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# Puget Sound shoreline inventory and assessment using boat-based lidar

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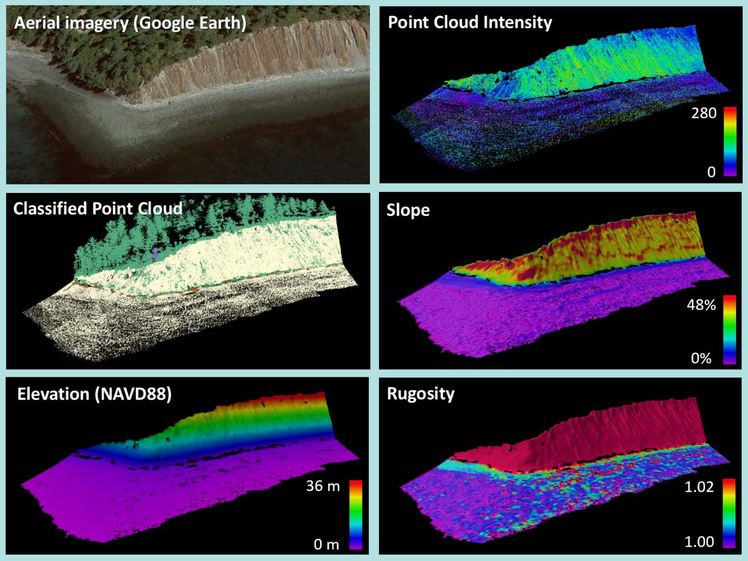
## Overview & Motivation

Boat-based lidar of Puget Sound shorelines collected by the Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) are developed to provide detailed, high-resolution mapping of topography, modifications, and habitat features for assessment of coastal conditions.

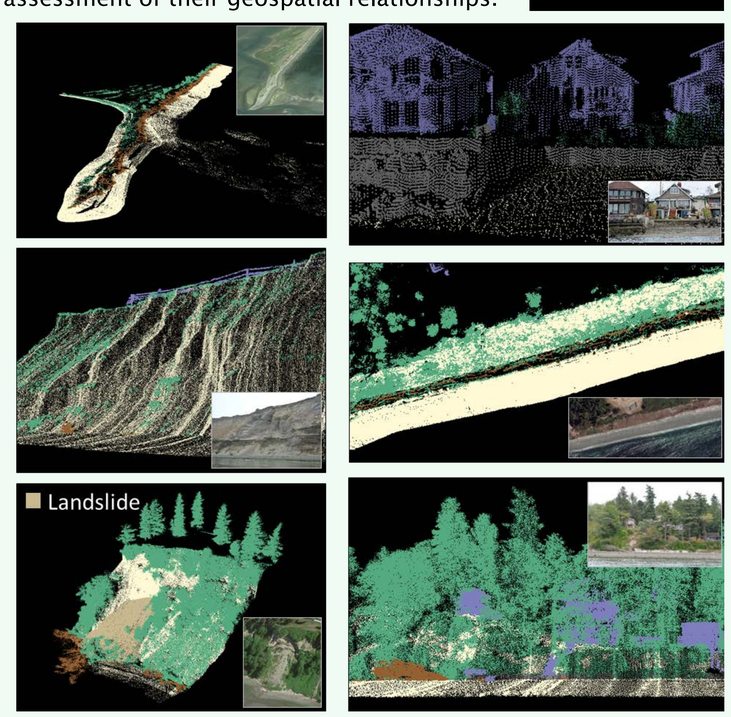



Quantitative measurements determined from lidar point clouds and digital elevation models (DEMs) can be compared to determine natural regional variability and the effects of shoreline modifications on process, structure, and function. Certain features provide metrics to assess nearshore habitat that are crucial for prioritizing ecosystem protection and restoration, and recovery of salmon, orcas, and marine birds.

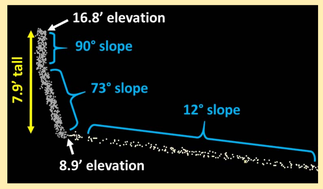
## Classified Lidar Point Clouds

Lidar data points are classified to differentiate the ground surface morphology from other landscape features such as shoreline armor, riparian vegetation, and large woody debris for efficient delineation, quantification, and assessment of their geospatial relationships.

- Ground
- Armoring
- Vegetation
- Large woody debris
- Man-made structures

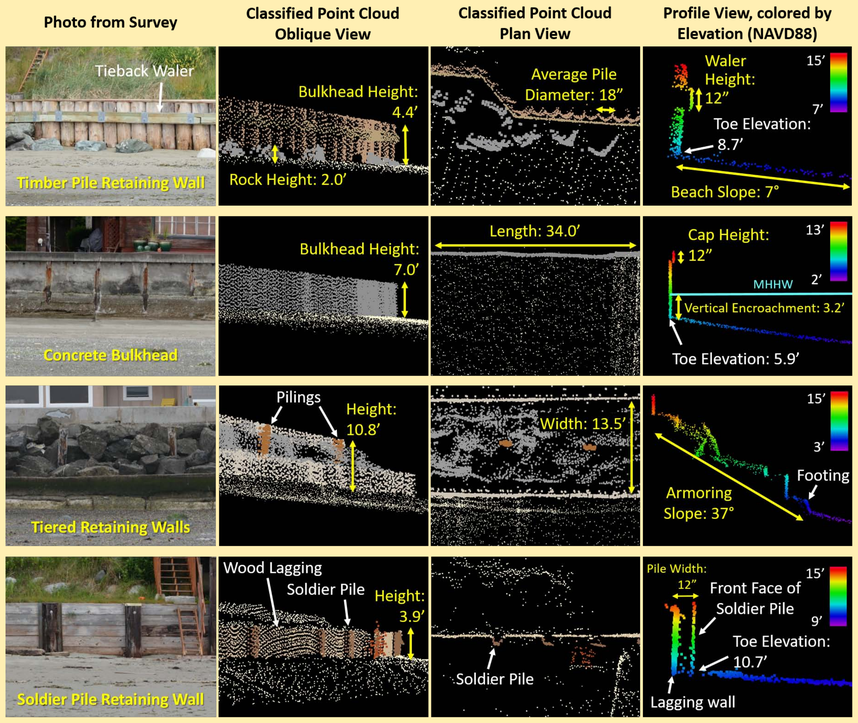



## Shoreline Armoring



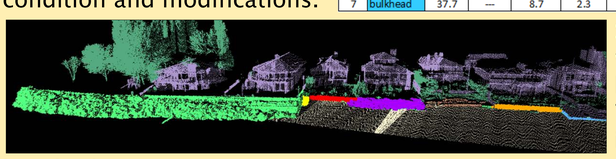

Bulkhead measurements

Accurate quantification and inventory of Puget Sound shoreline armor is crucial for assessment of impact and restoration opportunities. The high-resolution point clouds allow detailed mapping of shoreline armor attributes such as type, length, elevation, height, slope, and condition within the context of shoreform and beach morphology. The point cloud inventory of armor attributes allows for precise measurement and change detection that is accurately georeferenced in 3D map space.




The combination of high-resolution point clouds and photos from field surveys enables the identification and measurement of a wide variety of shoreline modifications. Comprehensive and precise geospatial mapping of shoreline armor attributes enables tracking of structure condition and modifications.

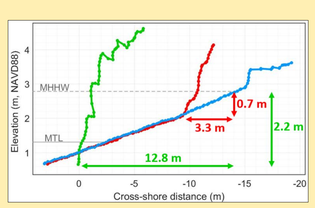
| FID | Type | Length (ft) | Width (ft) | Toe Elev. (ft) | Height (ft) | Vertical Encroachment rel. to MHHW (ft) | Slope (deg) | Area of LWD ($ft^2$) | Area of Overhang Veg. ($ft^2$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | rip-rap | 246.8 | 18.7 | 2.6 | 12.8 | 6.6 | 37 | 0 | 0 |
| 2 | stairs | 3.8 | 9.2 | 6.7 | 5.7 | 2.4 | 35 | 0 | 0 |
| 3 | bulkhead | 39.4 | --- | 8.6 | 3.6 | 0.5 | 90 | 0 | 0 |
| 4 | rip-rap | 58.4 | 7.5 | 7.0 | 5.9 | 2.1 | 43 | 0 | 0 |
| 5 | drift logs | 46.2 | 13.5 | 10.1 | --- | -1.0 | --- | 20 | 0 |
| 6 | bulkhead | 43.0 | --- | 9.7 | 3.3 | -0.6 | 78 | 0 | 0 |
| 7 | bulkhead | 37.7 | --- | 8.7 | 2.3 | 0.5 | 90 | 0 | 0 |

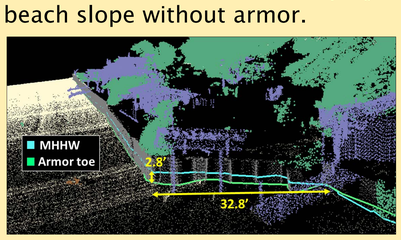


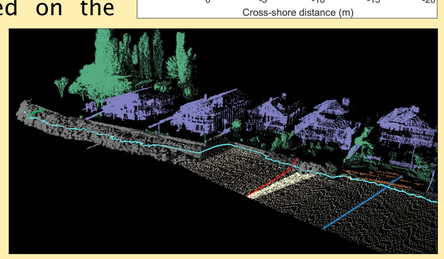
Shoreline armor varies in size, shape, location, and impact. The lower the armor is placed on the beach, the more it impacts nearshore processes, structure, and functions.

### Measuring Encroachment

The armor toe elevation relative to mean higher high water (MHHW) is a metric of how far the armor vertically encroaches on the beach. Boat-based lidar provides this metric, as well as horizontal encroachment measured to the location of MHHW as projected on the beach slope without armor.



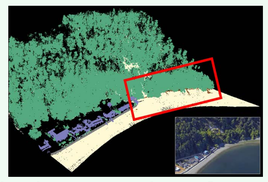



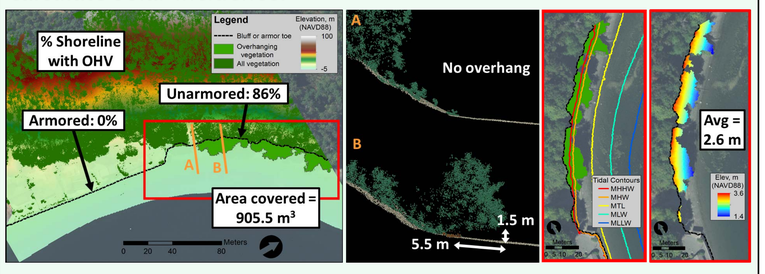
## Habitat Features

Shoreline armor is associated with reductions in riparian vegetation, large woody debris, wrack, and back beach width. Boat-based lidar maps each of these features, all of which provide critical habitat and nearshore ecosystem functions.

### Overhanging Vegetation

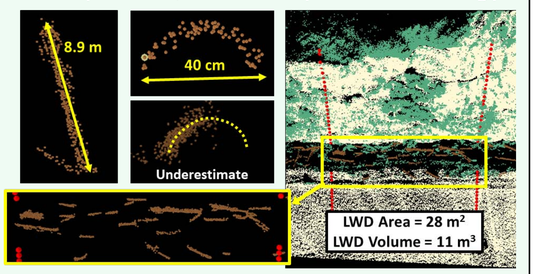


Overhanging and fallen riparian trees provide organic matter and shade to the upper beach substrate, which moderates summer temperature and moisture important to surf smelt spawning. The extent of overhanging vegetation can be accurately delineated and intersected with the ground surface DEM to quantify where and how much of the beach is covered. Vegetation width and height above the beach can be used to calculate solar incidence.




### Large Woody Debris (LWD)

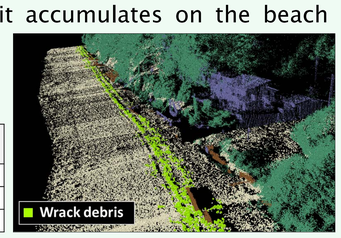
Large logs and downed trees provide invertebrate habitat, enhance local sediment deposition, and dissipate wave energy. The area of the beach covered by LWD can be quantified from boat-based lidar, as well as the size and quantity of individual logs and their location across the beach.




### Beach Wrack

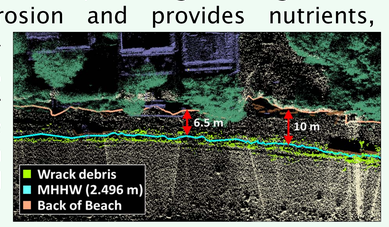
Wrack is stranded algae, seagrass, and terrestrial debris that can be mapped and quantified where it accumulates on the beach surface. Quantities can be compared to back beach width and relative encroachment of armor.

| Wrack Debris Measurements | Mean Elevation (m) | Surface area ($m^2$) |
|---|---|---|
| Lower Line | 2.41 | 187 |
| Upper Line | 2.72 | 123 |
| All Wrack | 2.53 | 310 |




### Back Beach Width

The back beach is the platform where wave energy dissipates, LWD, wrack, and sediment accumulate, and vegetation grows. It buffers the upland from erosion and provides nutrients, microhabitats, and services—refuge, foraging, spawning, roosting, and nesting. Boat-based lidar efficiently maps the variability in back beach width and features along natural and armored shorelines.





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