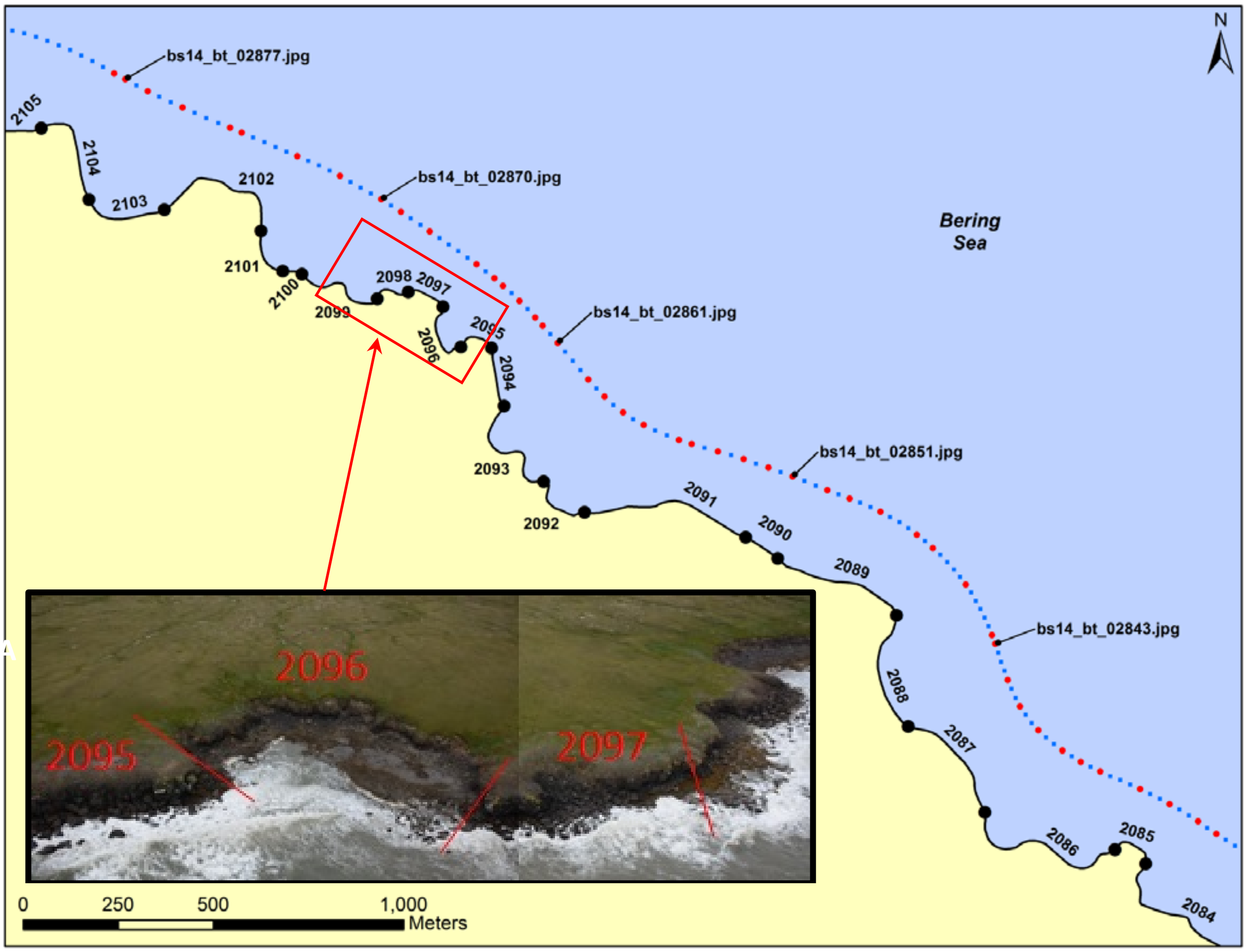


Figure 8. Example of the delineation of the digital shoreline of Nunivak Island in the Bering Sea. The inset shows a mosaic of the high resolution digital still images of the section of shoreline highlighted by the red box, with the corresponding Unit breaks shown on the photos. The blue dots show the helicopter flight line with each dot representing a 1-second positional fix for the video imagery and the red dots showing the photo locations.

The spatial framework of ShoreZone is dependent on the digital shoreline. ShoreZone mapping can only be accurately displayed if the digital shoreline is accurate, so it is important to use the best available at the time. In Alaska, the operational standard for most ShoreZone mapping is the NOAA Coast63 shoreline which is a rough cartographic representation of the Mean High Water line derived primarily from United States Geological Survey (USGS) topographic maps at 1:63,360 scale (1 inch=1 mile). Much of this is based on ca. 1950 aerial photographs. Since then, substantial changes have modified the shoreline, including coastal erosion, major storm events and the 1964 earthquake in Alaska that altered the shoreline up to 15 m in some places.

Tests conducted by the National Park Service (NPS) in Alaska along three park shorelines have shown discrepancies of well over 100 m between the digital shoreline and what is seen on the imagery (Figure 9). When significant discrepancies between the digital shoreline and the imagery are identified during mapping, ShoreZone mappers typically do not make alterations to the digital layer. Missing shoreline features, those that are present on the digital shoreline but not observed in the imagery are generally not deleted since these could be offshore reefs that do not appear on the imagery but should remain part of the basemap. It can happen that more shoreline is noted in the imagery than appears on the digital shoreline, for example, a lagoon behind the beach that is tidal in nature but is not represented digitally. This discrepancy is recorded by putting a multiplier in the geodatabase field called Shore Problem that indicates how much more shoreline length should be represented by the digital shoreline.

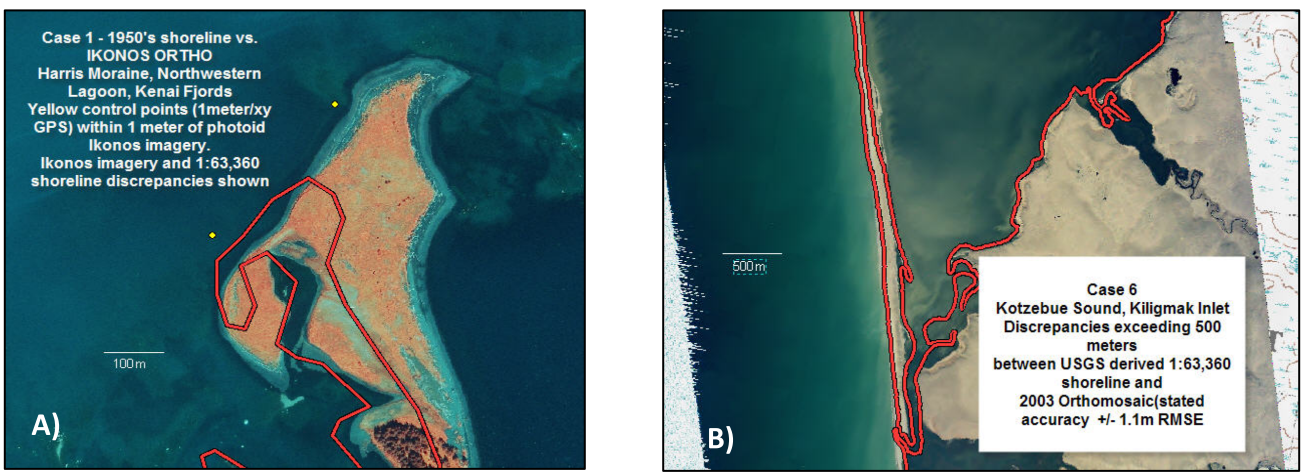


Figure 9. Discrepancies between the Coast 63 digital shoreline and satellite imagery for two National Parks in Alaska. A) shows Kenai Fjords and B) shows Kotzebue Sound.

The unit is the primary part of the ShoreZone spatial framework and provides the structural foundation. To provide a more detailed description of the shore, each alongshore unit is also vertically partitioned into across-shore zones (which is where ShoreZone gets its name) and components which are across-shore subdivisions of each of those zones.

ShoreZone defines three across-shore **Zones**: the supratidal (A Zone), the intertidal (B Zone) and the subtidal (C Zone) (see Figure 10). The supratidal zone lies between the Mean Higher High Water (MHHW) and the upper limit of marine influence. The supratidal is also referred to as the splash zone, with the upper edge often marked by the presence of terrestrial vegetation. The intertidal zone lies between the Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW) indicated by a line of swash debris or the base of the black lichen on rocky shores. This region is inundated by the daily tide cycle. The subtidal zone is defined as anything below the water line on the imagery for the purposes of ShoreZone mapping.

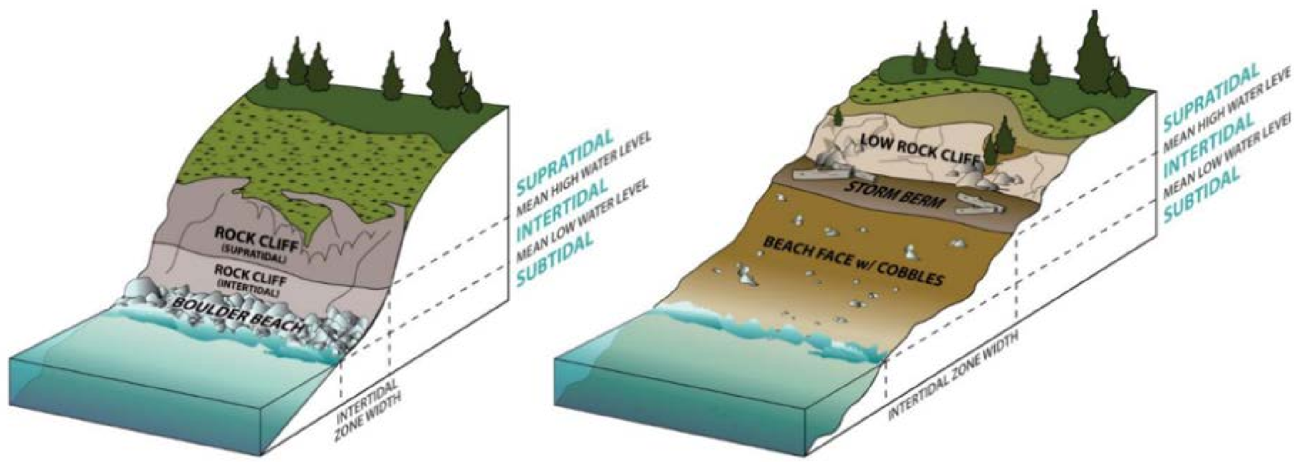


Figure 10. Across-shore zones and components on a steep (left panel) and moderately inclined (right panel) shoreline.

During the classification, each across-shore zone is subdivided into **Components**, which are defined based on morphology and sediment texture. Features such as dunes, beach berms, beach faces, and beach terraces are examples of across-shore features that would be broken out as separate Components within a zone. The Components are numbered from highest to lowest elevation along an across-shore profile within each Zone (e.g. A1 is the highest supratidal Component; A2 is next lower and closer to the intertidal; B1 is the highest intertidal Component and B2 would be the lower intertidal; the subtidal generally only has one Component, the C1). The Components can be thought of as forming an across-shore transect as a person would observe when walking from the terrestrial area (dominated by terrestrial vegetation) seaward towards the low-water line.

Component boundaries are estimated from observed changes in slope and texture that define different morphologic forms. For example, the B1 could be dominated by a pebble-sand beach face, while the B2 is characterized by a wide mud tidal flat. The general assumption is that each component is uniform in the alongshore direction. In reality, there may be some alongshore variation so each across-shore Component can be defined by primary, secondary and tertiary descriptors if necessary.

As ShoreZone moved into the Bering Sea, Chukchi Sea and Beaufort Sea, the typical definitions of the supratidal and intertidal zones needed to be refined for Arctic coasts which have small tide ranges, ice dominated morphologies, and wide supratidal zones meaning the boundary of the supratidal can be difficult to determine from the imagery. Thus, for Arctic coasts, the supratidal zone is defined as the area infrequently submerged by extreme meteorological tides or storm surge, and often marked at the uppermost edge by the tidal debris lines, ice scour or by damaged or dead vegetation. The intertidal zone is defined as being regularly submerged by normal meteorological tides and is often marked by a recent tidal swash line. In the absence of a swash line this may be determined by a difference in surface texture or by a slope break (see Figure 11).

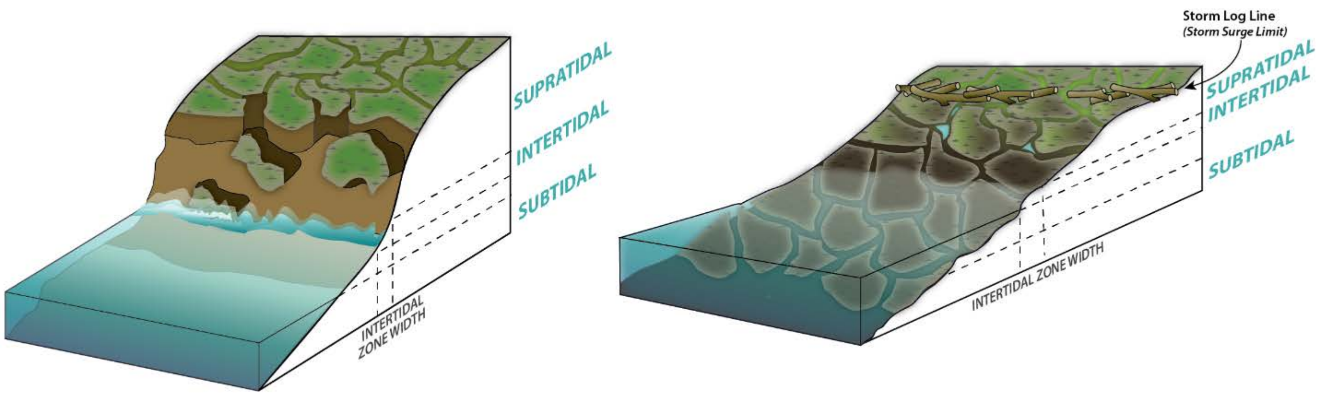


Figure 11. Examples of eroding tundra cliff (left) and inundated tundra (right) typical of those on Arctic coasts in Alaska. Note that the intertidal zone widths are often narrow, while storm surge extent may be very wide.

3.2 Physical ShoreZone Attributes

The overall goal of ShoreZone physical mapping is to provide a description of the coastal geomorphology and a basic framework for the biological characterization of the coast. As described in the previous section, ShoreZone breaks the digital shoreline into a series of alongshore segments, and then links a systematic description of the across-shore morphology to each of those line segments by using a standard set of codes. The basic premise is that the physical attributes (such as morphology, substrate and energy) are the 'building blocks' of the coastal ecological system upon which the biological components form communities. The physical attributes are therefore characterized first in the ShoreZone mapping workflow, followed by the biological attributes which are defined in Section 3.3. Section 3.2.1 describes the alongshore attributes which are called 'Unit Level' attributes and Section 3.2.2 describes the across-shore attributes which are called 'Component Level' attributes. Please note that these attributes and definitions are applicable to the sections of the coastline classified after January 1, 2016 (see Figure 3 for the specific sections of the coastline). Although most of the definitions have remained consistent over the entire extent of ShoreZone, a few attributes have been added and/or modified over time, so the protocol specific to the section of shoreline of interest should be consulted prior to any analysis.

3.2.1 Unit Level Physical Attributes

Coastal Class

The Coastal Class attribute summarizes the dominant structuring process (Table 2), slope, width, and morphology/substrate character of the intertidal zone of the unit. Most intertidal coastal morphologies are a result of wave energy acting on the shoreline (Table 3). Shores that are not dominated by wave action include estuarine, anthropogenic, current-dominated, glacial ice, lagoon and permafrost shorelines (Table 4). Please note that a '50% Rule' applies to these Coastal Classes, meaning that at least 50% of the intertidal zone of the unit needs to be structured by the given process for these Coastal Class to apply. The exception is Coastal Class 31 and the specific criteria for assigning that Class is given in Table 4. To improve consistency between mappers guidelines have been developed for assigning Coastal Class (Table 5). An online data dictionary with photographic examples of each Coastal Class from multiple regions will be made available on the NOAA ShoreZone website in 2018. Please note that this attribute has been referred to as 'Shoretype' in some previous versions of the protocol.

Coastal Class is often used to model distribution of coastal resources that require particular sediment conditions. It can be used in conjunction with other attributes such as Wave Exposure or Biobands to refine any modelling exercise.

Table 2. Guidelines for determining the dominant structuring process for the ShoreZone Unit.

Dominant Structuring Process	Guidelines for Classification
Wave Energy	The dominance of wave energy as a structuring process is evident from eroding shoreline landforms (e.g. cliffs or platforms) or accretional landforms resulting from wave-generated sediment processes (e.g. spits, barrier islands, swash bars, berms). For stable shorelines without evidence of erosion or accretion, wave energy is assumed dominant if no other structuring process is evident.
Riparian	Riparian processes are usually found in an enclosed embayment with restricted wave fetch and significant freshwater input. These freshwater influences often create deltaic forms and may result in marsh formation in the upper intertidal zone. The substrates are commonly fine (e.g., muds) and can include organics such as peats.
Anthropogenic	Anthropogenic processes are considered dominant when man-made structures and/or substrates comprise more than 50% of the intertidal zone.
Current	Current dominated shorelines are generally salt-water, high current channels caused by tidal flow or are found between islands or the constricted entrances to saltwater lagoons. Intertidal zone widths are often narrow and wave fetch is restricted.
Glacial	In an area dominated by glacial processes, glacial ice fronts dominate the intertidal zone (tide water glaciers). This will be restricted to a few locations.
Lagoon	A lagoon is an enclosed water body that is connected to salt water by either a permanent inlet, ephemeral inlet or storm wash-over such that the water body is permanently or at least occasionally salty. The tidal range is often restricted due to a sill height or narrow channel. Wave fetches are limited and wave exposure low.
Periglacial	In periglacial process dominant areas, permafrost and pore ice control the shoreline morphology. Thermokarst features such as ground ice slumps can dominate the coastal morphology. Thaw subsidence resulting from melting of permafrost can create unique morphologies such as inundated tundra (e.g., thaw subsidence has obviously contributed to submergence of the tundra surface below mean sea level).

Table 3. Definitions of the wave-structured shore types (after Howes *et al*. 1994) for the Coastal Class attribute. See Table 5 for guidelines on assigning these Coastal Classes.

Substrate	Sediment	Width	Slope	Coastal Class	
				Description	Code
Rock	n/a	Wide (30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Rock Ramp, wide	1
			Flat (<5°)	Rock Platform, wide	2
		Narrow (<30 m)	Steep (>20°)	Rock Cliff	3
			Inclined (5-20°)	Rock Ramp, narrow	4
			Flat (<5°)	Rock Platform, narrow	5
Rock & Sediment	Gravel	Wide (>30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Ramp with gravel beach,	6
			Flat (<5°)	Platform with gravel beach,	7
		Narrow (<30 m)	Steep (>20°)	Cliff with gravel beach	8
			Inclined (5-20°)	Ramp with gravel beach	9
			Flat (<5°)	Platform with gravel beach	10
	Sand & Gravel	Wide (>30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Ramp w gravel & sand	11
			Flat (<5°)	Platform with G&S beach,	12
		Narrow (<30 m)	Steep (>20°)	Cliff with gravel/sand	13
			Inclined (5-20°)	Ramp with gravel/sand	14
			Flat (<5°)	Platform with gravel/sand	15
	Sand	Wide (>30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Ramp with sand beach,	16
			Flat (<5°)	Platform with sand beach,	17
		Narrow (<30 m)	Steep (>20°)	Cliff with sand beach	18
			Inclined (5-20°)	Ramp with sand beach,	19
			Flat (<5°)	Platform with sand beach,	20
Sediment	Gravel	Wide	Flat (<5°)	Gravel flat, wide	21
		Narrow (<30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Gravel beach, narrow	22
			Flat (<5°)	Gravel flat or fan	23
	Sand & Gravel	Wide (>30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	n/a	-
			Flat (<5°)	Sand & gravel flat or fan	24
		Narrow (<30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Sand & gravel beach,	25
			Flat (<5°)	Sand & gravel flat or fan	26
	Sand/Mud	Wide (>30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Sand beach	27
			Flat (<5°)	Sand flat	28
			Flat (<5°)	Mudflat	29
		Narrow (<30 m)	Steep (>20°)	n/a	-
			Inclined (5-20°)	Sand beach	30
			Flat (<5°)	n/a	-

Table 4. Coastal Classes associated with structuring processes other than wave energy.

Dominant Structuring Process	Description	Coastal Class
Riparian	**Organics, fines and vegetation** dominate the unit; may characterize units with large marshes in the supratidal zone IF the marsh represents >50% of the combined supratidal and intertidal area of the unit, even if the unit has another dominant intertidal feature such as a wide tidal flat or sand beach. This coastal class may also be applied if a significant amount of marsh (25% or more) infringes on the intertidal zone.	31
	Low vegetated peat are areas of low-lying peat banks; usually vegetated in the supratidal zone, but not always vegetated in the intertidal zone. Minimal mineral sediment is present.	39
Anthropogenic	***Permeable man-made structures*** such as rip-rap, wooden crib structures where surface oil from a spill will easily penetrate the structure.	32
	Impermeable man-made structures such as concrete seawalls and steel sheet pile.	33
Current	***Current-dominated*** shore types occur in elongate channels with restricted fetches and where currents (tidal or otherwise) are the dominant structuring process.	34
Glacial	***Glacial ice*** dominates a few places on the Alaska coast where tide-water glaciers are present. These locations are characterized by unstable ice fronts.	35
Lagoon	***Lagoons*** represent a special coastal feature that has some salt-water influence but may be largely disconnected from other marine processes such as tides and high wave exposure. Lagoons are distinguished from estuaries, which must have fluvial or deltaic landforms. Intertidal zones are often narrow and restricted in elevation. Saltwater influxes may be only episodic.	36
Periglacial (Permafrost)	***Inundated tundra*** occurs where thaw-subsidence on low-relief shorelines causes the tundra surface to sink below mean sea level. Often the polygon fracture patterns associated with ice-wedges polygons are evident.	37
	Ground ice slumps are areas where the thaw of high ice content shores causes mass-wasting in distinct patterns including ground ice slumps, thermo-erosional falls, and solifluction lobes.	38

Table 5. Mapping guidelines used for Coastal Class attribute classification.

Category	Guidelines for Classification
Rock (Codes 1-5)	Rock substrate dominates the intertidal zone of the unit, with little or no unconsolidated sediment or organics (<10% of the overall unit area).
Rock and Sediment (Codes 6-20) vs. Sediment Dominated (Codes 21-30)	When a unit consists of a beach with rock outcrops/platforms, the Coastal Class should be coded to emphasize the beach sediment (Codes 21 to 30) unless the rock outcrops/platforms make up 25% or more of the total intertidal area of the unit. When the rock outcrops are 25% or more, the Coastal Class should be coded to reflect the influence that the rock has on the unit (Codes 6 to 20).
Supratidal rock with intertidal beaches	When a unit consists of a supratidal cliff/ramp with an intertidal beach, the Coastal Class should be coded to reflect the importance of the beach (Codes 21 to 30) even if the cliff/ramp slightly infringes (<3 m) on the high intertidal zone. When the cliff/ramp significantly infringes on the intertidal zone (>3 m), a "Rock and Sediment" classification should be applied (Codes 6 to 20).
Coastal Class 11	When a unit consists of a prominent cliff in the supratidal and > 3 meters in the intertidal, in conjunction with a beach face containing sand and gravel (>25% of unit) and an intertidal zone wider than 30 meters, slope is ignored and Coastal Class 11 is used.
Coastal Class 13	When a unit consists of a significant cliff in the supratidal and > 3 meters in the intertidal, in conjunction with a beach face containing sand and gravel (>25% of unit) and an intertidal zone < 30 meters, slope is observed and Coastal Class 13 is used.
Sand Rule	To include sand in Coastal Class assignment, particles that are 2 mm and finer must be observed as >10% of the sediment type, or when a patch of sand is 10m or more in diameter.
Veneers	When a boulder/cobble/pebble beach is observed in a protected or semi-protected area, it should be noted that these materials are almost always a veneer overlying sand. This should be taken into consideration when coding the materials and choosing a Coastal Class. If the geologist's commentary mentions sand in nearby units with similar wave exposures, apply the presence of sand to the unit. Close examination of the lower intertidal in the digital still photos will often reveal the presence of sand, even if the commentary lacks mention of it. If there is no evidence or commentary regarding sand, do not assume it is present.

Wave Exposure

Wave energy is a dominant physical attribute of the intertidal that affects community structure directly through episodic disturbance events and indirectly by controlling substrate dynamics over short and long term periods. The lack of bare space is often the limiting factor governing community structure in the rocky intertidal, thus, the most profound direct effect of waves on community structure is the creation of bare space allowing recruitment from the plankton. Denny *et al*. (2004) discusses the forces generated by waves on intertidal organisms in terms of patch dynamics, one of the most important processes by which rocky intertidal communities are structured. Unconsolidated substrates can be moved by the direct impact of waves, by wave run-up, and by wave generated currents. On beaches with mobile substrates, the particles can be rolled or entrained continually, seasonally, or episodically in high wave energy environments. Mobile substrates typically harbor fewer organisms than stable substrates, for example, rounded pebble and sand beaches are typically depauperate of macrobiota, while stable substrates such as bedrock, large boulders, and angular pebble beaches are relatively species rich. Intertidal fauna in heavy surf must have thick shells and strong muscular attachments (limpets and snails), permanent attachments (barnacles), or the ability to seek refuge in crevices or interstitial spaces (crabs and worms). The floral community must likewise adapt to the forces of the nearshore surf and swash zone, and in the absence of wave run-up, must also tolerate long hours of desiccation. The measurement of wave energy is therefore fundamental to understanding the structure of intertidal communities.

The Wave Exposure attribute is an estimate of the amount of wave energy that could potentially impact the intertidal zone of the unit. Howes *et al*. (1994) recommended that wave exposure be based on maximum fetch, where wave exposure increases with increasing fetch distance; therefore, the Wave Exposure attribute in ShoreZone is assumed to be a function of the fetch window of the unit. The standard definition of fetch is the length of water over which a given wind can be blown. However, that maximum fetch can be modified by several factors. Changes in coastal orientation, presence of offshore islands, or the proximity to shoaling bathymetry will attenuate the height and wavelength of open ocean waves. Protection may also be provided by a short sea fetch resulting from the distribution of land masses surrounding the unit. Thus, ShoreZone uses this attenuated or modified *effective* wave exposure to characterize the wave climate for alongshore units (Table 6).

Table 6. Definitions for the Wave Exposure attribute.

Effective Fetch Range (km)	Wave Exposure Category
<1	Very Protected
1-10	Protected
10–50	Semi-Protected
50–500	Semi-Exposed
500–1000	Exposed
>1000	Very Exposed

It is a rare to have the exposure change directly from the Exposed category to the Protected category in adjacent units, although it does occasionally occur. In most cases, there will be a transition zone that includes a few units of Semi-Exposed to Semi-Protected or both. For example, the entrance to a bay will tend to have a slightly higher exposure than the head of the bay due to its location and processes such as wave refraction.

<u>Intertidal Zone Width</u>

Coastal and Ocean Resources has adopted the use of Structure from Motion (SfM) with our oblique aerial imagery to measure width. SfM is a digital image processing technique for generating 3-D spatial data for use in mapping and GIS applications, and for indirect measurements of objects. SfM operates under the same principals as stereoscopic photogrammetry so that 3-D structure can be resolved from a series of overlapping, offset images (Figure 12) and requires at least 50% overlap between images. The images for ShoreZone are acquired from a fast-moving helicopter but 1-second still imagery captures from the video still have at least 60% overlap provided the flight speed does not exceed 100 km/hr. The ShoreZone workflow was modified in this protocol to include the creation of SfM orthophotos using those video captures which are imported into Google Earth. Google Earth GIS tools are then used to measure the width of the intertidal zone from the estimated Mean High Water line to the edge of the water in the imagery (Figure 13). This represents a significant technological improvement over past estimates of width, which was done purely from the imagery and whatever reference points could be found on the shoreline.

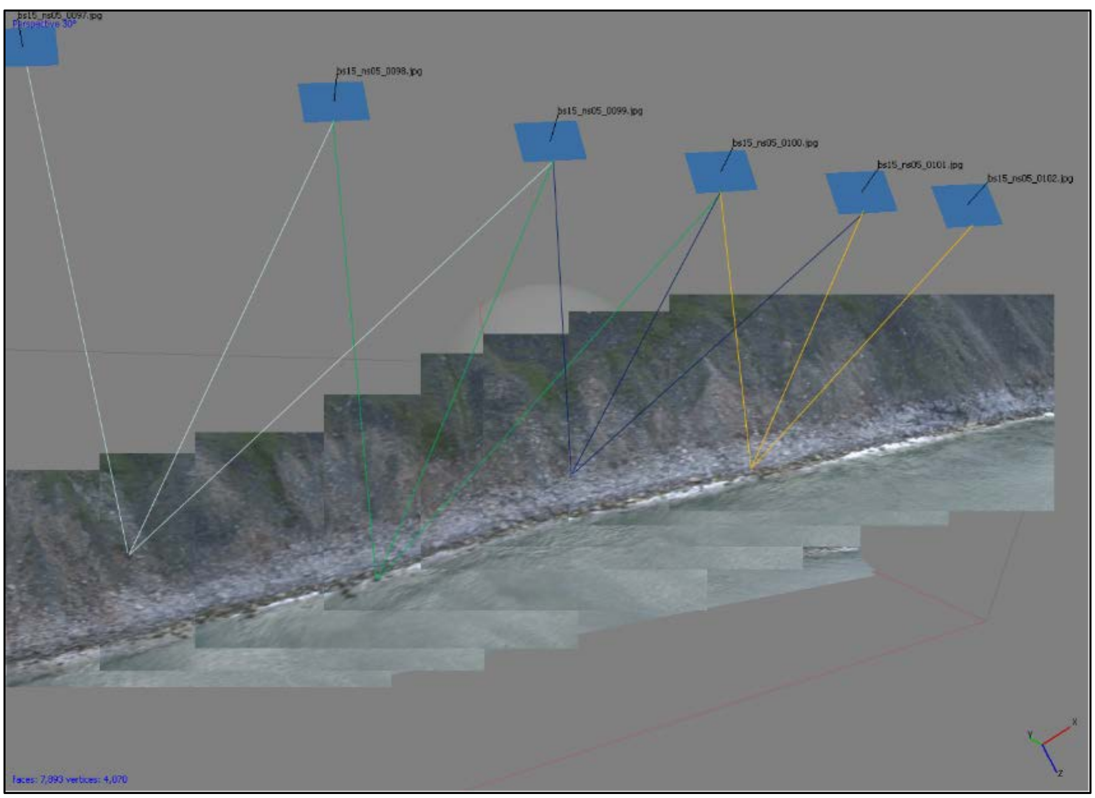


Figure 12. The Structure from Motion processing technique for video frames with 60% overlap.

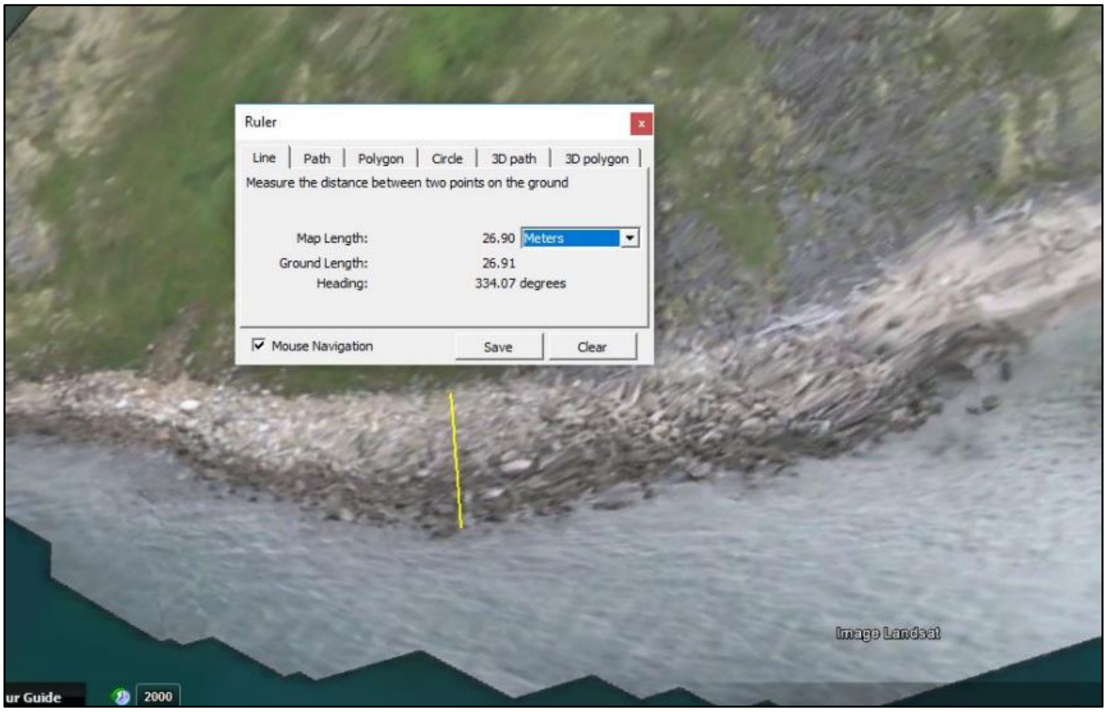


Figure 13. An Ortho-rectified image created using Structure from Motion with overlapping ShoreZone video captures. They are exported to Google Earth for width measurements of the intertidal shoreline.

<u>Intertidal Zone Area</u>

The area of the unit intertidal zone (in m^2) calculated using the Intertidal Zone Width multiplied by the Digital Shoreline Length which is calculated in ArcGIS using the best available digital shoreline. This method assumes that the digital shoreline length is relatively straight, as opposed to highly crenulated and that the width of the intertidal zone does not vary much along the length of the unit. The Intertidal Zone Area could potentially be used to calculate estimates of the amount of substrate in each unit or calculating biomass estimates for the Biobands when used in conjunction with the percent cover estimates.

<u>Aspect</u>

Aspect is the shore normal compass direction the unit faces (Figure 14) and is useful to estimate the amount of insolation a unit receives. Shore unit Aspect can also affect the volume of debris accumulation, wave energy input, and wind and sun-induced desiccation. South-facing shorelines receive more sunlight which can cause evaporation from organisms directly exposed to its rays; therefore, some flora and fauna are more common on north facing beaches (or on north facing boulders) than on south facing aspects. The Aspect is recorded as one of the 8 cardinal compass points (i.e. N, NE, E, SE, S, SW, W, NW).

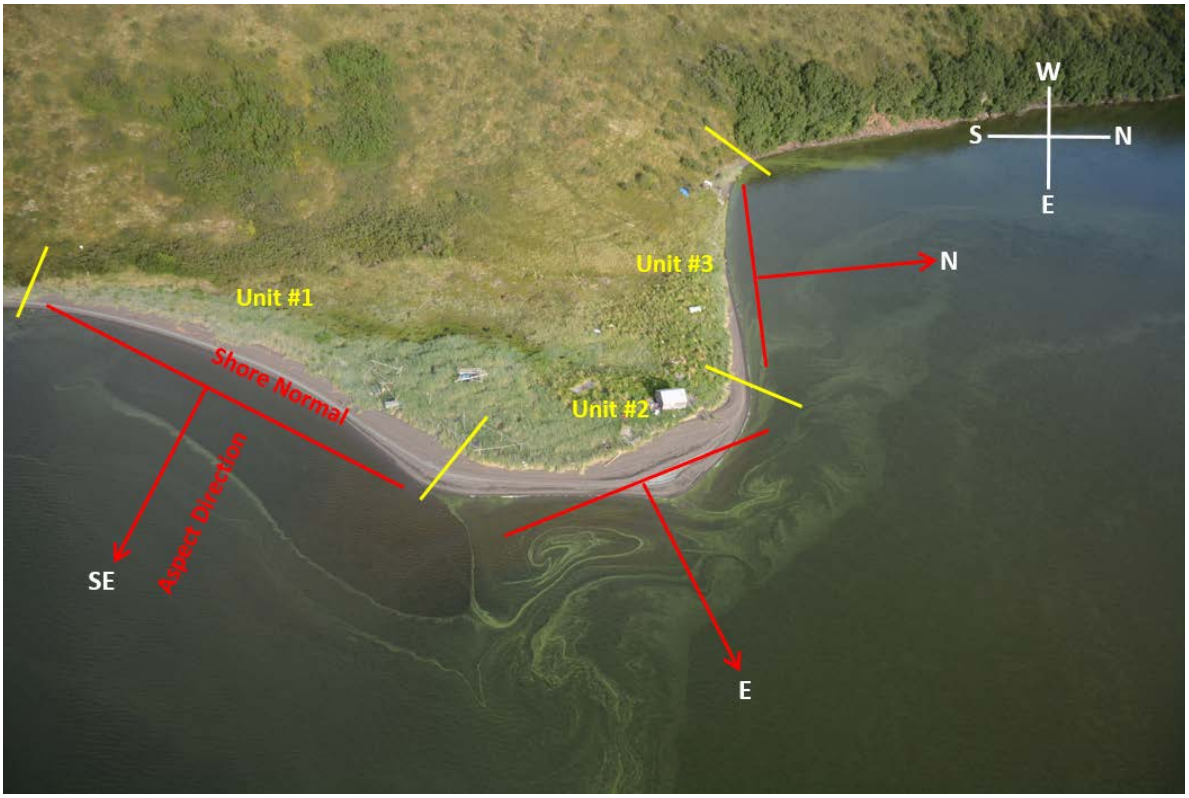


Figure 14. Determining the Aspect attribute of each alongshore Unit.

Intertidal Slope Category

This attribute is the slope of the B Zone, calculated using the equation: Slope = $\tan^{-1}$(Tidal Height/Intertidal Zone Width). Tidal Height is the projected (modelled) tide height or sea level elevation (in meters) of each unit on the day and time the imagery was taken. This estimate is taken from the nearest or most relevant tide station (from the NOAA Tides and Currents website). It should be noted that this estimate is only as accurate as the tide station information (which can be problematic along remote areas of the Alaska coast) and the width estimation using Structure from Motion. To account for that potential uncertainty, we created categories (Table 7) for the slope attribute to alleviate some of the potential sources of error as well as reduce inter-mapper variability. Although this is a new attribute, it is backward compatible with the rest of the ShoreZone dataset as previous estimates can be rolled into these categories if desired.

Table 7. Intertidal Slope Category definitions.

Slope Category	Degree Range
Flat	<2
Low Incline	2-4
Moderate Incline	5-10
High Incline	11-20
Steep	21-45
Very Steep	>45

Iribarren Category

Wave Exposure provides a good estimate of the total energy acting on a Unit; however, the morphology of the wave that results from the interaction of that energy with the slope of the beach face can also be an important factor in structuring the biotic community.

Wave morphology can be modelled for each unit by calculating how the slope and wave energy might interact using an algorithm called the Iribarren number (Battjes 1974). Table 8 shows the calculated Iribarren values for each Intertidal Slope Category/Wave Exposure category combination in the ShoreZone classification. This calculation also requires the wave height, period and interval for each Wave Exposure category. This information was taken from the U.S. Army Corps of Engineers wave prediction curves (Department of the Army 1984). These values are then rolled into four categories: Spilling, Plunging, Collapsing and Surging (see Figure 15 for illustration). The Plunging and Collapsing categories generally represent highly dynamic shorelines if the substrate is unconsolidated (Komar 1998).

Table 8. Iribarren Number value table for each Wave Exposure and Slope Category combination.

Slope Category	Wave Exposure Category: Very Protected	Protected	Semi-Protected	Semi-Exposed	Exposed	Very Exposed
Flat	0.03	0.05	0.06	0.10	0.10	0.10
Low Incline	0.15	0.27	0.32	0.49	0.48	0.52
Moderate Incline	0.31	0.55	0.64	0.99	0.97	1.05
High Incline	0.64	1.14	1.31	2.04	2.01	2.16
Steep	1.77	3.13	3.61	5.59	5.53	5.93
Very Steep	3.06	5.41	6.25	9.69	9.57	10.27
	Iribarren Number					

Iribarren Categories: Blue = Spilling, Green = Plunging, Yellow = Collapsing, Orange = Surging

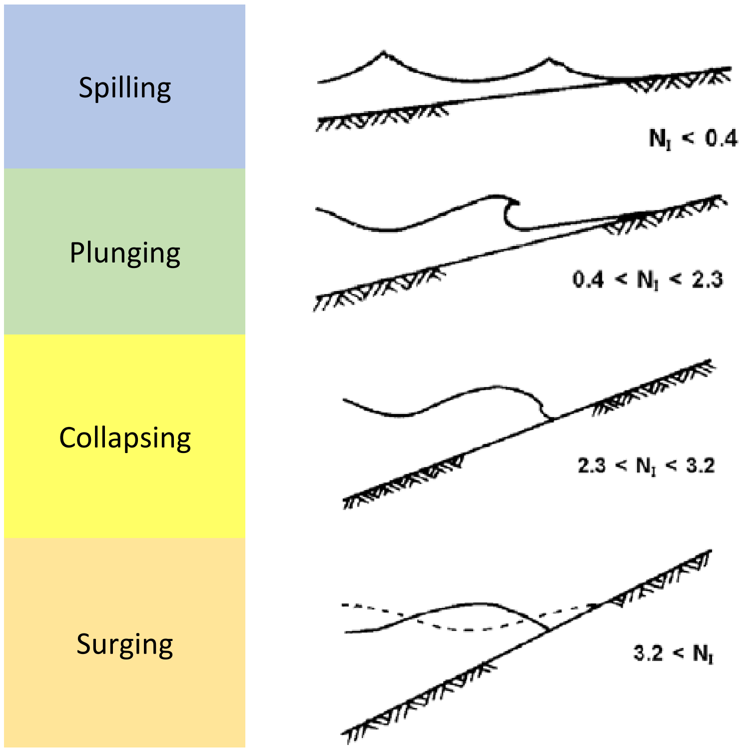


Figure 15. Illustration of the type of wave morphology represented by each Iribarren Category (after Komar 1998).

Oil Residence Index (ORI)

The Oil Residence Index is an overall assessment of the potential persistence of a crude oil spill that strands on a shoreline defined by the Unit's Wave Exposure category and Coastal Class (Table 9). Other fuel types, such as diesel and bunker fuels, may have substantially different persistence periods. ORI is a relative index ranging from 1 to 5 where 1 indicates short persistence (days to weeks) and 5 indicates lengthy persistence (months to years) (Table 10). The unit ORI classification uses the "best-available" estimate of Wave Exposure class which in most cases is the Biological Wave Exposure. Where there is no Biological Wave Exposure classification (e.g., on sandy beaches where there is no attached biota), the ORI classification uses the physical Wave Exposure. The ORI value can be used for oil spill response strategy to help identify shoreline sensitivity in the event of a spill.

Table 9. Definitions of the Unit level ORI attribute. See Table 3 for definitions of the Coastal Classes and Table 27 for definitions of the Biological Wave Exposure categories.

Coastal Class	Biological Wave Exposure					
	VE	E	SE	SP	P	VP
1	1	1	1	2	3	3
2	1	1	1	2	3	3
3	1	1	1	2	3	3
4	1	1	1	2	3	3
5	1	1	1	2	3	3
6	2	3	5	4	4	4
7	2	3	5	4	4	4
8	2	3	5	4	4	4
9	2	3	5	4	4	4
10	2	3	5	4	4	4
11	1	2	3	4	5	5
12	1	2	3	4	5	5
13	1	2	3	4	5	5
14	1	2	3	4	5	5
15	1	2	3	3	4	4
16	1	2	3	4	5	5
17	1	2	3	4	5	5
18	1	2	3	4	5	5
19	1	2	3	4	5	5
20	1	2	3	4	5	5
21	2	3	5	4	4	4
22	2	3	5	4	4	4
23	2	3	5	4	4	4
24	1	2	3	4	5	5
25	1	2	3	4	5	5
26	1	2	3	4	5	5
27	2	2	3	3	4	4
28	2	2	3	3	4	4
29	999*	999	999	3	3	3
30	2	2	3	3	4	4
31	999	999	5	5	5	5
32	2	2	3	3	5	5
33	1	1	1	2	2	2
34	999	999	999	4	4	4
35	1	1	1	1	1	1
36	999	999	999	5	5	5
37	999	999	999	5	5	5
38	999	999	2	3	3	3
39	999	5	5	5	5	5

*'999' indicates this combination rarely occurs and is left to mapper discretion

Table 10. Definition of the categories for the ORI attribute.

ORI Category	Estimated Persistence
1	Days to Weeks
2	**Weeks** to Months
3	Weeks to **Months**
4	**Months** to Years
5	Months to **Years**

Environmental Sensitivity Index (ESI)

The NOAA Environmental Sensitivity Index (ESI) is a shoreline habitat classification widely applied throughout the U.S. and is used by response personnel to prioritize shorelines for cleanup and mitigation following oil spill (Tables 11). ShoreZone applies the ESI shoreline classification, as described in Petersen *et al*. (2002) (Table 11), to each alongshore Unit with up to three values depending on the complexity of the Unit. The Most Sensitive ESI category (highest value) is also pulled out as a separate attribute and is the one used to represent the ESI value for the Unit.

Table 11. ESI shoretype values for the Estuarine environment (all marine shorelines are classified as estuarine in Petersen *et al*. (2002)).

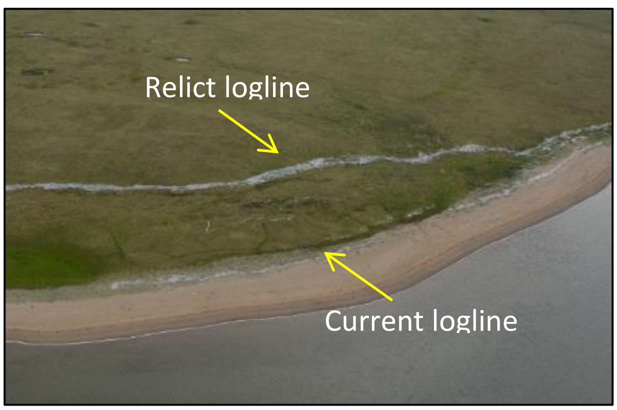
ESI No.	Description for Estuarine Environment
1A	Exposed rocky shores; exposed rocky banks
1B	Exposed, solid man-made structures
1C	Exposed rocky cliffs with boulder talus base
2A	Exposed wave-cut platforms in bedrock, mud, or clay
2B	Exposed scarps and steep slopes in clay
3A	Fine- to medium-grained sand beaches
3B	Scarps and steep slopes in sand
3C	Tundra cliffs
4	Coarse-grained sand beaches
5	Mixed sand and gravel beaches
6A	Gravel beaches; Gravel Beaches (granules and pebbles
6B	Gravel Beaches (cobbles and boulders)
6C	Rip rap (man-made)
7	Exposed tidal flats
8A	Sheltered scarps in bedrock, mud, or clay; Sheltered rocky shores (impermeable)
8B	Sheltered, solid man-made structures; Sheltered rocky shores (permeable)
8C	Sheltered rip rap
8D	Sheltered rocky rubble shores
8E	Peat shorelines
9A	Sheltered tidal flats
9B	Vegetated low banks
9C	Hypersaline tidal flats
10A	Salt- and brackish-water marshes
10B	Freshwater marshes
10C	Swamps
10D	Scrub-shrub wetlands; mangroves
10E	Inundated low-lying tundra

Coastal Vulnerability Module

The Coastal Vulnerability Module (CVM) was introduced to the ShoreZone program in 2012 to rank the shoreline in terms of potential sensitivity to coastal change, especially to rising sea levels. It was originally applied to permafrost dominated shorelines in the Beaufort and Chukchi Seas; however, sea level rise and the loss of sea ice in other areas covered by ShoreZone has been a growing concern so the CVM was adapted for non-permafrost shorelines as well. There are 4 attributes that make up the CVM: the Flood Zone Index, the Stability Index, Vulnerability Observations and the newly added Coastal Vulnerability Index (CVI). The Flood Zone Index and Stability Index have been modified slightly for this protocol from the previous version of the CVM to better fit the CVI calculation. These attributes are defined below.

Flood Zone Index

The potential width of the flood zone adjacent to an alongshore unit is interpreted from aerial imagery. Indicators include relict loglines or storm berms above the active berms or loglines (Figure 16). The width of the flood zone is the metric used to assess vulnerability to flooding with wider areas being more vulnerable. The Flood Zone Index categories are: Very Low (1-5 m), Low (5-10 m), Moderate (10-50 m), High (50-100 m) and Very High (>100 m).



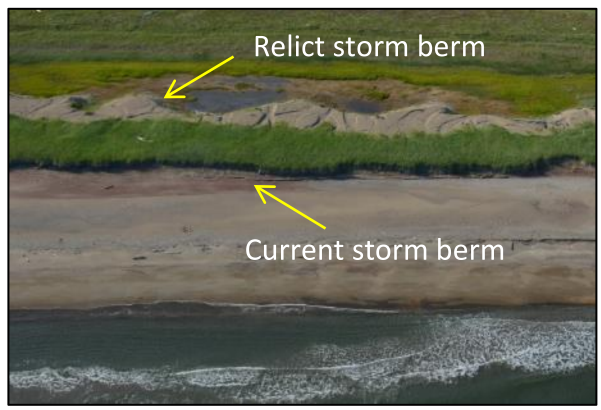


Figure 16. Examples of aerial images used to determine the flood zone width. The left image shows a relict log line on the tundra in northern Norton Sound and the image on the right shows a relict storm berm now vegetated by dune grass just south of Nome in Norton Sound.

Stability Index

The relative rate of shoreline erosion is estimated to assess shoreline stability. Erosional shorelines (showing evidence of volumetric loss) are considered more vulnerable than actively accreting shoreline (showing evidence of volumetric gain). Even though the ShoreZone images record one point in time and cannot therefore be used to measure rates directly, interpretation of shoreline features can provide an indicator for rates of change. For example, scarps or "cut banks" indicate actively eroding shorelines, rocky shorelines are relatively stable, and spits devoid of vegetation indicate active accretion (Figure 17). The Stability Index categories are: 1= Very high (>2 m/yr, erosional), 2= High (1 to 2 m/yr, erosional), 3= Moderate (1 to -1 m/yr, stable), 4= Low (-1 to +1 m/yr, accretional), 5= Very low (>2 m/yr, accretional).

Figure 17. Examples of indicators for determining the rate of erosion or accretion. The image on the left shows an eroding peat bank (Very High category) on the exposed coast of the Yukon-Kuskokwim Delta near Angyoyaravak Bay and the image on the right shows an accretional spit (Very Low category) by the city of Teller in Port Clarence, Norton Sound.

Vulnerability Observations

This attribute classifies features that are potentially important to determination of the vulnerability of the coastline to sea level change (Table 12). This attribute is not included in the Coastal Vulnerability Index.

Table 12. Features recorded for the Vulnerability Observations.

Category	Feature
Mass Wasting	Ground ice slumps
	Block slumps
	Debris flows/solifluction
	Ice Wedges
Wetlands	Lagoonal complex
	Deltaic complex
	Tidal creek complex (multiple, branching channels)
	Marsh clones
	Associated mudflats
	Submerged morphology
	Relict river morphology
	Relict shoreline morphology
	Scrub/shrub wetland
Anthropogenic	Anthropogenic features that are potentially vulnerable to flooding
Other	Add description of relevant feature
None	Unit assessed, no relevant features (none of the above)

ShoreZone Coastal Vulnerability Index

A ShoreZone Coastal Vulnerability Index (SZCVI) was recently added to ShoreZone that ranks five shoreline attributes and uses an algorithm to combine them into a single value to estimate the vulnerability of a shoreline Unit to coastal inundation due to sea level rise (Table 13). The SZCVI is intended to meet the growing need of coastal managers for information about the vulnerability of coastlines and at the relevant spatial scales of coastal communities (100s m). The methods of Thieler and Hammer-Klose (1999, 2000a and 2000b) (http://woodshole.er.usgs.gov/project-pages/cvi/) are used to calculate the SZCVI using coastal geomorphology (using Coastal Class), the maximum tide range, the erosion rate (using the Stability Index), the Flood Zone Index and significant wave height. The attributes are either directly assessed from the imagery or are available from public data sources.

The maximum tide range is the maximum mean annual value from the most appropriate local tide station as taken from the NOAA Tides and Currents website. This attribute is included because when we discuss the effects of sea level rise on the coastline, we are mainly concerned with inundation and erosion of the supratidal (the area above the daily tide cycle). That is because many coastal communities and coastal resources are found in the supratidal zone and the intertidal will not be as affected by rising sea levels since it is an ecosystem defined by changing water levels. Sea level rise will interact with the daily tidal cycles to create supratidal flooding at the highest tides. This effect will be swamped by the natural tide range in areas with large tide ranges while the effect will be more noticeable in areas with smaller tide ranges. For example, if relative sea level rise is predicted at 0.2 m over the next 50 years, an area with a 6 m tide range will see little time during the tide cycle when that 0.2 m rise will be able to cause supratidal flooding. This stands in contrast to a portion of the coast with a 0.3 m tide range, where that 0.2 m change becomes much more significant over the entire tidal cycle.

Much of the flooding that occurs along coastlines is associated with extreme events such as storms. The amount of damage that storm surge can cause is dependent on a combination of factors such as coastal geomorphology and local tide range (which are captured in the Coastal Class, Flood Zone Index and max tide range attributes). However, another factor that can exacerbate damage by storms is the height of the waves breaking at the coast. The height of the waves that reach the shoreline is in turn dependent on the exposure of that stretch of shoreline, which is dependent on factors such as the offshore fetch and aspect of the shoreline relative to the predominant wind direction as well as any occlusion by other landforms. For ShoreZone, the Wave Exposure category is used to derive the significant wave height (in meters) using the U.S. Army Corps of Engineers wave prediction curves (Department of the Army 1984).

Table 13. The ranking matrix for the ShoreZone Coastal Vulnerability Index attributes.

Variable	Ranking Category and Value				
	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
Geomorphology (Coastal Class) (Attribute A)	1,3,4,8	2,5,6,7,9, 10,13,18, 32,33, 35	11,12,14, 15,16,17, 19,20,34	21,22,23, 25,27,36	24,26,28,29, 30,31, 37,38,39
Geomorphology (Description)	Rocky, cliffed coasts Fjords	Medium cliffs Indented coasts	Low cliffs Glacial drift Alluvial plains	Cobble beaches Estuaries Lagoons	Barrier/Sand beaches Marshes Mud flats Deltas
Flood Zone Index (m) (Attribute B)	1-5	5-10	10-50	50-100	>100
Stability Index (erosion/accretion (m/yr)) (Attribute C)	>2.0	1.0 - 2.0	1.0 - -1.0	-1.1 - -2.0	>-2.0
Max Tide Range (GT) (m) (Attribute D)	>6.0	4.1 - 6.0	2.0 - 4.0	1.0 - 1.9	<1.0
Significant Wave Height (m) (with Wave Exposure Category) (Attribute E)	<1 (VP, P)	1.0 - 2.0 (SP)	2.1 - 4.0 (SE)	4.1 - 6.0 (E)	>6.0 (VE)

Once all five of the attributes have been ranked for each unit (see Table 13) then an SZCVI value must be calculated. We use the equation developed by Thieler and Hammer-Klose (1999, 2000a and 2000b):

$$SCVI = \sqrt{((A*B*C*D*E) / 5)}$$

The calculated SZCVI values can range from 0.447 to 25. The values are then ranked into four categories (Low, Moderate, High and Very High) using the criteria in Table 14.

Table 14. Criteria for defining the ShoreZone CVI categories.

CVI Rank	CVI Value Range	Cutoff Criteria
Low	<4.5	Maximum of three 'Low' ranked attributes and two 'Moderate' ranked attributes
Moderate	4.5 – 9.9	Maximum of three 'Moderate' ranked attributes and two 'High ranked attributes
High	10 – 17	Maximum of three 'High' ranked attributes and two 'Very High' ranked attributes
Very High	>17	At least three 'Very High' ranked attributes and two 'High' ranked attributes

CMECS and ShoreZone

The Coastal and Marine Ecological Classification Standard (CMECS) is "a catalog of terms that provides a means for classifying ecological units using a simple, standard format and common terminology" and was approved by the Federal Geographic Data Committee in 2012. CMECS was developed to provide scientists the means to analyze ecological data across different projects, collected using different methodologies, by providing a common terminology for that data. It has been adopted by NOAA and other agencies as the standard for ecological data in the U.S. It is therefore important that any federal datasets can be successfully cross-walked with CMECS. Coastal and Ocean Resources have been working with NOAA Coastal Services Center to successfully cross-walk the ShoreZone attributes. This is not always a straight-forward process, so at the moment Coastal Class is the only attribute being delivered as a CMECS code, although we also place each ShoreZone unit into the CMECS Biogeographic Regions which were originally developed by the CEC (Wilkinson *et al*. 2009). The Forms, Materials and Biobands are also able to be cross-walked and that classification is currently under development for future ShoreZone deliverables.

3.2.2 Component Level Physical Attributes

Each alongshore Unit is vertically partitioned into Zones which are then further divided into across-shore Components. This section describes the physical attributes that are classified for each Component. Some of the same attributes are classified at the Unit level and at the Component level, although slightly different criteria can apply at the Component level and those differences are described with each attribute below.

Component Width

The width (in meters) for each component is estimated using the same methodology as the Intertidal Zone Width except that instead of estimating the width of the entire intertidal zone, the width of each intertidal component is estimated. The supratidal zone component widths are also estimated but not the subtidal component (of which there is typically only one) because the subtidal zone does not have a defined across-shore end point so it does not have a width associated with it.

Component Slope

The slope of each supratidal and intertidal component is estimated from the ShoreZone imagery using the calculated Intertidal Zone Slope as a general guide.

Component Process

The dominant structuring process (wave energy, glacial, current dominated etc.) for the intertidal zone is an integral part of the Coastal Class. That process is considered the Unit level structuring process; however, different processes could be dominant for different components of the intertidal zone. For example, a rip rap wall in the upper intertidal is structured by anthropogenic processes while a gravel and sand beach below it would be structured by across-shore waves. Also, the supratidal has an entirely different set of processes that structure the geomorphologic Forms which are not described as part of the Coastal Class. For examples, dunes are structured by Eolian (wind) Transport while a lagoon is structured by Hydrologic (Ponded) processes. Therefore, each component in the supratidal and intertidal zones is given a process from the categories listed in Table 15. The subtidal zone Component is not given a process because it cannot be determined from the imagery.

Table 15. Categories and codes for the Component Process attribute.

Process Category	Process Code
Anthropogenic (Impacted)	A
Eolian Transport (wind)	E
Gravity (mass-wasting)	M
Hydrologic (Across-shore Waves)	W
Hydrologic (Fluvial Current)	Cf
Hydrologic (Tidal Current)	Ct
Hydrologic (Alongshore Current)	Cx
Hydrologic Ice (Glacier)	Ig
Hydrologic Ice (Sea)	Is
Hydrologic Ice (River)	If
Hydrologic (Ponded)	Hr
Hydrologic Groundwater (Karst)	Hk
Hydrologic Groundwater (Seeps)	Hs
Periglacial (Slumping/Eroding)	Pe
Undefined/Other	X

Component Forms and Materials

Each across-shore component of the supratidal and intertidal zones are given a detailed description of the geomorphic Forms and Materials that comprise those Forms. The upper case first letter of the Form code represents a general category, such as 'C' for Cliffs or 'B' for Beaches, and the following lower case letters represent modifiers for that category. For example, "Cl" describes a Cliff that is less than 5 m in height. Definitions of the Form codes are listed in Table 16 and mapping guidelines for the classification of each Form code are listed in Table 17.

The substrate that comprises each form is described using Material codes. Material codes also have a major category such as 'R' for Rock and 'C' for Clastics, followed by modifiers. For example, Csp would be a Clastic material comprised of sand (dominant) and pebbles (secondary). All Material codes are listed in Table 18 and guidelines for the classification of each Material code are given in Table 19. Each across-shore component can be described by primary, secondary and tertiary Forms and Materials to encompass the natural variability found in the coastal zone. The use of this descriptive coding system allows the dataset to be searched for specific features while providing the mapper with a flexible means of describing the wide-range of intertidal morphologies and sediment textures.

Table 16. Definitions of the Form codes (after Howes *et al*. 1994). Codes that are crossed out were used in previous ShoreZone mapping but are no longer in use.

A = Anthropogenic

a	pilings, dolphin
b	breakwater
c	log dump
d	derelict shipwreck
f	float
g	groin
h	*shell midden*
i	cable/ pipeline
j	jetty
k	dyke
l	*breached dyke*
m	marina
n	ferry terminal
o	log booms
p	port facility
q	aquaculture
r	boat ramp
s	seawall
t	landfill, tailings
u	*tide gates*
w	wharf
x	outfall or intake
y	intake
z	*beach access*
*****	**undefined (comment)**

B = Beach

b	berm (intertidal or supratidal)
c	~~washover~~ channel
f	face
i	inclined (no berm)
m	multiple bars / troughs
n	relic ridges, raised
p	plain
r	ridge (single bar; low to mid intertidal)
s	storm ridge (occurs as marine influence; supratidal)
t	low tide terrace
v	thin veneer over rock (also use as modifier)
w	washover fan
*****	**undefined (comment)**

C = Cliff (>20° slope)

stability/geomorphology	
a	active/eroding
p	passive (vegetated)
c	cave
slope	
i	inclined (20°-35°)
s	steep (>35°)
height	
l	low (<5m)
m	moderate (5-10m)
h	high (>10m)
modifiers (optional)	
f	fan, apron, talus
g	surge channel
t	terraced
~~r~~	~~ramp~~
e	**pillar**
*****	**undefined (comment)**

D = Delta

b	bars
f	fan
l	levee
m	multiple channels
p	plain (no delta, <5°)
s	single channel
*****	**undefined (comment)**

E = Dune

b	blowouts
i	irregular
n	relic
o	ponds
r	ridge/swale
p	parabolic
v	veneer
w	vegetated
*****	**undefined (comment)**

F = Reef

(no vegetation)	
f	horizontal (<2°)
i	irregular
r	ramp
s	smooth
*****	**undefined (comment)**

I = Ice

g	glacier ice
i	**non-glacial ice**
*****	**undefined (comment)**

L = Lagoon

o	open
c	closed
*****	**undefined (comment)**

M = ~~Marsh~~ Riparian

c	tidal creek
m	tidal creek complex (multiple branching channels)
d	dead from saltwater inundation
e	levee
f	drowned forest
h	high
l	mid to low (discontinuous)
o	pond
s	brackish, supratidal
t	*tidal swamps, shrub/scrub*
*****	**undefined (comment)**

O = Offshore Island

(not reefs)	
b	barrier
c	chain of islets
t	table shaped
p	pillar/stack
w	whaleback
elevation	
l	low (<5m)
m	moderate (5-10m)
h	high (>10m)

P = Platform (<20° slope)

f	horizontal **(<5° slope)**
g	surge channel
h	high tide platform
i	irregular
l	low tide platform
r	ramp **(5-19° slope)**
t	terraced
s	smooth
p	tidepool
e	**seastack**
*****	**undefined (comment)**

R = River Channel

a	perennial
i	intermittent
m	multiple channels
s	single channel
*****	**undefined (comment)**

T = Tidal Flat

b	bar, ridge
c	tidal channel
e	ebb tidal delta
f	flood tidal delta
l	levee
p	tidepool
s	multiple tidal channels
t	flats
w	plunge pool
*****	**undefined (comment)**

U = Tundra

g	ground ice slump
i	inundated
o	isolated thaw ponds
p	plain or level surface
r	ramp
*****	**undefined (comment)**

X = Undefined

Q = Cultural Feature

Table 17. Guidelines for mapping Component Forms.

Form Category	Guidelines
Cliffs: Active vs. Passive (Casl vs. Cpsl):	A cliff is considered active when there is bare substrate showing (this is the most common case). A cliff is considered passive when it has substantial vegetation growing on it, suggesting a highly stable surface.
Beach berm (Bb) vs Beach Storm Ridge (Bs)	A beach berm receives frequent marine influence, contains more recently mobilized sediment, and may be found in the intertidal zone or sometimes in the lower supratidal zone. A beach storm ridge receives occasional marine influence and is only mapped in the supratidal zone. There will often be terrestrial vegetation growing on a beach storm ridge (grasses and trees), suggesting it is stable. A beach berm will not have vegetation growing on it, owing to its more mobile nature.
Beach face (Bf) vs Beach veneer (Bv)	A beach face is solely composed of mobile sediments and shows no evidence of underlying bedrock. A beach veneer code is used when a rock platform has a near continuous covering of sediment over it. The underlying rock platform will be obvious and poke through the sediment.
Beach low-tide terrace (Bt) vs Tidal flat (Tt)	A Bt can be used for flat beaches (<2 degrees) that occur in the upper B zone. It can also be used in the lowest B zone IF the width of that zone is <10% of the overall intertidal zone width. Typically a Tt is used when the width of that B zone is >30 m.
Beach plain (Bp)	A beach plain is a supratidal feature and should not be used as a code in the intertidal zone. Generally they are rare features but can be found on outer exposed coastlines. Beach plains are wide, flat features that show coastal progradation, as evidenced by a series of shore-parallel, vegetated ridges in the supratidal zone. Washover features may cut across the beach plain in places (use the washover fan modifier (w) in the coding, i.e. Bpw). Tidal channel vs. River single channel: (Tc vs. Rs): Most rivulets that occur on tidal flats are Rs or Ri, but not Tc. A Tc should be mapped only when the tidal flat is wide (>200 m), flat (<3°) and shows no visible fluvial source.
Reefs (F) vs Offshore Islands (O)	Islands that are on the digital shoreline are mapped according to the aforementioned rules. If it is not on the digital shoreline, it is not included in the mapping of the main unit. Reefs are not vegetated and are thus mapped as a secondary form of the main shore unit using the reef (F) code.

Table 18. Definitions of the Material Code (after Howes *et al*. 1994). Codes that are crossed out were used in previous ShoreZone mapping but are no longer in use.

A = Anthropogenic

a	metal (structural)
c	concrete (loose blocks)
d	debris (man-made)
f	fill, undifferentiated mixed
o	concrete (solid cement blocks)
r	rubble, rip rap
t	logs (cut trees)
w	wood (structural)

B = Biogenic

c	coarse shell
f	fine shell hash
g	grass ~~on dunes~~
l	dead trees (fallen, not cut)
o	organic litter
p	peat
t	trees (living)
z	permafrost

C = Clastic

a	angular ~~blocks~~ boulders (25cm – 3m diameter)
b	boulders (rounded, subrounded, 25cm – 3m)
c	cobbles (6 cm – 25 cm)
d	diamicton (poorly-sorted sediment containing a range of particles in a mud matrix)
f	fines/mud (mix of silt/clay, <0.0.63 mm diameter)
~~g~~	~~unsorted mix (pebble, cobble, boulder)~~
k	clay (compact, finer than fines/mud, <4 micron diameter)
p	pebbles (0.5 cm to 6 cm)
~~r~~	~~rubble (boulders>1 m diameter)~~
n	**granules (2-5mm diameter)**
s	sand (0.063 to 2 mm diameter)
t	tephra (volcanic pumice and ash)
~~$~~	~~silt (0.0039 to 0.063 mm)~~
x	angular fragments (mix of block/rubble, >3m)
v	sediment veneer (used as modifier)
z	permafrost

I = Ice

i	ice (e.g., ice wedges in permafrost)

R = Bedrock

rock type:

i	igneous
m	metamorphic
s	sedimentary
v	volcanic

rock structure:

1	bedding
2	jointing
3	massive

U = Undefined

W = Water

f	**freshwater**
s	**marine**
u	**unknown**

Cultural Codes

a	**fish camp**
b	**boulder alignment**
c	**canoe run**
d	**ruins**
f	**fishtrap**
h	**housepit**
m	**shellhash midden**
p	**holding pond**
t	**clam terrace**
v	**anthropogenic meadow/root garden**
*****	**undefined**

Table 19. Guidelines for mapping Component Materials.

Form Category	Guidelines
Clastic Materials (C)	Sediments should be listed in the order of abundance. For example, a sand and gravel beach comprised of mostly sand, some pebbles, and occasional cobbles should be coded as Cspc. If it is obvious that one type of material overlies another, use the veneer modifier (e.g. v Cbc/Cps).
Veneer (v)	Layers of sediment over top of other sediment should also be coded in order of abundance. For example, if there is an abundance of boulders and some cobbles overlying sand, this would be coded as v Cbc/Cs. The lowercase v is not used for organics (such as trees, grass, or logs) overlying substrate. If there are logs in the supra-tidal zone overlying boulders and cobbles, which are overlying rock, code as follows. Form 1: Pr - At/Cbc, Form 2: Pr – v Cbc/R. In general the logs should be mapped in Form 1 unless the logs are very scarce. Note that there is a special veneer indicator on the data entry where the Veneer Indicator field is either “blank” = no veneer or “v” = veneer; use “v” when unconsolidated sediment overlies rock or other sediment (e.g. v Cbc/Cps); do not use when organics overlie substrate (e.g. Bt/Cps or At/Casl).
Biogenic Logs (Bl) vs Anthropogenic Logs (At)	Biogenic Logs (Bl) have eroded or fallen from a forested shoreline owing to coastal, fluvial, or mass wasting processes. In most cases, these logs will have a root ball or some portion of the roots still attached, indicating that they have not been cut. In other cases they may be lying across the intertidal zone while still being attached to the ground in the supratidal zone. Anthropogenic Logs (At): Logs that have been cut due to logging activities. These logs have most likely escaped from log booms and will not have any roots or branches attached. Most logs that are in the supratidal and high intertidal zones are Anthropogenic Logs and should be coded as such. When there are also living trees and grasses, avoid trying to lump the logs into the biogenic code by using a Bltg code. For example: when both trees and logs over boulders and cobbles are present, and the logs are the most abundant/significant, use the following coding for Materials: Mat1 = At/Cbc, Mat2 = Bt/Cbc. When trees and organics are most abundant/significant, use the following coding for Materials: Mat1 = Bt/Cbc, Mat2 = At/Cbc. Note that no veneer (v) is used for either of these Material codes.
Undefined (U)	If the material is not visible or cannot be determined from the imagery alone, the Material code should be ‘U’ for Undefined.

Component Oil Residence Index

The Oil Residence Index (ORI) is determined for each supratidal and intertidal across-shore component using the Unit level Physical Wave Exposure and the dominant Material (substrate type) of the primary Form of the Component (Table 20). The ORI categories are the same at both the Unit and Component level (Table 9).

Table 20. The lookup table for the ORI attribute at the component level.

	Wave Exposure					
Component Substrate	**VE**	**E**	**SE**	**SP**	**P**	**VP**
Rock	1	1	1	2	3	3
Anthropogenic, impermeable	1	1	1	2	2	2
Boulder	2	3	5	4	4	4
Cobble	2	3	5	4	4	4
Pebble	2	3	5	4	4	4
Sand with Pebble, Cobble or Boulder	1	2	3	4	5	5
Sand without Pebble, Cobble or Boulder	2	2	3	3	4	4
Mud	999*	999	999	3	3	3
Organic/peat/vegetation	999	999	999	5	5	5
Anthropogenic, permeable	2	2	3	3	5	5

*’999’ indicates this combination occurs rarely so is left to mapper discretion

Shore Modifications

One of ShoreZone's strengths is the cataloging of human-modified or anthropogenic changes to the shoreline. This information can be used to estimate regional trends in human-modification of shores. The primary, secondary and tertiary Shore Modification Code is recorded for each unit (Table 21). For each type of shore modification (i.e. boat ramp, concrete bulkhead, dyke, landfill, sheet pile etc.), the percent of the alongshore length within the Unit is also estimated (Table 22). A total estimation of each type can be calculated for various regions (e.g. in SE Alaska, rip-rap is the most common Shore Modification and occurs along 145 km of shore or ~0.5% of the coast).

Pilings are not considered a Shore Modification unless they are driven in side-by-side to form a retaining wall, in which case the Shore Modification code for wooden bulkhead would be used. Floats also are not cataloged as part of the Shore Modification attributes. Fill and tailings placed deliberately at landings, industrial sites or around structures are cataloged as landfill. Domestic trash and debris around a house is not considered as landfill. The 'Impacted' code is new in this protocol and is meant to encompass evidence of human activities with no actual anthropogenic structures or materials, like ATV trails on the beach.

Table 21. List of the codes used for the Shore Modification Code attribute.

Code	Description
BR	Boat Ramp
CB	Concrete Bulkhead
LF	Landfill
SP	Sheet pile
RR	Rip Rap
WB	Wooden Bulkhead
PS	Pile-supported Wharf
AI	Impacted
FL	Marina/Floats
DS	Deep-sea Shipping
RS	Recreational Slips
UU	Undefined

Table 22. The percent alongshore length categories for Shore Modifications.

Category	Percent Cover (%)
1	<5
2	5-25
3	26-50
4	51-75
5	76-95
6	>95
NA	Not Assessed

Coastal Cultural Features Module (optional)

This optional classification module can be added to the standard physical ShoreZone classification, which includes all attributes described so far. Coastal cultural features are usually archaeological sites, either in the supratidal or intertidal, that are visible from the aerial imagery. This module will only be classified at the request of a client and with the specific attributes to be classified determined on a project-by-project basis. Examples of potential cultural features are listed in Table 23.

Table 23. Cultural feature codes and descriptions.

Code	Feature
a	Fish Camp
b	Boulder Alignment
c	Canoe Run
d	Ruins
f	Fish Trap
h	House Pit
m	Shell Hash Midden
p	Holding Pond
t	Clam Terrace
v	Anthropogenic
u	Meadow/Root Garden
*	Undefined

3.3 Biological ShoreZone Attributes

Units delineated as alongshore coastal segments by the physical mappers are the framework to which biological attributes are attached. Biological mappers do not create additional units or change the spatial depiction of the Unit and all biological attributes are recorded within the spatial framework provided by the physical mappers.

Intertidal biota are strongly affected by the rise and fall of the tide and often show spatially distinct horizontal banding that corresponds to the elevation and slope of the beach and consequently the duration and area of submergence. The biological ShoreZone mapping attributes are based on the interpretation of patterns of biota observed in the aerial imagery, with data recorded on the occurrence and extent of species assemblages. In ShoreZone, we call those assemblages **Biobands** (Figure 18). Biobands are recorded at the Component level; however, two Unit level attributes (Biological Wave Exposure and Habitat Class) are then interpreted based on the Biobands present within the Unit. Correspondingly, this section is organized with the Component level attributes defined first (Section 3.3.1) and the Unit level attributes second (Section 3.3.2).

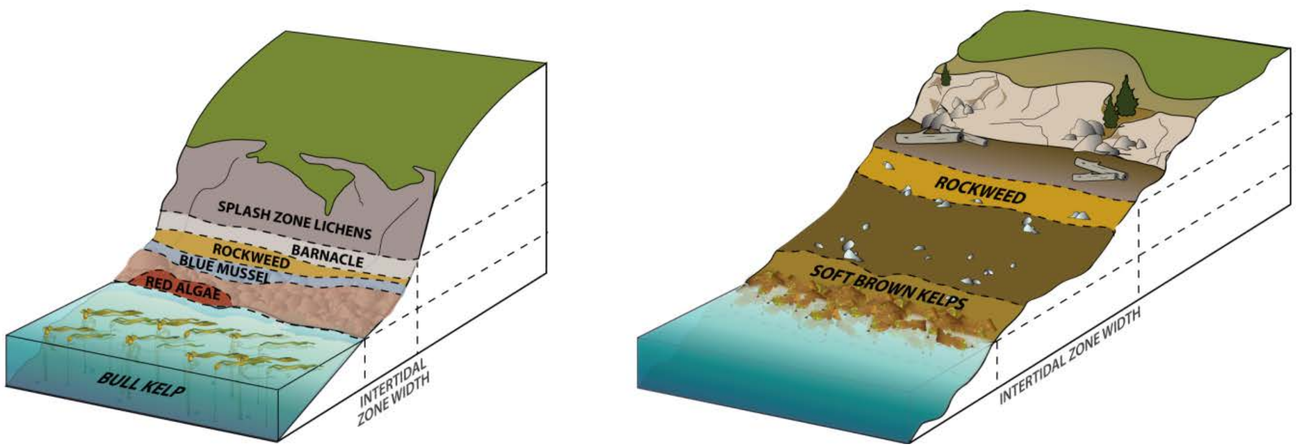


Figure 18. Typical Bioband combinations on a rocky shore (left) and a sediment shore (right).

3.3.1 Component Level Biological Attributes

<u>Biobands</u>
A Bioband is an observed assemblage of coastal biota, found on the shoreline at characteristic wave energies, substrate conditions and typical across-shore elevations. Biobands are spatially distinct, with alongshore and across-shore patterns of color and texture that are visible in aerial imagery. They are one of the most used attributes of the ShoreZone dataset, mostly for mapping regional distributions of biota and resource management applications.

Biobands are generally named for the dominant species or group that best describes the entire assemblage. Some Biobands are named for a single indicator species (such as the Blue Mussel Bioband), while others represent an assemblage of co-occurring species (such as the Red Algae Bioband). The indicator species listed for each Bioband are those which best describe the overall appearance and assemblage present for the band. The full Bioband list with associated color, texture and elevation can be found at the end of this section. An online data dictionary with photographic examples of each Bioband from multiple biogeographic areas will be made available on the NOAA ShoreZone website in 2018.

A new nested Bioband classification scheme was developed and applied to all ShoreZone mapping completed after January 1st, 2015. Part of this scheme was the application of a new four-digit code for each Bioband with a consistent naming convention. Another part was the creation of Primary, Secondary and Tertiary Biobands which nest under each other with increasing specificity in terms of the biotic assemblage described. In addition, some of the original Biobands were split to better describe observed biota as ShoreZone continues to move into new areas and imaging resolution continues to improve. Some new Biobands were also added in response to ShoreZone surveys being conducted in Arctic areas that are fundamentally different from other coasts previously described by ShoreZone. The nested organization of the new scheme gives new options for analysis for Biobands that serve a similar ecological function, or those that can't be identified with high confidence, as they can now be rolled up into a well-defined 'higher level' Bioband for analysis. This facilitates regional comparisons within the ShoreZone dataset as Bioband names and descriptions have been added over time and over different regions. For example, there are five Tertiary Biobands described under the Secondary Bioband level of Wetland Vegetation, including three salt marsh Biobands from three different regions; however, all five Biobands look similar in the aerial imagery and serve similar ecological functions. By rolling them up into the Wetland Vegetation Bioband they could be analyzed with more confidence over a larger area of coastline.

Some Biobands are generally observed with higher confidence than others and may be visible as discrete patches at lower density than more obvious Biobands. For example, the Red Algae Bioband is usually low turf and mixed with kelp bands and therefore can be hidden by larger seaweeds. Often the Eelgrass and Surfgrass Biobands are easier to see, even if present as scattered patches, as they are usually a color contrast to the lower intertidal seaweed (often the large browns of the Soft-brown Kelps or the Dark Brown Kelps). The nearshore canopy kelps (Bull Kelp, Dragon Kelp and Giant Kelp) are also generally observed with higher confidence, as they all have large sized individuals and are easier to see even when the band is patchy.

Each Bioband observed in a unit is described using several metrics, described in Table 24. These new metrics were added in 2015 and have been refined in this version of the protocol. The percent length of the unit covered by the Bioband is assessed for all Biobands in all zones. This links the Bioband occurrence to the spatial framework of ShoreZone, which is primarily based on the linear digital shoreline. Biobands in the supratidal and subtidal are also quantified by a width category of Narrow (<10m), Medium (10-30m) and Wide (>30m) except the supratidal lichens which have width categories of Narrow (<1m), Medium (1-5m) and Wide (>5m). The lichen width categories are defined to help determine the Biological Wave Exposure which is why they have different width categories. In addition, for intertidal Biobands, the percent cover of the Zone is estimated using the same categories as for the percent alongshore length code for Shore Modifications (Table 22). Percent cover cannot be estimated for supratidal and subtidal Biobands because the limits of those zones cannot be defined with the same level of accuracy as the intertidal zone. See Figures 19 and 20 for illustrations of the metrics for the Biobands in each zone.

The full definitions for all Biobands are found in Tables 25, 26 and 27.

Table 24. Bioband metrics for the Biobands in each Zone.

<table>
<tr><th>Zone</th><th>Bioband Length (as % of total unit length)</th><th>Bioband Width Category</th><th>Percent Cover (as % of Zone area)</th></tr>
<tr><td>Supratidal (A Zone)</td><td rowspan="4"><5%
5-25%
26-50%
51-75%
76-95%
>95%
Not Assessed</td><td>Narrow (<10 m),
Medium (10-30 m),
Wide (>30 m),
Not Assessed</td><td rowspan="2"></td></tr>
<tr><td>Supratidal splash zone Biobands*</td><td>Narrow (<1 m),
Medium (1-5 m),
Wide (>5 m),
Not Assessed</td></tr>
<tr><td>Intertidal (B Zone)</td><td></td><td><5%
5-25%
26-50%
51-75%
76-95%
>95%
Not Assessed</td></tr>
<tr><td>Subtidal (C Zone)</td><td>Narrow (<10 m),
Medium (10-30 m),
Wide (>30 m),
Not Assessed</td><td></td></tr>
</table>

*This includes all Biobands listed under the primary level Splash Zone Bioband (SPZO, LICH, BLLI, YELI, WHLI). These have different width categories than the other supratidal zone Biobands because the width categories listed here have been associated with specific Biological Wave Exposures. It also keeps the recording of these Biobands consistent with previous ShoreZone mapping.

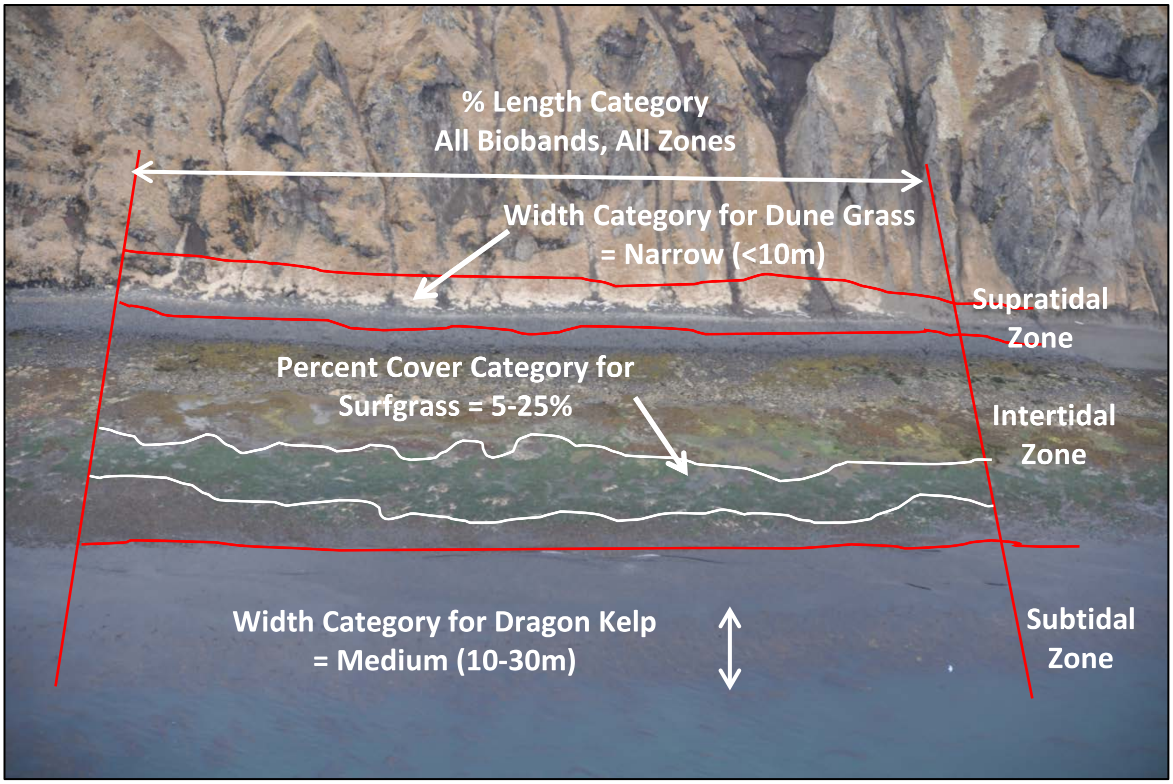


Figure 19. Illustration of the width metric for the supratidal Biobands not under the Splash Zone (SPZO) primary category and the subtidal Biobands, and the percent cover metric for intertidal Biobands.

Figure 20. Illustration of the width category metric for the supratidal Splash Zone (SPZO) Biobands. These are all listed under the primary SPZO Bioband in Table 24.

Table 25. Definitions for the supratidal Biobands. This combines Biobands used in Oregon State, Washington State, British Columbia and Alaska. Not all Biobands are applicable to all areas so it is noted in the Bioband description if it is specific to a certain region.

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Terrestrial Vegetation				**TEVE**	A	N/A	N/A	Non-specific vegetation existing in the supratidal zone that does not fit into any other more specific supratidal bioband or cannot be clearly identified from the imagery.	All
	Tundra		TUN	**TUND**	A	Green to Grey-green	*Salix* spp. *Vaccinium* spp. *Dupontia fisheri*	Low turf of dwarf shrubs, herbs, grasses, sedges with lichens and mosses, in uppermost supratidal and splash zone. May be inundated in storm surge.	All
	Trees & Shrubs			**TRSH**	A	Greens and browns	N/A	Non-specific trees and shrubs in the supratidal zone that do not fit into any other more specific tree/shrub bioband or cannot be clearly identified from the imagery.	All
		Deciduous Trees		**DETR**	A	Greens and browns, white-grey	*Alnus* spp. *Betula* spp.	This bioband consists mostly of stands of alder and birch trees mixed with understory shrubs in the supratidal zone. Mostly confined to river banks.	All
		Coniferous Trees		**COTR**	A	Greens and browns	*Picea* spp. *Pinus* spp.	This bioband consists mostly of stands of pine and spruce trees mixed with understory shrubs in the supratidal zone. Mostly confined to river banks.	All
		Shrub Meadow	MSH	**SHME**	A	Pale green	*Deschampsia caespitosa* *Picea sitchensis*	A narrow strip at the uppermost marsh edge, next to the tree line; usually a transition to spruce forest, including small spruce, shrubs and mixed grasses, sedges and herbs. Created for Oregon SZ.	VP to P
	Grasses			**GRAS**	A	Green to blue-green to beige	N/A	Non-specific grass in the supratidal zone that does not fit into any more specific grass bioband or cannot be clearly identified from the imagery.	All
		High Grass Meadow	MAG	**HIGM**	A	Pale grassy green or beige	*Deschampsia caespitosa* *Trifolium wormskjoldii*	Mixed grassy meadow, on uppermost salt marsh, interfingers with Salt Marsh (TRI) or Sedge (SED) at lower elevation transition. Specific to Oregon SZ	VP to P
		European Beach Grass	AMM	**EUBG**	A	Beige-green	*Ammophila* spp.	Outer coastal sand dunes, forming clumps and stabilizing active dunes. Non-native species which is displacing native dune grass species. Specific to Oregon.SZ.	SE to E
		Dune Grass	GRA	**DUGR**	A	Pale blue-green	*Leymus mollis*	Found in the upper intertidal zone, tall grasses observed as clumps continuous on dunes, in logline or on beach berms. This band may be the only band present on high-energy beaches.	VP to E

Table 25. Con't

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Splash Zone			VER[†]	**SPZO**	A	Black, white or bare rock	N/A	Non-specific band marking the upper limit of the intertidal zone that does not fit into any more specific splash zone bioband. All bands in the splash zone are recorded by width: Narrow (<1m), Medium (1m-5m) or Wide (>5m)	All
	Lichen			**LICH**	A	Black, white to yellow/ green white	N/A	Non-specific lichen band in the supratidal zone that does not fit into any more specific splash zone bioband.	All
		Black Lichen		**BLLI**	A	Black to grey-black	*Verrucaria* sp. Encrusting black lichens	Visible as a dark stripe on bare rock marking the upper limit of the intertidal zone.	All
		White Lichen		**WHLI**	A	Creamy white to pinkish-grey	*Coccotrema maritimum* Encrusting white lichens	Visible as a bright white stripe on bare rock marking the upper limit of the intertidal zone. When present, this band usually occurs above the Black Lichen band.	All
		Yellow Lichen		**YELI**	A	Bright to dark yellow or orange	*Caloplaca* spp. *Xanthoria* spp.	Visible as bright yellow to dark orange blotches, sometimes forming a stripe, on bare rock. Usually co-occurs with the Black Lichen bioband.	SE to VE

[†]The previous Splash Zone Bioband (VER) has been split into several current Bioband codes (LICH, BLLI, WHLI, YELI) so these bands would need to be rolled together for comparison for the VER Bioband.

Coastal and Ocean Resources

Table 26. Definitions for the invertebrate Biobands. This combines Biobands used in Oregon State, Washington State, British Columbia and Alaska. Not all Biobands are applicable to all areas so it is noted in the Bioband description if it is specific to a certain region.

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Invertebrate				**INVE**	B & C	N/A	N/A	Non-specific band of invertebrates that does not fit into any more specific invertebrate bioband or cannot be clearly identified from the imagery.	All
	Crustaceans			**CRUS**	B	N/A	N/A	Non-specific band of crustaceans that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Barnacle	BAR‡	**BARN**	B	Grey-white to pale yellow	*Balanus glandula* *Semibalanus cariosus*	Visible on bedrock or large boulders. Can form an extensive band in higher exposures where algae have been grazed away.	P to VE
		Mud Flat Shrimp	CAL	**MUFS**	B	Mottling on sand flats, burrows	*Neotrypaea californiensis* *Upogebia pugettensis*	On sand/mud flats in larger estuaries, where textured surface indicates presence of infauna. Specific to Oregon and Washington State SZ.	VP to P
	Molluscs			**MOLL**	B	N/A	N/A	Non-specific band of molluscs that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Blue Mussels	BMU	**BLMU**	B	Black or blue-black	*Mytilus trossulus*	Visible on bedrock and on boulder, cobble or gravel beaches. Appears in dense clusters that form distinct black patches or bands, either above or below the barnacle band.	P to VE
		California Mussels	MUS	**CAMU**	B	Grey-blue	*Mytilus californianus*	Dominated by a complex of California mussels (*Mytilus californianus*) and thatched barnacles (*Semibalanus cariosus*) with gooseneck barnacles (*Pollicipes polymerus*) seen at higher exposures.	SE to VE
		Oyster	OYS	**OYST**	B	Dark beige to brown	*Crassotrea gigas*	Generally inconspicuous and of limited extent in BC. Includes areas of oyster aquaculture on mudflats in Oregon and Washington State, in particular in Coos Bay and Yaquina Bay. Specific to Oregon, BC and Washington State SZ.	VP to P

‡ The previous Barnacle (BAR) bioband has been split into BARN and WILA (described in Table 27) so these would have to be rolled together to be equal to the previous BAR band.

Table 26. Con`t

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Invertebrate	Sponges			**SPON**	B & C	Commonly yellow, purple or red	N/A	Encrusting sponges usually occur as brightly colored patches at the waterline or in the shallow subtidal. Associated with high wave energy or current-dominated habitats.	SP to E
	Cnidarians			**CNID**	B & C	N/A	N/A	Non-specific band of cnidarians that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Anemones		**ANEM**	B & C	Usually white to yellow and red	N/A	Anemones usually appear as small circular dots of colour in the low intertidal and shallow subtidal. It is usually associated with high wave energy or current-dominated habitats. Could include *Metridium* spp. and *Urticina* spp.	SP to E
	Echinoderms			**ECHI**	B & C	N/A	N/A	Non-specific band of echinoderms that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Urchin Barrens	URC	**URBA**	C	Coralline pink/white	*Strongylocentrotus franciscanus*	Shows rocky substrate clear of macroalgae. Often has a pink-white color of encrusting coralline red algae. May or may not see urchins.	SP to E
		Sand Dollars	DEN	**SAND**	Lower B & Upper C	Black spots within beige sand matrix	*Dendraster excentricus*	Beds of sand dollars, usually on sand beaches. Specific to Washington State SZ.	P to SE

Table 27. Definitions for the intertidal/subtidal vegetation Biobands. This combines Biobands used in Oregon State, Washington State, British Columbia and Alaska. Not all Biobands are applicable to all areas therefore it is noted in the Bioband description if it is specific to a certain region.

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Intertidal/ Subtidal Vegetation				**INSV**	B & C	N/A	N/A	Non-specific intertidal or subtidal vegetation that does not fit into a more specific bioband or cannot be clearly identified from the imagery.	All
	Wetland Vegetation			**WEVE**	A & upper B	Greens and browns	N/A	Non-specific wetland vegetation in the supratidal zone that does not fit into any more specific wetland bioband or cannot be clearly identified from the imagery.	VP to E
		Sedges	SED	**SEDG**	A & upper B	Bright green to yellow-green	*Carex lyngbyei*	In wetlands around lagoons and estuaries. Usually associated with freshwater. This band can exist as a wide flat pure stand or be intermingled with dune grass. Often the SAMA band forms a fringe below.	VP to SE
		Spartina	SPA	**SPAR**	Upper & mid B	Bright green	*Spartina* spp.	*Spartina*-invaded and *Spartina*-dominated salt marshes and mudflats. Specific to Washington State.	P to SP
		Salt Marsh	PUC	**SAMA**	A & upper B	Light, bright or dark green with red-brown	*Puccinellia* spp. *Plantago maritima* *Glaux maritime* *Deschampsia* spp.	Appears around estuaries, marshes, and lagoons and is usually associated with freshwater. In some areas, it can be sparse plants on coarse sediment or a wetter, peaty meadow with associated herbs and sedges.	VP to SE
		Salt Marsh (Oregon & Washington State)	TRI	**SAMO**	A & upper B	Light, bright or dark green with red-brown	*Triglochin maritima* *Distichlis spicata* *Deschampsia caespitosa*. *Scirpus americanus* *Salicornia virginica*	Appears around estuaries, marshes, and lagoons, associated with fresh water. Separated as 'high marsh' and 'low marsh' according to elevation/salt water inundation in Oregon, but describes only a 'high marsh' in Washington State. Can be sparse vegetation on coarse sediment or a wetter, peaty meadow with an assemblage of herbs, grasses and sedges. Specific to Oregon and Washington State SZ.	VP to SE
		Salt Marsh (BC & Washington State)	SAL	**SAMB**	A & upper B	Light, bright, or dusty green	*Salicornia virginica*	Salt-tolerant herbs and grasses associated with freshwater. This band is often associated with estuaries, marshes, and lagoons although it is not uncommon as a fringing meadow in the supratidal. Used to describe a 'low marsh' in Washington State and generally lacking associated grass species in that classification. Specific to BC and Washington State.	SE to VP

Table 27. Con't

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Intertidal/ Subtidal Vegetation	Biofilm		BFM	**BIOF**	B	Rusty orange-beige or dark green-black	Bacterial or diatom mat, blue-green algal mat	Low turf or stain on sediment. Includes moss-like turf of blue-green algal mat. Usually seen in pools of washover bars and river deltas.	P to SE
		Diatom	DIA	**DIAT**	B	Beige or bleached white	Diatoms	This band describes bare-looking lower intertidal areas in the coastal fjords of BC where a low turf of encrusting filamentous diatoms may be present. Specific to BC SZ.	P to SP
	Green Algae		ULV	**GRAL**	B	Various shades of green	*Ulva* sp. *Monostroma* sp. *Cladophora* sp. *Acrosiphonia* sp.	Found on a variety of substrates. The band consists of filamentous and/or foliose green algae. Filamentous species often form a low turf of dark green.	VP to E
	Red Algae		RED[†]	**REAL**	B	Various shades of red, pink, gold	N/A	Non-specific band of red algae that does not fit into a more specific red algae bioband or cannot be clearly identified from the imagery.	P to VE
		Coralline Red Algae		**CORA**	B	Pink to whitish-pink	*Corallina* sp. *Lithothamnion* sp.	A combination of foliose and encrusting coralline algae occurring in the low intertidal. Lush coralline red algae indicate highest wave exposures.	SE to VE
		Filamentous and Foliose Red Algae		**FFRA**	B	Dark to bright red and red-brown	*Odonthalia* sp. *Neorhodomela* sp. *Palmaria* sp. *Neoptilota sp.* *Mazzaella* sp.	Diversity of foliose red algae indicates medium to high exposures, with filamentous species, often mixed with green algae, occurring at medium and lower exposures.	P to E
		Winter Laver	BAR[‡]	**WILA**	Upper B	Pale green to greenish-gold	*Porphyra pseudolanceolata* *Porphyra hiberna*	These species of *Porphyra* grow in the high intertidal of more exposed coasts in the winter season (sometimes seen in spring or summer in colder climes). *P. hiberna* replaces *P. psuedolanceolata* south of Sitka Sound. It is associated with the Barnacle bioband.	SE to E
		Bleached Red Algae	HAL	**BRAL**	B	Olive, golden or yellow-brown	Bleached foliose/ filamentous red algae	Common on bedrock platforms, and cobble or gravel beaches. Distinguished from the FFRA band by color, although may be similar species. The bleached color usually indicates lower wave exposure.	P to SP
		Graceful Red Weed	GCA	**GRRW**	B	Dark reddish brown	*Gracilaria* spp.	Usually present as patches in the mid-intertidal on sandy and muddy tidal flats. Specific to Washington State SZ.	P to SP

Table 27. Con't

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	Secondary Level	Tertiary Level							
Intertidal/ Subtidal Vegetation	Rooted Vegetation			**ROVE**	B & C	Green to green-grey	N/A	Non-specific rooted vegetation in the lower intertidal and/or shallow subtidal that do not fit in any more specific intertidal/subtidal bioband or cannot be clearly identified from the imagery.	VP to SE
		Surfgrass	SUR	**SURF**	B & C	Bright to dark green	*Phyllospadix* sp.	Appears in tide pools on rock platforms, often forming extensive beds. This species has a clearly defined upper exposure limit of Semi-Exposed and its presence in units of Exposed wave energy indicates a wide across-shore profile, where wave energy is dissipated by wave run-up across the broad intertidal zone.	SP to SE
		Eelgrass	ZOS	**EELG**	B & C	Bright to dark green	*Zostera marina*	Commonly visible in estuaries, lagoons or channels, generally in areas with fine sediments. Eelgrass can occur in sparse patches or thick dense meadows.	VP to SP
	Brown Bladed Algae			**BRBA**	B & C	Various shades of brown	N/A	Non-specific bladed brown algae in the lower intertidal and/or shallow subtidal that do not fit in any more specific kelp bioband or cannot be clearly identified from the imagery.	All
		Alaria	ALA	**ALAR**	B & C	Dark brown to red-brown	*Alaria marginata*	Common on bedrock cliffs and platforms, and on boulder/cobble beaches. This band has a distinct ribbon-like texture, and may appear iridescent..	SP to E
		Soft Brown Kelps	SBR	**SOBK**	B & C	Brown to yellow-brown to olive	*Saccharina latissima* *Cystoseira sp.* *Sargassum muticum*	This band is defined by non-floating large browns and can form lush bands in semi-protected areas. The kelp fronds have a ruffled appearance and can be encrusted with diatoms and bryozoans giving the blades a 'dusty' appearance.	VP to SE
		Dark Brown Kelps	CHB	**DABK**	B & C	Dark brown	*Laminaria setchelli* *Lessoniopsis littoralis* *Laminaria longipes* *Laminaria yeozensis*	Found at higher wave exposures, these stalked kelps grow in the lower intertidal. Blades are leathery, shiny, and smooth. A mixture of species occurs at the moderate wave exposures, while single-species stands of *Lessoniopsis* occur at high exposures.	SE to VE

Table 27. Con't

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	Secondary Level	Tertiary Level							
Intertidal/ Subtidal Vegetation	Brown Non-Bladed Algae			**BRNA**	B & C	Various shades of brown	N/A	Non-specific non-bladed brown algae that does not fit into a more specific algal bioband or cannot be clearly identified from the imagery.	All
		Rockweed	FUC	**ROCK**	B	Golden-brown to brown	*Fucus distichus*	Appears on bedrock cliffs and boulder, cobble or gravel beaches. Commonly occurs at the same elevation as the barnacle band.	VP to E
		Sargassum	SAR	**SARG**	Lower B & C	Golden-brown to brown	*Saragssum muticum*	This bioband descrbes continuous stands of Sargassum in the lower intertidal and nearshore subtidal. It is often 'fuzzy' looking and golden-brown in colour. Specific to Washington State SZ.	P to SP
	Brown Canopy-Forming Algae			**BRCA**	C	Dark brown	N/A	Non-specific canopy kelp that does not fit into any more specific canopy kelp bioband or cannot be clearly identified from the imagery.	P to VE
		Dragon Kelp	ALF	**DRKE**	C	Dark brown to golden-brown	*Eularia fistulosa*	Canopy-forming kelp, with winged blades on gas-filled center midrib. Usually associated with silty, cold waters near glacial outflow rivers. Range: southern Southeast AK to Aleutian Islands, AK.	SP to SE
		Giant Kelp	MAC	**GIKE**	C	Dark brown to golden-brown	*Macrocystis pyrifera*	Canopy-forming giant kelp, long stipes with multiple floats and fronds. If associated with NER, it occurs inshore of the bull kelp. Range: Baja California, Mexico to Kodiak Islands, AK.	P to SE
		Bull Kelp	NER	**BUKE**	C	Dark brown	*Nereocystis luetkeana*	Distinctive canopy-forming kelp with many long strap-like blades growing from a single floating bulb atop a long stipe. Can form an extensive canopy in nearshore habitats, usually further offshore than *Eularia fistulosa* and *Macrocystis pyrifera*. Often indicates higher current areas if observed at lower wave exposures. Range: Point Conception, CA to Unimak Island, AK.	SP to VE

† The previous Red Algae (RED) bioband has been split into CORA and FFRA. These need to be combined to be equal to the old RED band (NOT including WILA, GRRW or BRAL).

‡ WILA used to be an associate species for the old Barnacle (BAR) band and was not mapped as a separate band as the surveys were often completed in the summer months when WILA is not present.

3.3.2 Unit Level Biological Attributes

Biological Wave Exposure

Biological Wave Exposure is assigned based on the observations of the presence and abundance of biota in each alongshore Unit. Exposure categories are defined with a typical set of Biobands, using the known wave energy tolerances for the indicator species, as compiled from scientific literature and expert knowledge. The Biobands present in each shore Unit are essentially used as a 'proxy' for estimating the energy in each shore Unit. Values range from Very Protected to Very Exposed. Guidelines for assigning the Biological Wave Exposure category to each unit are listed in Table 28. Biobands generally observed at each wave exposure are considered 'typical' but are not 'obligate'; that is, not all the indicator Biobands occur in every unit classified with a particular Biological Wave Exposure.

The six Biological Wave Exposure categories have the same names as those used in the physical mapping to characterize Wave Exposure; however, the physical Wave Exposure is based on fetch estimates and coastal geomorphology. The Biological Wave Exposure category is generally considered to be a better index of exposure than are estimates derived from fetch measurements, and is used as the best available wave exposure estimate when available. On many of the Arctic coasts, extended sections of shoreline are dominated by mobile sediment beaches where attached biota are largely absent, and using observations of biota to estimate wave exposure categories is not possible. On those bare sediment beaches, the best available wave exposure estimate is the attribute assigned by the physical mappers from wind fetch observation, and that is deemed to be equivalent to the Biological Wave Exposure. The best available wave exposure estimate is the one used in the look up matrix for assigning the unit's Oil Residence Index as well as for determining each Units' Habitat Class (see below for Habitat Class definition).

The biota of the upper intertidal tends to have similar species assemblages in different wave exposure categories and geographic areas and are thus considered weak indicators of the biological exposure. For example, the ubiquitous Barnacle Bioband is found across all exposure categories. In contrast, lower intertidal Biobands are more diagnostic of particular wave exposures. For example, the Surfgrass Bioband is indicative of Semi-Exposed environments, while the Eelgrass Bioband is indicative of Semi-Protected (SP) and Protected (P) environments. On the rocky coasts of the Gulf of Alaska, the highest energy coastlines are generally indicated by the co-occurrence of the Dark Brown Kelp and Red Algae Biobands, while a lush Soft Brown Kelps Bioband is one of the indicators of Semi-Protected wave exposures. Combinations of the Red Algae or Alaria Biobands with either of the brown kelp bands occur in areas of transition between Semi-Protected and higher wave exposure categories.

The Biological Wave Exposure is recorded as the highest exposure category observed in the unit, according to the indicator species and Biobands present. In units where shoreline is complex, or where there are wide intertidal platforms, there may actually be a range of exposures and associated indicator species spanning the across-shore width of the Unit, from the waterline (where the energy is highest) to the splash zone (where it is the lowest).

Table 28. Guidelines for assigning the Biological Wave Exposure attribute.

Biological Wave Exposure Category	Guidelines for Classification
Very Exposed (VE)	This exposure category is used only for areas of extreme high wave energy, where the shoreline is predominantly a vertical rock cliff and there is no moderation of open ocean swells in nearshore. The Splash Zone is extremely wide (>20m).
Exposed (E)	The Splash Zone is wide to very wide (10-20m). The upper intertidal is usually bare-looking, with only a thick Barnacle Bioband visible. The lower intertidal tends to have a lush Dark Brown Kelp Bioband mixed with Red Algae. Nearshore canopy kelp, if present, is Bull Kelp.
Semi-Exposed (SE)	The Splash Zone will usually be medium to wide in width (5-10m). This is the exposure category with the highest species diversity. It is indicated by the presence of Dark Brown Kelps, lush Red Algae (especially Coralline Red Algae), Alaria and in some locations, the Surfgrass Biobands.
Semi-Protected (SP)	The Splash Zone is medium to narrow in width (1-5m). It is indicated by Barnacle, Rockweed and Green Algae Biobands which may be quite lush. In higher SP, Red Algae and Alaria Biobands are often observed. Eelgrass occurs in the lower Semi-Protected areas and Surfgrass can be found in the higher Semi-Protected areas.
Protected (P)	Attached biota can be patchy due to lack of circulation, although in areas with good circulation the biobands can be quite lush. It is indicated by patchy Barnacle, Rockweed and Green Algae Biobands in the intertidal and Eelgrass or sparse Soft Brown Kelps in the subtidal. If the Splash Zone is present it is narrow (<1m). Canopy kelps not usually present. Canopy kelps in otherwise Protected areas can indicate a current dominated Habitat Class.
Very Protected (VP)	Use of this category is limited to areas of very low wave exposure and limited diversity of biota, as are seen at the extremely sheltered heads of inlets or in ponded lagoons with a limited intertidal range. Often only the wetland Biobands will be present, and the intertidal is bare of attached biota.

Habitat Class

Habitat Class is a summary attribute that combines both physical and biological characteristics observed for a particular shoreline Unit. The species assemblages present on the shore are a reflection of both the Biological Wave Exposure and the physical characteristics of that shore segment as defined by the Coastal Class assigned by the physical mapper, which incorporates process, sediment, slope and width. The interaction of the wave exposure and those physical properties determines the substrate mobility, which in turn determines the presence and abundance of attached biota. Where the substrate is stable (i.e. bedrock or large boulder) epibenthic assemblages can establish. Where the substrate is mobile, attached biota will likely be sparse or absent (i.e. higher energy sand or pebble beaches). Thus, the Habitat Class assigned to an Exposed shore with a mixture of rock and mobile sediment will be different from that of a Protected shore with a wetland complex, summarizing the habitat of the Unit and reflecting biophysical features. Most units have the Habitat Class category determined by wave energy as that is the most common structuring process. Other categories of structuring processes are: riparian, current, glacial, anthropogenic, lagoon and periglacial (Table 29).

The three classes of substrate mobility used in ShoreZone habitat characterization are:

Immobile or Stable: Substrates such as bedrock, boulders, and cobbles (could even be pebbles on a low energy coast).

- Usually bedrock platforms or cliffs.
- Depending on the exposure, this category may include units with bedrock and large boulders covered in algae or even sediment only beaches (large sediment size and low wave exposure).
- If the unit contains <10% mobile sediment it is still classified as immobile.

Partially Mobile: Mixed substrates such as a rock platform with a beach or sediment veneer, or Units where energy varies across the beach. The partial mobility of the sediment limits the presence of attached biota that would likely occur on a stable rock shoreline.

- Can range from totally mobile beaches with bedrock outcrops to bedrock platforms with pockets of sediment (>10% of total area).
- Units are categorized as Partially Mobile if sediment areas of the unit have little or no attached biota. An example would be a sediment beach that is bare in the upper half of the intertidal with Biobands occurring on the lower beach. This pattern is often seen at moderate wave exposures.

Mobile: Substrates such as sandy beaches where coastal energy levels are sufficient to frequently move sediment, thereby limiting the presence of epibenthic biota.

- Intertidal is mostly bare of attached biota.
- Can have supratidal Biobands and/or nearshore subtidal Biobands.
- If the area of the unit contains <10% immobile sediment it is still classified as mobile.

Table 29. Definitions of the Habitat Class categories. Habitat Class codes in shaded boxes are very infrequent and in most cases, do not occur.

Dominant Structuring Process	Substrate Mobility	Coastal Type	Description	Biological Exposure Category					
				Very Exposed (VE)	Exposed (E)	Semi-Exposed (SE)	Semi-Protected (SP)	Protected (P)	Very Protected (VP)
Wave energy	Immobile	Rock **or** Rock & Sediment **or** Sediment	In high wave exposures, only solid bedrock shorelines will be classified as 'immobile'. At the lowest wave exposures, this could include sediment beaches that exhibit lush epibiota.	10 VE_I	20 E_I	30 SE_I	40 SP_I	50 P_I	60 VP_I
	Partially Mobile	Rock & Sediment **or** Sediment	These categories can describe units with a combination of Immobile and Mobile substrates or a unit that is composed entirely of partially mobile sediment.	11 VE_P	21 E_P	31 SE_P	41 SP_P	51 P_P	61 VP_P
	Mobile	Sediment	These categories are intended to indicate sediment beaches where no epibenthic macrobiota are observed. Very fine sediment may be mobile even at the lowest wave exposures, while at the highest wave exposures large-sized boulders could be mobile and bare.	12 VE_M	22 E_M	32 SE_M	42 SP_M	52 P_M	62 VP_M
Riparian	Variable	Organic*	These processes may encompass a variety of substrate types and wave exposures and therefore a wide number of Habitat Class categories. In general, these units follow the dominant process defined by the Coastal Class attribute.		23 E_E	33 SE_E	43 SP_E	53 P_E	63 VP_E
Current	Variable	Current-Dominated				34 SE_C	44 SP_C	54 P_C	
Glacial	Variable	Glacier					45 SP_G	55 P_G	65 VP_G
Anthropogenic	Variable	Impermeable				36 SE_X	46 SP_X	56 P_X	66 VP_X
		Permeable				37 SE_Y	47 SP_Y	57 P_Y	67 VP_Y
Lagoon	Variable	Lagoon				38 SE_L	48 SP_L	58 P_L	68 VP_L
Periglacial	Variable	Permafrost			29 E_T	39 SE_T	49 SP_T	59 P_T	69 VP_T

*Coastal Class 39 (Low Vegetated Peat) was moved from Periglacial processes to Riparian Processes in this protocol revision.

Section 4.0
ShoreZone Verification Studies

ShoreZone image interpretation and mapping is performed by a team of physical and biological scientists with academic science degrees and experience in geography, biology, mapping, and environmental projects. A quality assurance and control (QA/QC) protocol requires 10% of each physical and biological mappers' work to be reviewed by another mapper. Database QA/QC and data-entry integrity is ensured by a database manager with at least two years of ShoreZone mapping experience. Several factors influence the complexity of shoreline mapping, including the natural geomorphology, the coastal crenulations, the quality of the imagery and associated commentary and the quality of the digital shoreline basemap.

The ShoreZone mapping technique has been assessed to establish qualitative and quantitative confidence levels in ShoreZone maps and data in various studies including: a study of the repeatability of mapping in Southeast Alaska; an external review conducted by Schoch (2009); field verification studies in Victoria, British Columbia (Harney and Morris 2007) and Sitka, Alaska (Harney *et al*. 2009). This section summarizes the principal findings of each study.

The Nature Conservancy provided funding for a study of the repeatability of physical and biological mapping procedures performed by Coastal and Ocean Resources, Inc. and Archipelago Marine Research, Ltd., respectively (Harney and Morris 2007). The principal objective of this study was to examine the repeatability of ShoreZone mapping techniques using imagery collected in Southeast Alaska in 2005 and 2006. Three 10-km test sections in Southeast Alaska were randomly selected and mapped by three physical mappers and three biological mappers. Variability between mappers was assessed with respect to:

- segmentation (Unit breaks) delineated by physical mappers
- alongshore Unit classifications
- across-shore Component data within units
- geomorphic feature inventory
- Bioband inventory, Biological Wave Exposure and Habitat Class categories

The major sources of inter-mapper variability identified in this study were:

- delineation of alongshore Unit boundaries
- digitizing of Unit breaks on the digital shoreline
- mappers' individual decision-making, recognition and experience
- human error

The principal conclusions of the Harney and Morris (2007) study were:

- Shoreline segmentation (Unit boundary delineation) by physical mappers showed the most variability but did not preclude the ability to inventory the geomorphic and biologic features of the shoreline.
- Poor matches or mismatches between physical data attributes were not common, but the sources of variability for such cases included: discerning the relative importance (abundance) of sand in the intertidal, the interpretation of slope in rock outcrops and decision-making in transitional units (such as those dominated by rock but with some gravel).
- The consistency in interpretation of biological exposure categories (mapped at the Unit level) was high, with nearly all Units mapped in all three sections scoring as matches. Similarly, the interpretation of the Habitat Class categories (also mapped at the Unit level) showed 77% match or better in all three Test Sections.
- Much of the consistency in biological data was attributable to the nature of data entry, in which Bioband observations were restricted to three choices (blank/absent, patchy, or continuous). Unit level classifications were assigned based on these presence/absence observations of biota. In addition, fields left blank by more than one mapper (indicating an absence of that Bioband) were included in the evaluation and considered matches.
- Nearshore canopy kelp Biobands (Giant Kelp, Bull Kelp and Dragon Kelp) were easily identified in aerial imagery, were recorded with the most confidence, and were highly consistent between mappers. Similarly, Eelgrass and Surfgrass were recorded with confidence, and observations of these Biobands were highly consistent between mappers.
- The lowest Bioband match scores were for the Red Algae (RED) and the Soft Brown Kelps (SBR), particularly in habitats with low wave exposure.

An external review conducted by Schoch (2009) suggested the following principal sources of error in the ShoreZone mapping technique:

- Segmentation errors caused by human subjectivity in the determination of alongshore Unit boundaries.
- Non-standardized resolution GIS vector basemaps and trying to join ShoreZone data to existing low resolution shoreline delineations.
- Classification errors caused by ambiguity of feature descriptors and the overall qualitative nature of ShoreZone.
- Inability of the ShoreZone classification to consistently describe actual shoreline features within a specified minimum (or maximum) mapping Unit.

The Integrated Land Management Bureau of the Province of British Columbia provided funding for a study on Vancouver Island to collect ground data using the same codes, individual mappers, and protocols as specified in aerial mapping. The principal objective of this study was to compare aerial mapping interpretations to ground survey observations in order to evaluate detection limits of physical and biological attributes. Ground crews were provided with Unit boundaries so Unit delineation was not compared. Site selection was not random because of the need to meet several requirements: shoreline accessibility; walk-able, contiguous sections of Units; as many different exposure categories as possible; maximize time during the low tide window.

The principal conclusions of this study included:

- Coastal Class assignment (to alongshore Units, by different mappers on the ground and using aerial data) matched in 80% of cases.
- Shore Modifications mapped using aerial imagery underestimated by 12% compared to ground observations, owing to seawalls covered by vegetation that were indistinct during flight.
- Across-shore Component data matched in 85% of comparisons.
- Wide, spatially-complex shorelines were most commonly mismatched, reiterating the findings of the repeatability study.

The National Oceanic and Atmospheric Administration (NOAA) and The Nature Conservancy (TNC) funded a field verification survey in Sitka, Alaska that followed similar protocols to the Victoria, BC survey (Harney *et al.* 2009). The principal conclusions of this ground verification survey were:

- Wave Exposure estimates were closely matched between aerial interpretations and ground interpretations.
- Sediment mobility estimated matched 88% between aerial and ground observations.
- Intertidal Width estimates matched in 63% units. Aerial mappers tended to underestimate widths.
- Estimates of Shore Modifications were highly consistent between aerial and ground observations.
- Coastal Class matched about 58% between aerial and ground observations; the relatively poor match is attributed to a large number of possible Classes (35) and the spatially complex nature of the foreshore.
- Across-shore geomorphology and substrate matched in 80% of the observations.
- Aerial and ground observations of Barnacle, Rockweed, Green Algae, Alaria, Soft Brown Kelps, Surfgrass, Eelgrass and Giant Kelp Biobands showed good matches whereas Dune Grass, Blue Mussels, Bleached Red Algae, Red Algae and Dark Brown Kelp Biobands showed poorer agreement between ground and aerial observations.

As a result of the recommendations from these verification and repeatability studies, and more informal feedback from users, a number of procedural updates have been implemented in the ShoreZone program over the years. In particular, guidelines for classification of key attributes were incorporated into the protocol to try and minimize inter-mapper variability. Some qualifications have also been added to specific feature classes and Biobands to indicate that lower confidence levels may apply to selected features. It is hoped these modifications will help to keep ShoreZone relevant and useful for researchers and managers.

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This protocol is based on input from many researchers in British Columbia, Washington State, Oregon and Alaska. The basic schema is taken from early work in BC (see Howes *et al.* 1994; Howes 2001). This version of the protocol built on previous versions of the ShoreZone protocol (Harper and Morris 2014, Harper and Morris 2004; Harney *et al.* 2008) and we acknowledge and appreciate the work of those previous authors that was incorporated here. Special thanks to Mary Morris for her extensive comments to improve this version of the protocol and her contributions to the history of ShoreZone section. We also wish to acknowledge Carl Schoch for his contributions to some sections.

The ShoreZone project has benefitted from a diverse group of funding agencies and supporters across its 120,000 km and 30-year extent. An updated list of partners can be found on ShoreZone.org and includes government agencies, non-profit organizations, First Nations and private companies.

References

Battjes, J. A. 1974. Computation of set-up, longshore currents, run-up and overtopping due to wind-generated waves. Department of Civil Engineering, Delft University of Technology, 74 p.

Beck, M. W. *et al.* 2001. The Identification, Conservation, and Management of Estuarine and Marine Nurseries for Fish and Invertebrates. BioScience 51(8): 633-641.

Berry, H.D., Harper, J.R., Mumford, T.F., Jr., Bookheim, B.E., Sewell, A.T., and Tamayo, L.J. 2004. Washington State ShoreZone Inventory user's manual, summary of findings, and data dictionary. Report prepared for the Washington State Dept. of Natural Resources Nearshore Habitat Program.

Costello, M. J. 2009. Distinguishing marine habitat classification concepts for ecological data management. Marine Ecology Progress Series 397: 253-268.

Crowder, L. B. *et al.* 2006. Resolving Mismatches in U.S. Ocean Governance. Science 313: 617-618.

Denny, M. W. *et al.* 2004. Quantifying scale in ecology: Lessons from a wave-swept shore. Ecological Monographs 74(3): 513-532.

Denny, M. W. *et al.* 2004. Quantifying scale in ecology: Lessons from a wave-swept shore. Ecological Monographs 74(3): 513-532.

Department of the Army 1984. Shore Protection Manual Volume 1. Coastal Engineering Research Center, U.S. Army Corps of Engineers, Vicksburg, MI, 652 p.

Groves, C. R. *et al.* 2002. Planning for Biodiversity Conservation: Putting Conservation Science into Practice. BioScience 52(6): 499-512.

Harney, J.N. 2007. Modeling habitat capability for the non-native European green crab (Carcinus maenas) using the ShoreZone mapping system in Southeast Alaska, British Columbia, and Washington state. Report prepared for NOAA National Marine Fisheries Service, Juneau, AK, 75 p.

Harney, J.N., J.R. Harper and M.C. Morris 2009. ShoreZone ground verification study conducted in Sitka, Alaska, May 2008. Contract Report by Coastal & Oceans Resources Inc. of Sidney, BC for NOAA-NMFS, Juneau, AK and The Nature Conservancy, Juneau, AK, 62 p.

Harney, J.N., and Morris, M. 2007. Analysis of the repeatability of ShoreZone coastal habitat mapping. Contract Report prepared for The Nature Conservancy, Juneau, AK and NOAA-NMFS, Juneau, AK 107 p.

Harney, J.N., Morris, M., and Harper, J.R. 2008. ShoreZone coastal habitat mapping protocol for the Gulf of Alaska. Contract Report prepared by Coastal & Oceans Resources Inc. of Sidney, BC for The Nature Conservancy, Juneau, AK, NOAA-NMFS, Juneau, AK, and the Alaska State Department of Natural Resources, Juneau, AK 137 p.

Harper, J.R., and Morris, M.C. 2004. ShoreZone mapping protocol for the Gulf of Alaska. Contract Report prepared by Coastal & Oceans Resources Inc. of Sidney, BC for the Exxon Valdez Oil Spill Trustee Council, Anchorage, AK. 61 p.

Harper, J.R. and M. C. Morris. 2014. Alaska ShoreZone Coastal Habitat Mapping Protocol. Prepared for Bureau of Ocean Energy Management (BOEM), Anchorage, AK. Prepared by Nuka Research and Planning Group LLC, Soldovia, AK. 164p. http://alaskafisheries.noaa.gov/shorezone/chmprotocol0114.pdf

Harper, J.R., M.C. Morris and S. Daley. 2013. ShoreZone Coastal Habitat Mapping Protocol for Oregon. Prepared by Coastal and Ocean Resources and Archipelago Marine Resources, Victoria, BC. Prepared for Oregon Department of Fish and Wildlife, Newport, OR. 114p.

Howes, D.E., J.R. Harper and E.H. Owens 1994. Physical shore-zone mapping system for British Columbia. Technical Report for the Coastal Task Force of the Resource Inventory Committee (RIC), RIC Secretariat. Victoria, BC, 71p.

Lourie, S. A. and A. C. J. Vincent 2004. Using biogeography to help set priorities in marine conservation. Conservation Biology 18(4): 1004-1020.

Komar, P.D. 1998. Beach Processes and Sedimentation, second ed. Prentice-Hall, Englewood Cliffs, NJ, 544 pp.

Owens, E.H., 1980. Physical shore-zone analysis, Saltspring Island, B.C. Unpublished contract report by Woodward-Clyde Consultants for Lands Directorate, Vancouver, B.C.

Petersen, J., J. Michel, S. Zengel, M. White, C. Lord, C. Plank. 2002. Environmental Sensitivity Index Guidelines. Version 3.0. NOAA Technical Memorandum NOS OR&R 11. Hazardous Materials Response Division, Office of Response and Restoration, NOAA Ocean Service, Seattle, Washington 98115 89p + App.

Schoch, G.C. 2009. The evaluation and analysis of ShoreZone intertidal habitat mapping in Cook Inlet. Contract Report by Coastwise Service, Homer, AK for the Cook Inlet Regional Citizens Advisory Council, Kenai, AK, 25 p.

Searing, G. F. and Frith, H. R. 1995. British Columbia Biological Shore-Zone Mapping System. Victoria. British Columbia: LGL Resource Associates, 46p.

Thieler, E. R. and Hammar-Klose, E. S. 1999. National assessment of coastal vulnerability to sea-level rise; US Atlantic Coast, USGS Report No. 99-593.

Thieler, E. R. and Hammar-Klose, E. S. 2000a. National assessment of coastal vulnerability to sea-level rise; preliminary results for the US Gulf of Mexico Coast. USGS Report No. 2000-179.

Thieler, E. R. and Hammar-Klose, E. S. 2000b. National assessment of coastal vulnerability to sea-level rise; preliminary results for the US Pacific Coast. USGS Report No. 2000-178.

Wilkinson T., E. *et al.* 2009. Marine Ecoregions of North America. Commission for Environmental Cooperation. Montreal, Canada. 200 p.

Appendix A
ShoreZone Geodatabase Data Dictionary

Table A1. Definitions for attributes in the Unit table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Physical Ident	A unique code to identify each unit following the format: Region/Area/Phy Unit/Subunit.	PHY_IDENT
Region	A geographic division of the coastline used to organize the Physical Units; makes up the first two numbers of the Phy Ident.	REGION
Area	A geographic division of each Region of the coastline used to organize the Phy Units; makes up the second two numbers of the Phy Ident.	AREA
Physical Unit	A four-digit number assigned during mapping which is unique within the geographic Region and Area; makes up the third set of numbers of the Phy Ident.	PHY_UNIT
Subunit	A single digit assigned during mapping that is used to identify point features (also called variants) within a linear Unit. They are numbered sequentially from the start of the unit. This makes up the fourth set of numbers in the Phy Ident. A value of '0' is assigned for the linear unit.	SUBUNIT
Type	A letter that describes the unit as either a linear feature (L) or a point feature (P); related to the Subunit attribute.	TypeID
Coastal Class	A higher-level classification of the intertidal habitat based on the overall intertidal sediment type and sediment size, across-shore intertidal width and across-shore intertidal slope for the unit for wave-dominated shorelines. Shorelines not structured by wave processes are classified by that dominant process.	COASTALCLASS
Length	Length, in metres, of the digital shoreline as calculated in ArcGIS from the digitized unit boundaries.	LENGTH_M
Intertidal Zone Area	The area of the beach face (in m^2) calculated using the equation: Area = Intertidal Zone Width x Length.	AREA_M2

Table A1 con't. Definitions for attributes in the Unit table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Shoreline Problem	A multiplier that indicates the amount the observed shoreline length differs from the digital shoreline length for a unit. For example, if there is half again as much shoreline that is not captured by the digital shoreline length, this field would be 1.5. This can be used to calculate the amount of actual shoreline not captured by the digital shoreline and to make the unit calculations based on unit length more accurate.	SHORE_PROB
Videotape	Unique code for the video file used in the classification. Current naming convention for ShoreZone video files is a four-digit code identifying the geographic region and year (ex. BS14 for Bering Sea 2014), a two-digit code for the survey team name (ex. NS for Team Norton Sound) and a two-digit number for the video file. Example: BS14_NS_01. Older video files may have different naming conventions.	VIDEOTAPE
Hr	The first two digits of the six-digit UTC time burned on the video image identifying the video frame where the start of the unit is in the centre of the viewing screen.	HR
Min	The third and fourth digits of the six-digit UTC time burned on the video image identifying the video frame where the start of the unit is in the centre of the viewing screen.	MIN
Sec	The last two digits of the six-digit UTC time burned on the video image identifying the video frame where the start of the unit is in the centre of the viewing screen.	SEC
Lost Shoreline Calculation	The calculation of the actual shoreline length for those units with a Shoreline Problem modifier of greater or less than 1.	LOST_SHORE
Wave Exposure	An estimate of the wave exposure experienced by the intertidal zone using a modification of observed maximum fetch which considers dissipation of wave energy due to occlusion of the shoreline.	EXP_OBSER
Oil Residence Index	Unit level ORI calculated using the Biological Wave Exposure and Coastal Class.	ORI
Shore Name	The name of the closest geographic feature to the unit; usually taken from the nautical charts or a gazetteer.	SHORENAME
Unit Comments	A field to record anything unusual that was noted by the physical mapper that is not captured by another field.	UNIT_COMMENTS

Table A1 con't. Definitions for attributes in the Unit table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Intertidal Zone Width	The width of the beach face. The width is estimated from a kmz file created using Structure From Motion software and represents the overall planar width of the beach face.	ITZ
Photo	A Yes (1) or No (0) field, this indicates if there is a Photo attached to the unit.	Slide
Entry Date	The date/time the unit was data entered into the database.	EntryDate
Modified Date	The date/time the unit was modified in the database.	ModifiedDate
Intertidal Zone Slope	The slope of the intertidal zone, calculated using the equation: Slope = $\tan^{-1}$(Tidal Height/Intertidal Zone Width). The estimation is placed into a slope category: Flat (0-1^{o}), Low Incline (2-4^{o}), Moderate Incline (5-10^{o}), High Incline (11-20^{o}), Steep (21-45^{o}) and Very Steep (>46^{o}).	Slope_calc
Iribarren Category	Describes the morphology of the waves produced at the wave power/slope categories measured/calculated for the unit. The categories are: Spilling, Plunging, Collapsing and Surging.	Irib_CLASS
Aspect	The compass orientation (N, NW, W, SW, S, SE, E or NE) of the bottom of the intertidal zone at 90 degrees to shore normal. See Figure 1 for an illustration. In most cases, this orientation will match the orientation of the digital shoreline (MHHW); for cases where the intertidal is wide and complex (like deltas, spits etc.) and the orientation of the intertidal does not match the MHHW, the mapper should use the average orientation at the waterline. If the waterline orientation is more than 45^{o} different from the digital shoreline it should be indicated with an asterisk. For example, if the waterline is oriented N but the digital shoreline is oriented W, this would be entered as N*.	Orient_dir
Tidal Height	The projected (modelled) tide height or sea level elevation (in meters) taken from the designated tide station. The tide station (from the NOAA Tides and Currents website) to be used for each tape is decided at the beginning of the mapping project and is entered in the videotape lookup table in the database. To get the tide height, set the correct date for the video and look at the tide height relative to the MHHW.	Tidal_height
ShoreZone Coastal Vulnerability Index	A value estimating the relative sensitivity of a unit to sea-level rise on a four-point scale (Low, Moderate, High, Very High).	CVI_RANK

Table A1 con't. Definitions for attributes in the Unit table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Biogeographic Region	A nested hierarchical biogeographic unit (based on CMECS biogeographic divisions) used to delineate areas with similar physical, chemical and biological characteristics. This will be automatically filled in after the regions have been defined.	Biogeographic_Domain
CMECS Coastal Class	This is a crosswalk of Coastal Class values with the CMECS system.	CMECS_Values
Biological Wave Exposure	An estimate of the wave energy in the intertidal zone based on the assemblage of biobands present in the unit. When biobands are not present in the intertidal (bare beaches, arctic coasts) the Wave Exposure value is used.	Exp_Bio
Habitat Class	This attribute combines the Biological Wave Exposure with an estimate of geomorphology and processes (Coastal Class) in the unit that might affect the composition of biobands in the unit. Mobility is estimated (Immobile, Partially Mobile and Mobile) for wave process dominated shorelines with estuarine, anthropogenic, current, glacial, lagoon and periglacial processes having their own categories.	HabClass
Bio Source	The media used to classify the unit (video, photo, video and photo). This can also be used to indicate poor quality video or photos, which gives an estimate of certainty around the mapped attributes.	BioSource
Bio Comments	A field to record anything unusual that was noted by the biological mapper that is not captured by another field.	BioUnitComments

Table A2. Definitions for attributes in the ESI table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Object ID	An automatically generated number field; this is the primary key for the Unit table and links the ESI record to the Unit record.	OBJECTID
Physical Ident	A unique code to identify each unit following the format: Region/Area/Phy Unit/Subunit.	PHY_IDENT
ESI Values	The ESI values for the intertidal zone of the unit. There may be up to three ESI values, each separated by a slash (ex. 1A/6B/10D).	ESI
Line	A code indicating the type of linear feature that is being classified.	LINE
Source	The type of media used in the classification (i.e. the source of the mapping data).	SOURCE_ID
Env	The categories for ESI are Estuarine, Riverine, Lacustrine or Palustrine. All coastal areas are considered Estuarine for ESI purposes.	ENVIR
Wetland	This is a Yes (1) or No (0) value with a Yes (1) indicating there is a wetland in the supratidal that is greater than 10m in width.	WETLAND
Most Sensitive ESI Value	The highest numerical ESI value (highest sensitivity to a potential oil spill) for the Unit is used to populate this field.	MOST SENSITIVE

Table A3. Definitions for attributes in the Photos table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Object ID	An automatically generated number field; this is the primary key for the Unit table and links the Photo record to the Unit record.	OBJECTID
Physical Ident	A unique code to identify each unit following the format: Region/Area/Phy Unit/Subunit.	PHY_IDENT
Photo Name 1 to 10	The file name of the photo(s) associated with the unit.	PhotoName01 to PhotoName10
Video Time 1 to 10	The video date/time associated with the respective photo.	VideoTime01 to VideoTime10

Table A4. Definitions for attributes in the Xshr table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Object ID	An automatically generated number field; this is the primary key for the Unit table and links the Xshr record to the Unit record.	OBJECTID
Physical Ident	A unique code to identify each unit following the format: Region/Area/Phy Unit/Subunit.	PHY_IDENT
Cross Link ID	A unique identifier for each across-shore record consisting of the Region/Area/Phy Ident/Subunit/Zone/Component (e.g. 12/03/1234/0/A/1)	CROSS_LINK
Zone	A code indicating the across-shore tidal elevation of the section of beach being described. The A Zone (supratidal) is defined as the area between the mean high water line and the limit of the marine influence (with marine influence being defined as either directly inundated by salt water on up to an annual basis or by other processes such as aeolian which carries salt in the wind). The B Zone (intertidal) is defined as the area between the mean high water line and the zero tide level. The C Zone (subtidal) is defined as being below the waterline in the imagery.	ZON
Component	A subdivision of the zones, numbered from highest to lowest elevation within each zone.	COMPONENT
Width	Estimated (or measured from the kmz for the intertidal zone) mean across-shore width of the component.	WIDTH
Slope	Estimated across-shore slope of the component. This attribute will be calculated for the intertidal zone in the Intertidal Zone Width field in the Unit table, but should be estimated for each component of the intertidal zone. Estimated slope categories are: Flat (0-1^o), Low Incline (2-4^o), Moderate Incline (5-10^o), High Incline (11-20^o), Steep (21-45^o) and Very Steep (>46^o).	SLOPE
Process	The dominant structuring process of the component.	ProcessDesc
Oil Residence Index	A measure of the length of time oil would stay resident in the component based on substrate size and composition. The value is based on the component substrate.	COMPONENT_ORI
Form Code 1 to 4	Indicates a geomorphic form within the across-shore component. They are recorded in order of most to least dominant.	Form1 to Form4

Table A4 con't. Definitions for attributes in the Xshr table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Material Prefix 1 to 4	Indicates if there is veneer associated with the Form Code. The only value in this field should be 'v'. If the field is blank, there is no veneer.	MatPrefix1 to MatPrefix4
Material Code 1 to 4	The substrate or other material that makes up the geomorphic form described in the Form Code for the across-shore component. They are recorded from most to least dominant.	Mat1 to Mat4
Description 1 to 4	This field translates the Form and Materials codes into a full written description.	FormMat1Text to FormMat4text

Table A5. Definitions for attributes in the XshrShoreMods table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Object ID	An automatically generated number field; this is the primary key for the Unit table and links the XshrShoreMod record to Unit the record.	OBJECTID
Physical Ident	A unique code to identify each unit following the format: Region/Area/Phy Unit/Subunit.	PHY_IDENT
Cross Link ID	A unique identifier for each across-shore record consisting of the Region/Area/Phy Ident/Subunit/Zone/Component (e.g. 12/03/1234/0/A/1)	CROSS_LINK
Form Code	Indicates the anthropogenic form within the across shore component.	FormCode
Material Code	The substrate or other material that makes up the anthropogenic form described in the Form Code for the across shore component.	MatCode
Description	This field translates the Form and Material Codes into a full written description.	FormMat Description
Modification Code	This attribute is here to make the Shore Modifications module consistent with what has been mapped previously, when Shore Mods were at the Unit level.	ShoreModificationCode
% Cover	The percent cover of the anthropogenic form described in Form Code.	SM_percent
Frm Count	A quantitative count of the shore modification described in the Form Code, where a count is appropriate.	SM_count
Shore Mod Description	This field translates the Modification Code into a full written description.	SM_description

Table A6. Definitions for attributes in the XshrCVM table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Object ID	An automatically generated number field; this is the primary key for the Unit table and links the XshrCVM record to the Unit record.	OBJECTID
Physical Ident	A unique code to identify each unit following the format: Region/Area/Phy Unit/Subunit.	PHY_IDENT
Cross Link ID	A unique identifier for each across-shore record consisting of the Region/Area/Phy Ident/Subunit/Zone/Component (e.g. 12/03/1234/0/A/1)	CROSS_LINK
Flood Zone Index	An index estimating the vulnerability of the terrestrial area beyond the A Zone to flooding. This is recorded for the A zone although it can extend far beyond the extent of the marine influenced area. This ranking will feed directly in to the Coastal Vulnerability Index.	Flooding_Class
Stability Index	A ranking of the vulnerability of the A and B Zone components to erosion. This is based on the presence of erosional or accretional forms within the unit. This ranking will feed directly in to the Coastal Vulnerability Index.	StabilityClassDescription
CVM Comment	A comment field relating specifically to issues around Coastal Vulnerability.	CoastalHazardsComment
Primary CVM Observation	The primary feature in the unit that is potentially important to determination of the vulnerability of the coastline to sea level change.	Primary_Observation
Secondary CVM Observation	The secondary feature in the unit that is potentially important to determination of the vulnerability of the coastline to sea level change.	Secondary_Observation
Tertiary CVM Observation	The tertiary feature in the unit that is potentially important to determination of the vulnerability of the coastline to sea level change.	Tertiary_Observation

Table A7. Definitions for attributes in the Bioband table of the ShoreZone geodatabase.

Attribute Name	Definition	Geodatabase Name
Object ID	An automatically generated number field; this is the primary key for the Unit table and links the Bioband record to the Unit record.	OBJECTID
Physical Ident	A unique code to identify each unit following the format: Region/Area/Phy Unit/Subunit.	PHY_IDENT
Cross Link ID	A unique identifier for each across-shore record consisting of the Region/Area/Phy Ident/Subunit/Zone/Component (e.g. 12/03/1234/0/A/1)	CROSS_LINK
Bioband Name	If the Bioband named as the column header was present in the Unit, it will be indicated as being either (P)atchy (<50% of the length of the unit) or (C)ontinuous (>50% of the length of the unit) or as (N)arrow (<1m), (M)edium (1-5m) or (W)ide (>5m) for the splash zone Biobands (see Table 25, Table 26 and Table 27 for the full nested, hierarchical bioband descriptions).	ALAR, ANEM, BARN, BIOF, BLLI etc.
Percent Length	The percent along-shore length of the unit occupied by a bioband, broken into more detailed categories than Patchy or Continuous.	ALAR_L, ANEM_L, BARN_L, BIOF_L, BLLI_L etc.
Percent Cover	The percent areal cover of the intertidal zone occupied by a bioband recorded in the intertidal. Not applicable to biobands recorded in either the supratidal or subtidal.	ALAR_PCV, ANEM_PCV, BARN_PCV, BIOF_PCV, BLMU_PCV etc.
Width Category	A width category is assigned to all supratidal and subtidal biobands. Not applicable to Biobands recorded in the intertidal.	ALAR_W, BRBA_W, BRCA_W, BRNA_W, BUKE_W etc.