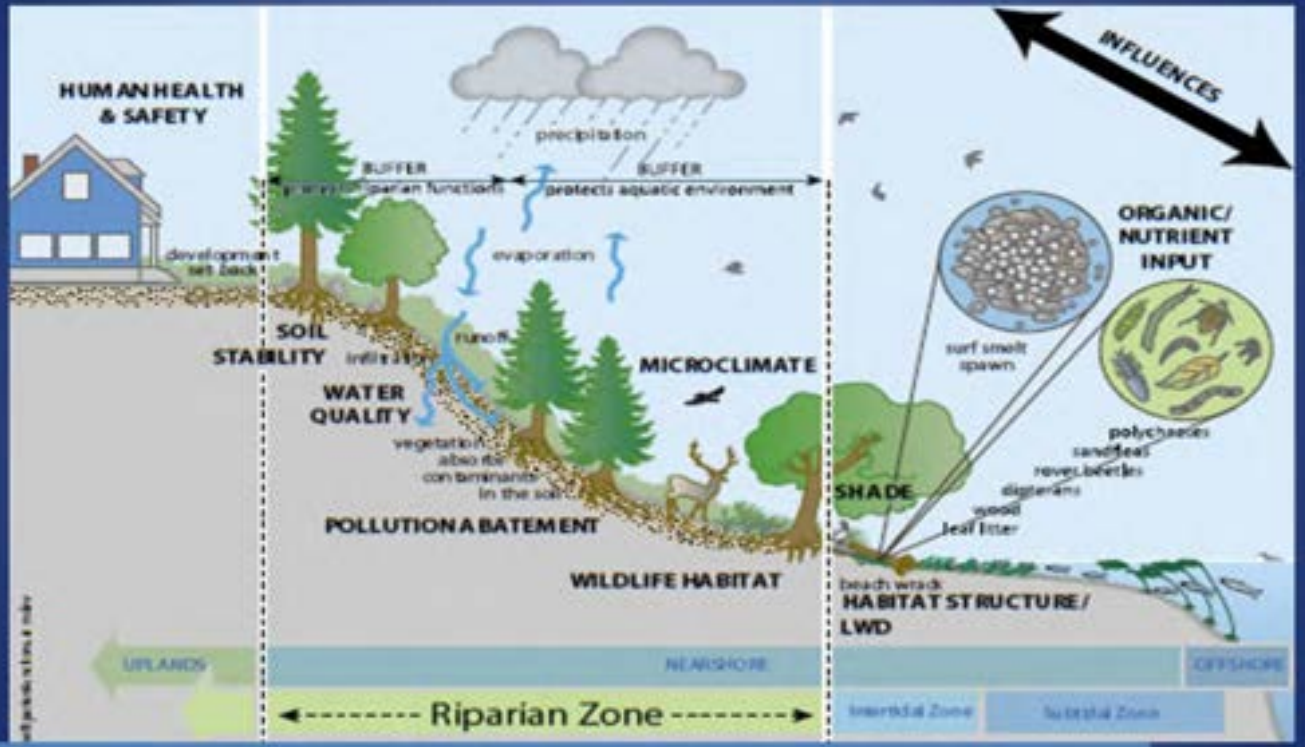
Dungeness High Bluff Ecosystems
Coastal Watershed Institute
November 4, 2026



'Nearshore' defined as extending from the area of tidal influence in lower rivers, riparian zone (along both river and marine shorelines), offshore to a depth of 30 meters mean low low water (MLLW)



Brennan, J.S., and H. Culverwell. 2004 Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems. Published by Washington Sea Grant Program Copyright 2005, UW Board of Regents Seattle,

Coastal Watershed Institute (CWI)

Important migratory corridor for numerous critical, declining, candidate, and or state and federally listed species





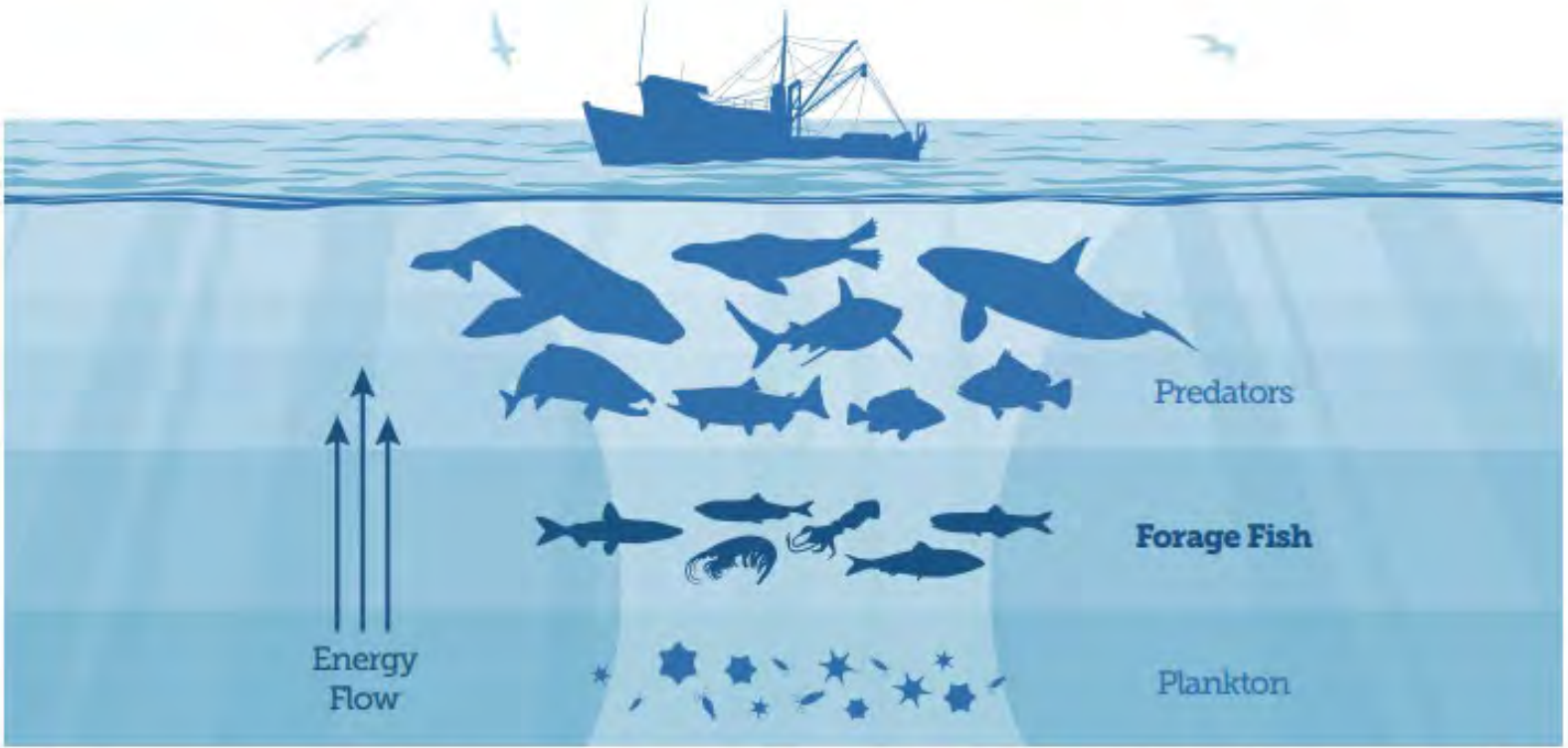




Sandlance



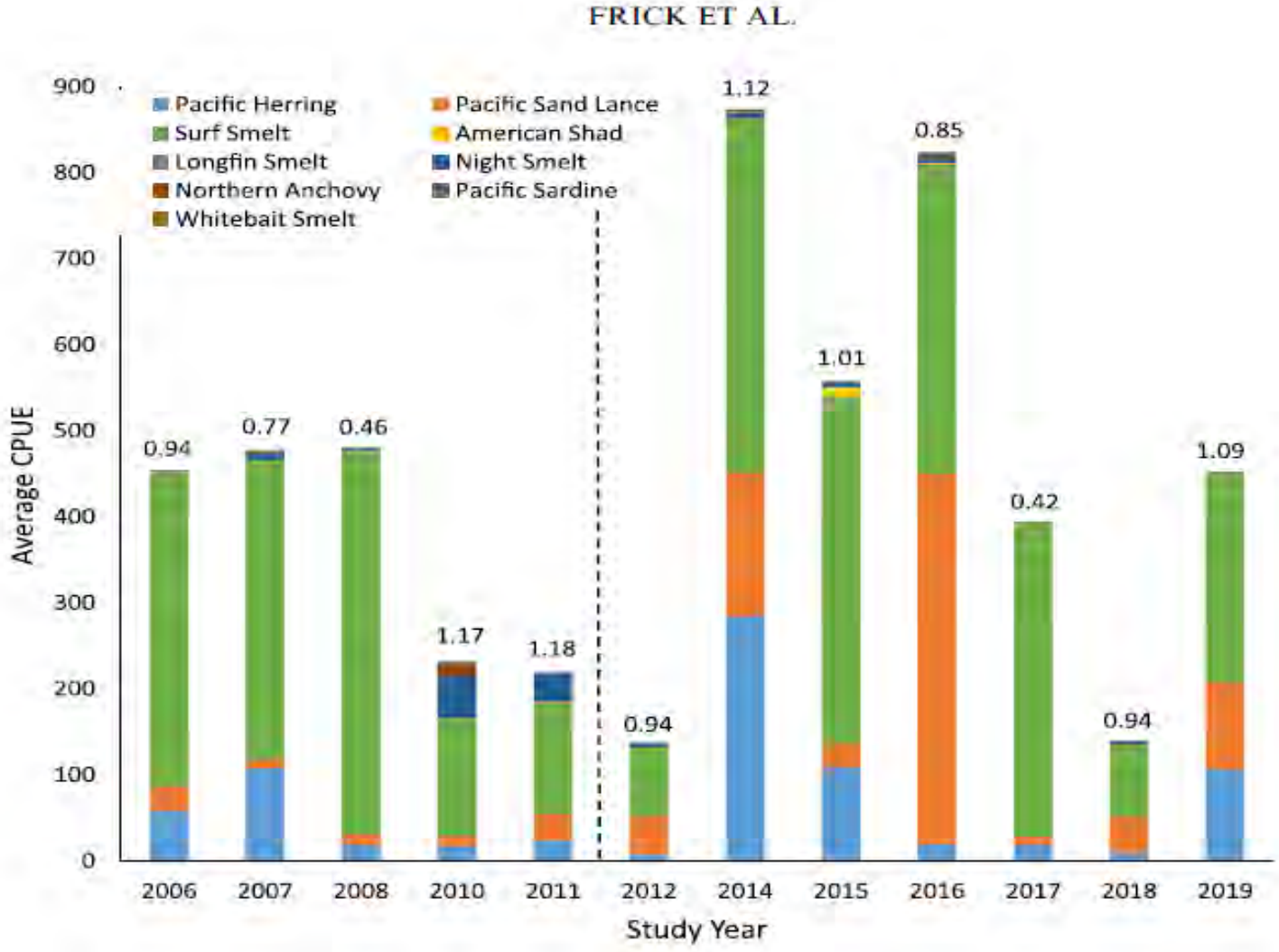
Key link in a healthy food web: Forage fish



Small schooling species such as sardines, sauries, and smelt—commonly known as forage fish—play a critical role in sustaining a vibrant Pacific Ocean. These species eat tiny plants and animals, in turn becoming an important food source for bigger fish, seabirds, and marine mammals.

© 2013 The Pew Charitable Trusts

Coastal Watershed Institute (CWI)



Forage Fish are a dominant guild of fish of our nearshore region (Frick et al., 2022)

Like salmon, forage fish are a historic and contemporary important species to the region's Tribes.

Forage fish use the nearshore for migration and for spawning








Surf smelt spawn
Photo by Dan Penttila

A drift cell is defined as consisting of three components: a site or reach of shoreline that serves as the **sediment source** and **origin** of a drift cell; a **zone of transport**, where wave energy moves drift material alongshore; and an area of **deposition** that is the terminus of a drift cell (Maclennan et al 2010)









https://apps.ecology.wa.gov/csoastalatlasmap

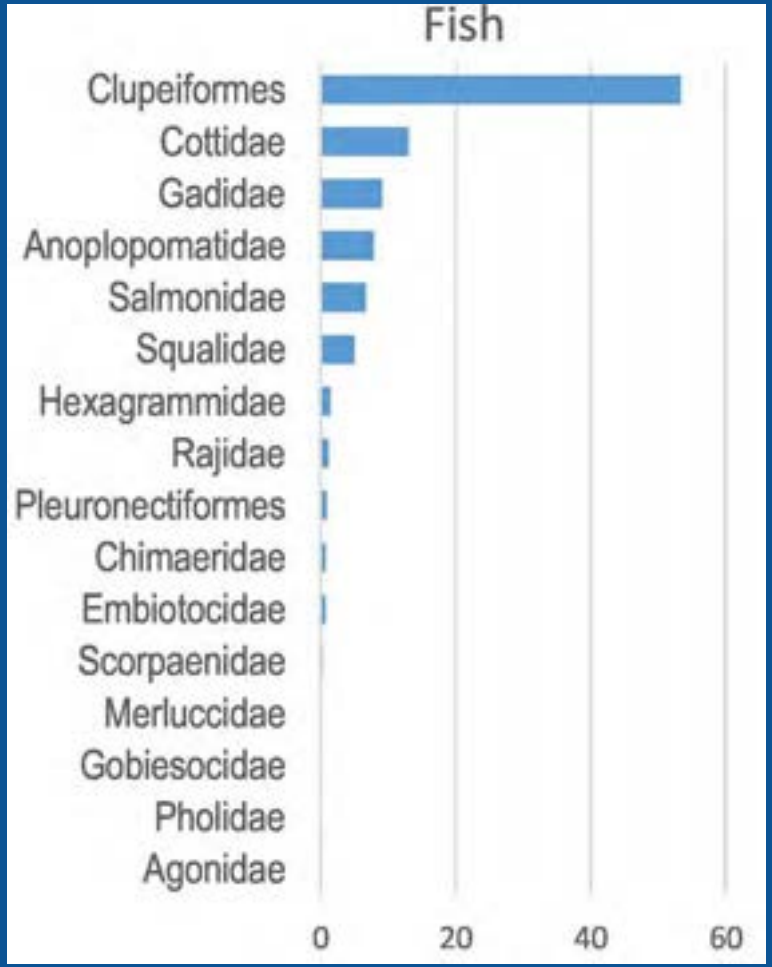
Coastal Watershed Institute (CWI)


Coastal Watershed Institute (CWI)



Data source: WDFW http://bit.ly/16eBpJH

Species	Drift cell	Drift cell length (miles)	Total spawning area (square feet)*
Surf smelt	Dungeness	8	404,040
	Elwha	6	66,700
Sand lance			
	Dungeness	8	240,000
	Elwha	6	20,000





Butler, et al,. 2019.

Feeder bluffs are critical for ecosystem form and function

Grain size, sediment feed rate, season, and volume, are all critical habitat features of coastal high feeder bluffs



Coastal Watershed Institute (CWI)

Dungeness feeder bluffs are the features that form Dungeness Spit-very small proportion of drift cell is armored.

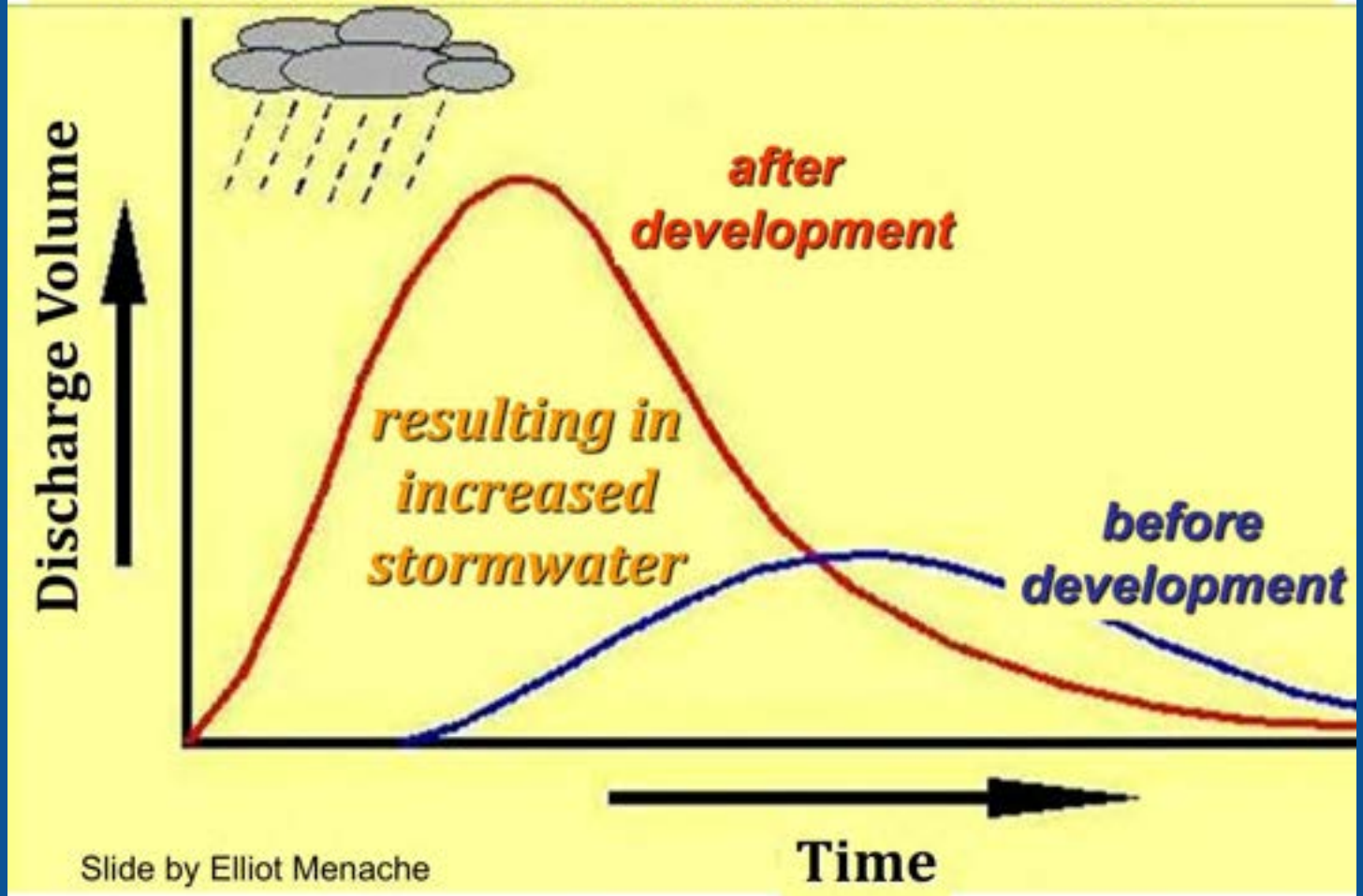
Only ½ mile (4 %) of feeder bluffs are within the Dungeness Refuge.

Who manages the rest?

Primarily Clallam County.



TIMING OF STORMWATER RUN-OFF



TOP of Feeder bluffs/riparian corridors

FORESTS PROTECT LAND FROM EROSION IN TWO BASIC WAYS

by providing

Hydrologic Benefits

VERY LITTLE STORMWATER RUN-OFF, SURFACE EROSION, OR SEDIMENTATION OCCURS

and through

Mechanical Soil Reinforcement

SHRUB & ESPECIALLY TREE ROOTS RESIST MASS SOIL MOVEMENT & SHALLOW LANDSLIDES

Slide by Elliot Menache




Anne Shaffer
Coastal Watershed Institute
www.coastalwatershedinstitute.org

HIGH BLUFF ECOSYSTEMS: WHAT THEY ARE AND WHY THEY MATTER

Join us for two community workshops
co-sponsored by the Coastal Watershed Institute (CWI)
and Jamestown SKlallam Tribe



NOVEMBER 4TH 6PM-8PM
PRESENTATION AT
DUNGENESS RIVER NATURE CENTER
1943 W HENDRICKSON RD, SEQUIM



NOVEMBER 7TH 8:30AM-10:00AM
ROCK WALK AT
DUNGENESS NATIONAL WILDLIFE REFUGE
554 VOICE OF AMERICA RD, SEQUIM

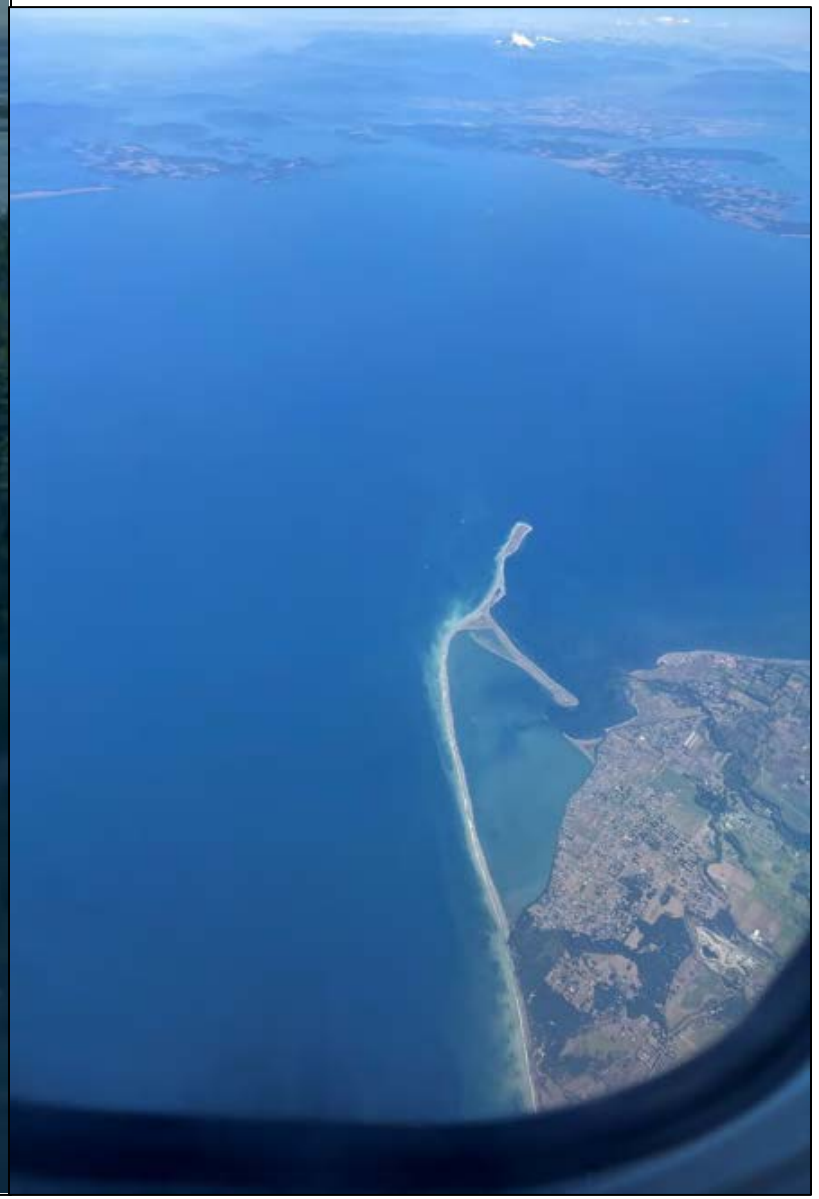
BOTH EVENTS ARE FREE AND OPEN TO THE PUBLIC

We are hosting a community workshop and field trip on the ecosystem form and function of high coastal bluffs-those important and spectacular shorelines just west of Dungeness Spit. CWI representatives Dave Parks, award winning hydrogeologist and underwater photographer, and Nicole Harris, CWI senior education and policy representative, have worked on coastal systems for decades and will lead the workshop and field "Rock Walk".

Parks will discuss the geologic history and evolution of Dungeness coastal bluffs west of the base of Dungeness Spit and discuss enduring research on the rates of coastal bluff erosion in the Dungeness drift cell. Harris will discuss ecosystem function of high bluff shorelines including importance for forage fish and salmon.

Coastal Watershed Institute

Thanks to:
Audubon River Center
Jamestown S'Klallam Tribe





"…the coastline is not really a line but rather a process through which marine forces and terrestrial and atmospheric processes converge to create a constantly evolving landscape."

Gary Griggs (JCR, 2026)



Introduction

- Why does bluff erosion matter?
- Geologic History of the Dungeness Bluffs
- Dungeness Bluff Erosion Studies
  - CWI/WDOE/WDNR, 2014
  - Parks, 2015
  - Knapp, 2016
  - Alampay, 2022
  - WDOE, 2026
- Bluff Management Considerations
- Bluff Erosion in the Future



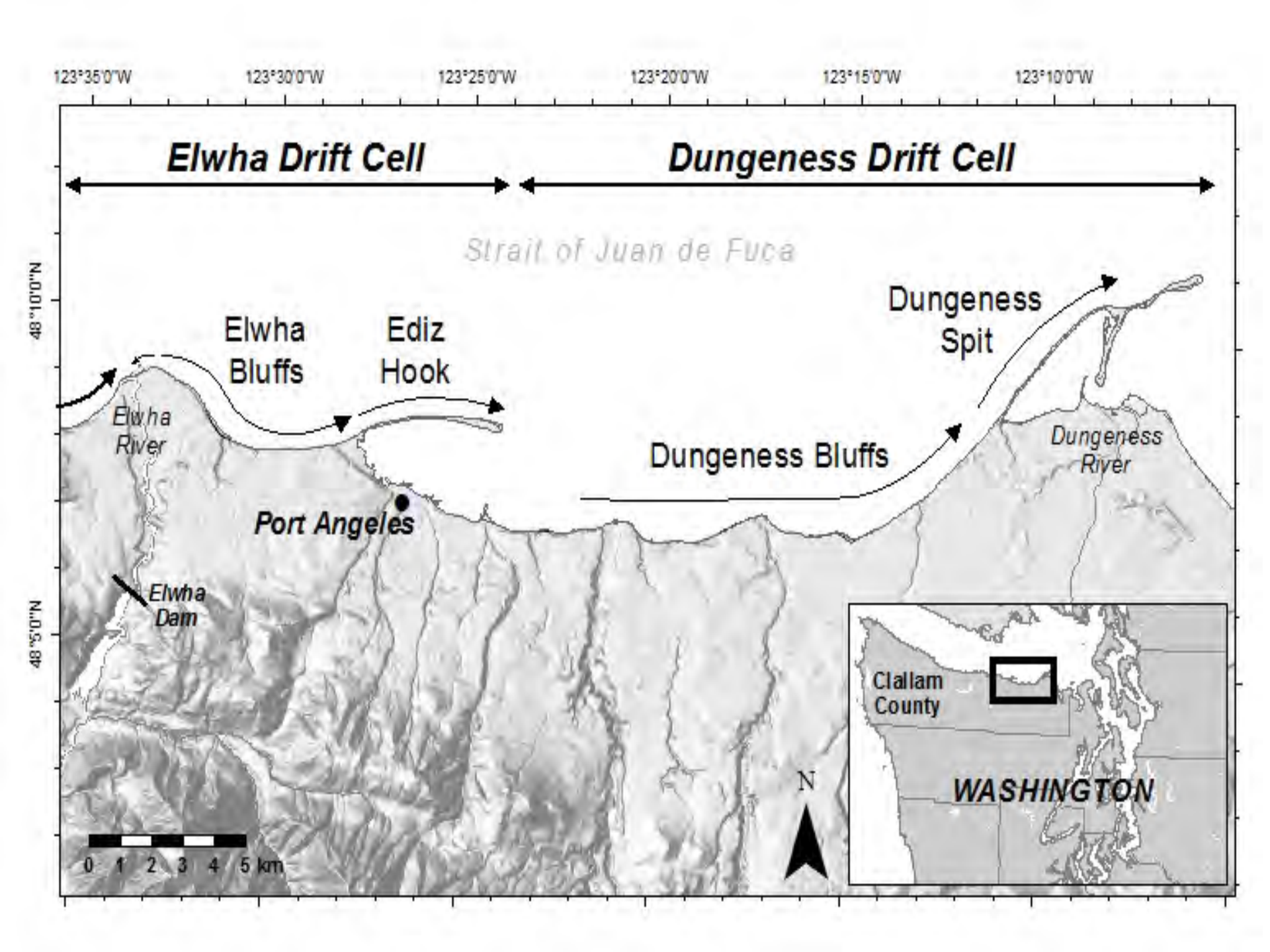
Dungeness Bluffs

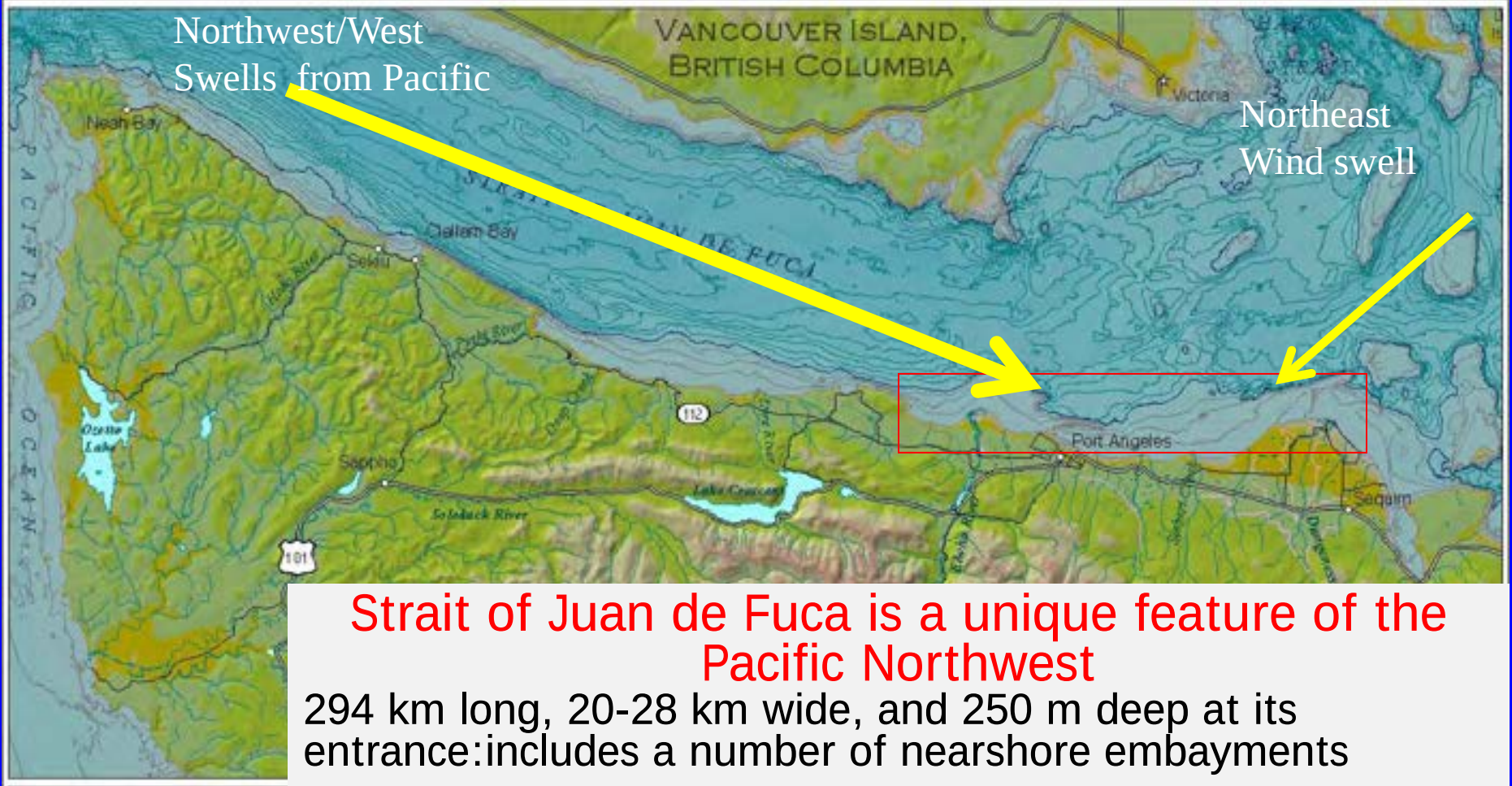


Definition of ‘bluff’

- A bluff is defined as **a steep shoreline slope formed in sediment (loose material such as clay, sand, and gravel) that has three feet or more of vertical elevation just above the high tide line**.

https://www.maine.gov/dacf/mgs/explore/marine/facts/bluff.html


123°35'0"W
123°30'0"W
123°25'0"W
123°20'0"W
123°15'0"W
123°10'0"W
48°10'0"N
48°5'0"N
Elwha Drift Cell
Dungeness Drift Cell
Strait of Juan de Fuca
Elwha Bluffs
Ediz Hook
Dungeness Spit
Elwha River
Dungeness Bluffs
Dungeness River
Port Angeles
Elwha Dam
0 1 2 3 4 5 km
N
Clallam County
WASHINGTON



Strait of Juan de Fuca is a unique feature of the Pacific Northwest

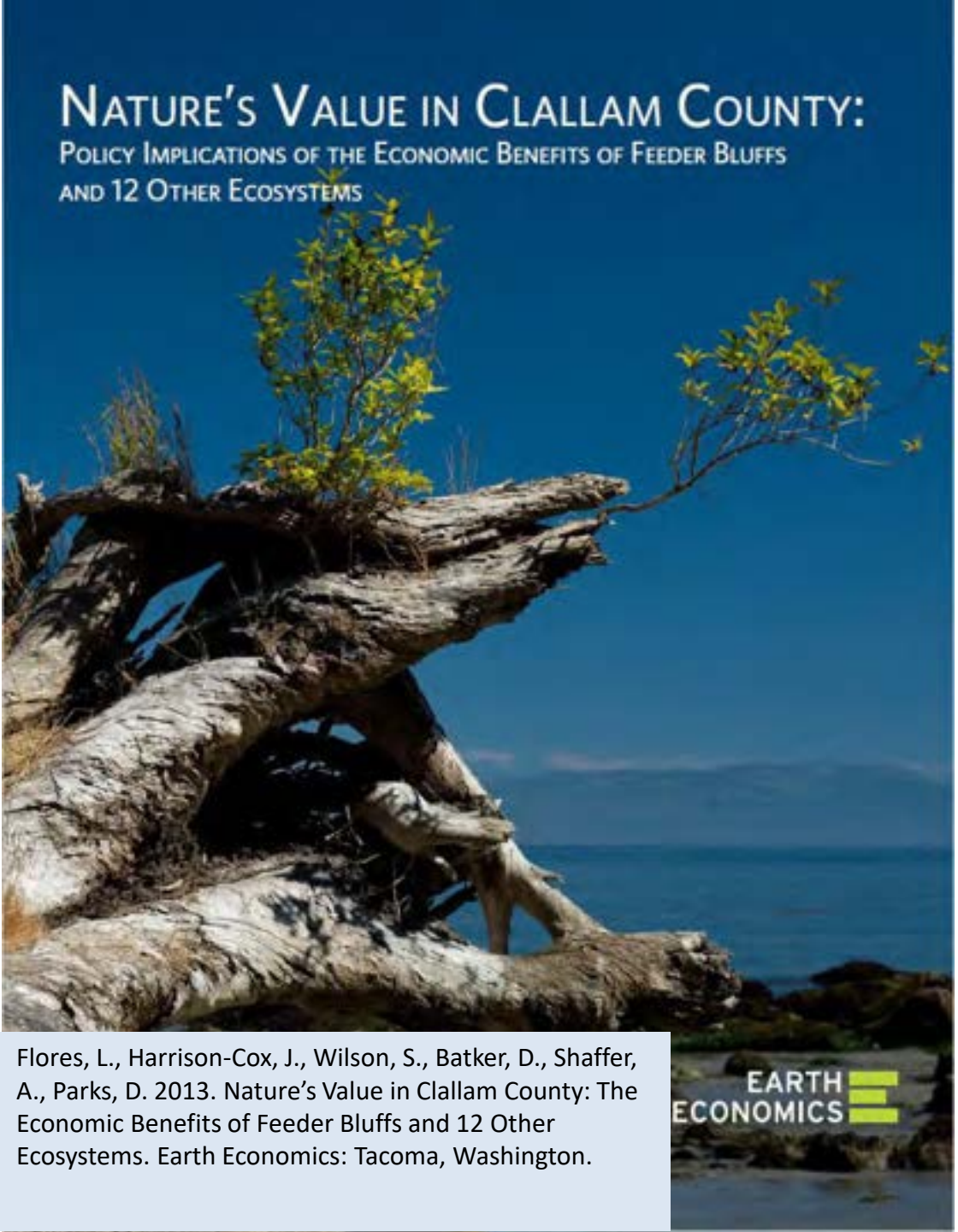
294 km long, 20-28 km wide, and 250 m deep at its entrance:includes a number of nearshore embayments

> 80% of the water from Puget Sound and Strait of Georgia flows through the Strait (Mackas and Harrison 1997)

High geographic, temporal (interannual and seasonal) variability in physical and biological processes that make up the Strait nearshore

Bluffs Supply Dungeness Spit with Sediment and Form Dungeness Bay





Flores, L., Harrison-Cox, J., Wilson, S., Batker, D., Shaffer, A., Parks, D. 2013. Nature's Value in Clallam County: The Economic Benefits of Feeder Bluffs and 12 Other Ecosystems. Earth Economics: Tacoma, Washington.

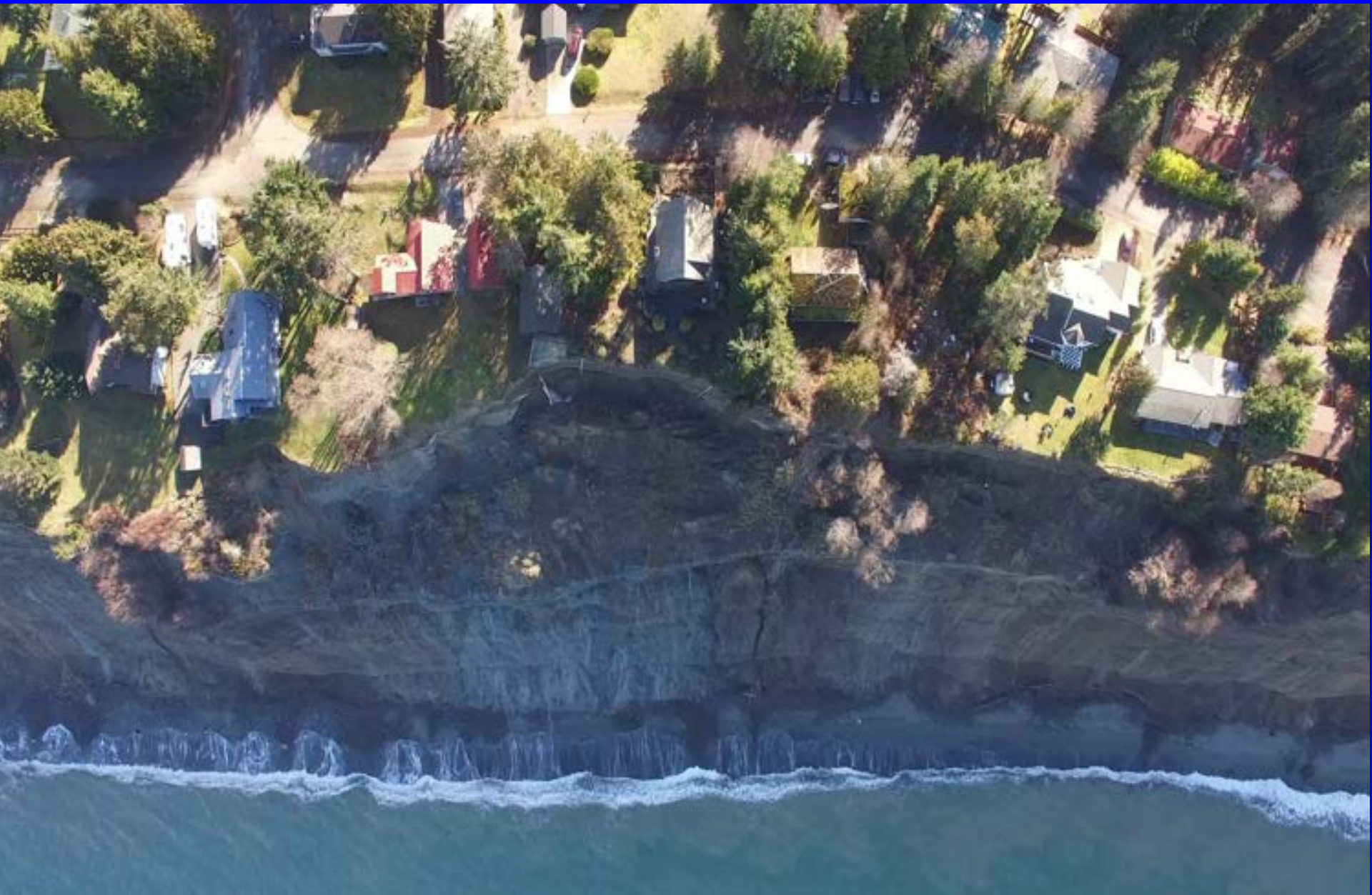
Feeder Bluffs Contribute $500,000/Year to Clallam County (Ecosystem Services)

Clallam County Nearshore Ecosystem contributes more than $15 million/year to Local and Regional Economies

Commercial and Recreational Fishing contribute $20 million/year.

Conservation of Nearshore Habitats (including feeder bluffs) is the most cost effective approach to sustaining local ecosystem services

Bluff Erosion is a Natural Hazard




Land Use
Precipitation
Infrastructure
Runoff
Groundwater
Freeze/Thaw
Wind
Sediment Delivery
Total Volume
Rate
Timing
Texture
Mixed Grain Beach Habitat
Beach Topography and Grain Size Changes
Net Sediment Transport Direction
Waves, Tidal Currents
MAR 20 2010

Bluff and Beach Terms



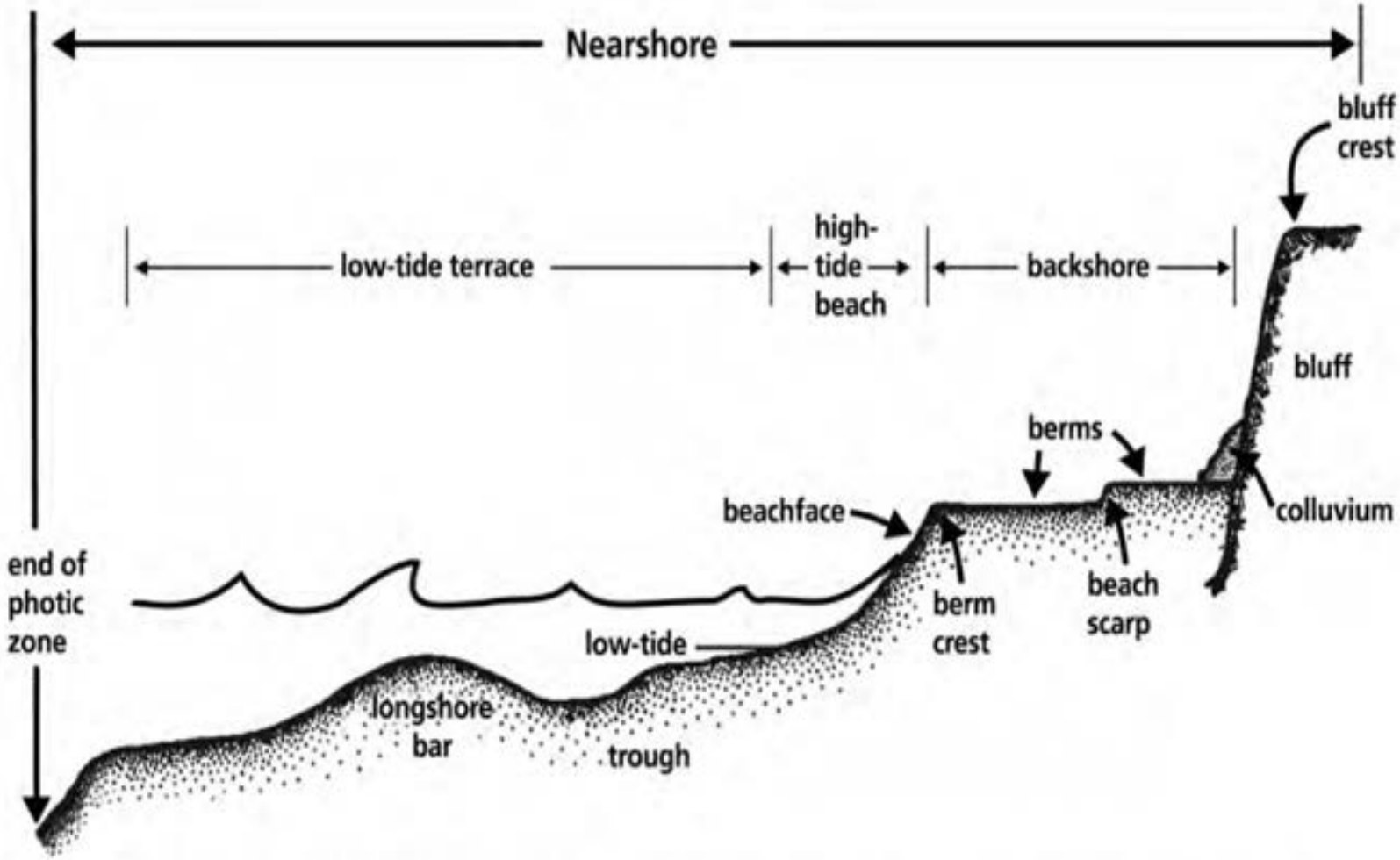


Figure 1. Cross-section of a beach with terminology used in the Puget Sound area (modified from Komar 1976). The entire area in the figure is now considered part of the nearshore zone in the Puget Sound region.

Johannessen, J. and A. MacLennan, 2007.

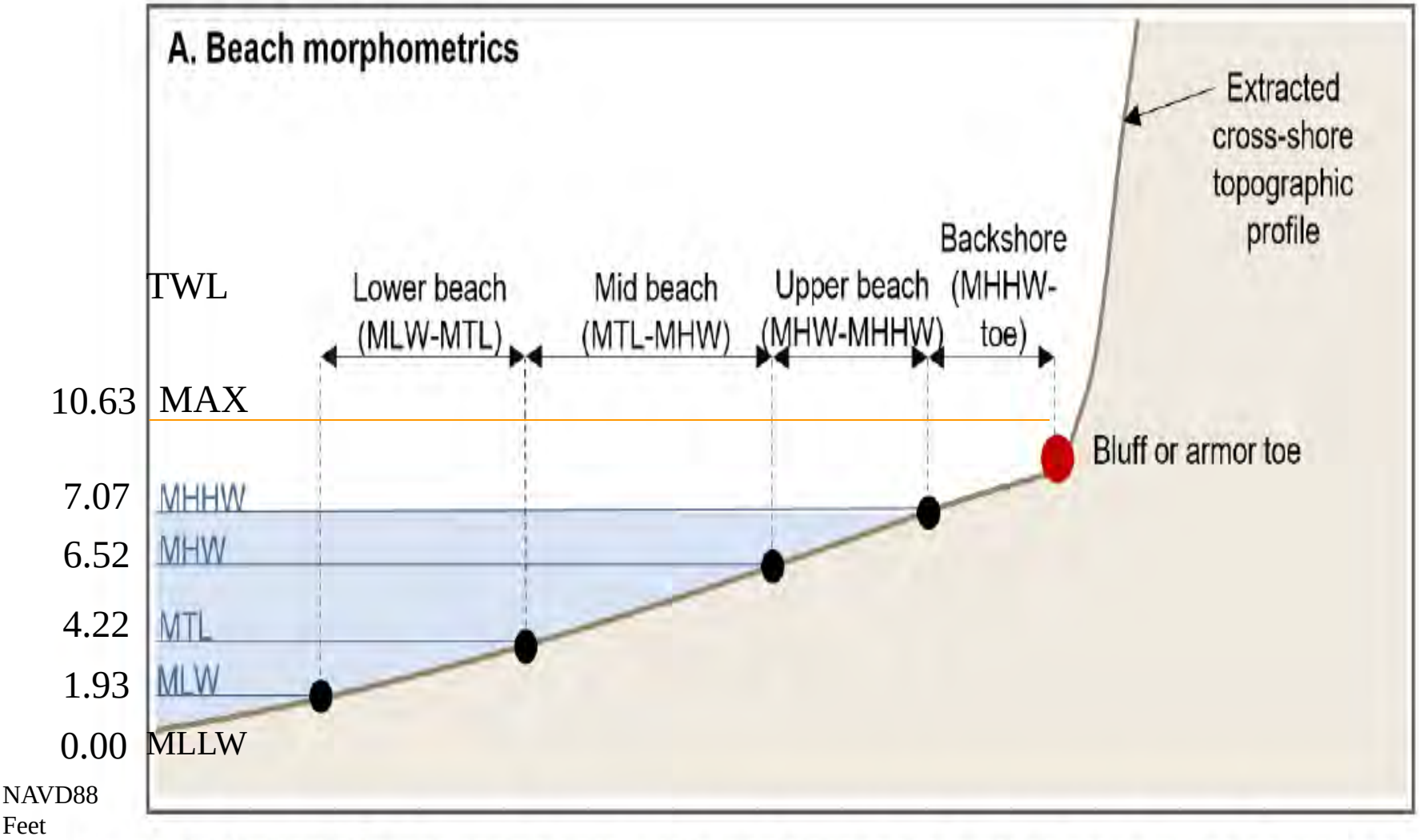


Figure 3. Method of measuring beach width and backshore metrics along cross-shore beach and bluff transects extracted from the lidar point cloud.

Modified from WDOE, 2026 (Tidal Datums Port Angeles, WA ID:9444090, NOAA).

Mixed Grain-Size Beaches-Boulders to Sand

Table 4. Krumbein Φ-Scale used for classifying digital grain size samples (Wentworth, 1922).

Φ scale	Size range (metric)	Size range (approx. inches)	Aggregate name (Wentworth Class)
> −8	> 256 mm	> 10.1	Boulder
−6 to −8	64–256 mm	2.5–10.1	Cobble
−5 to −6	32–64 mm	1.26–2.5	Very coarse gravel
−4 to −5	16–32 mm	0.63–1.26	Coarse gravel
−3 to −4	8–16 mm	0.31–0.63	Medium gravel
−2 to −3	4–8 mm	0.157–0.31	Fine gravel
−1 to −2	2–4 mm	0.079–0.157	Very fine gravel
0 to −1	1–2 mm	0.039–0.079	Very coarse sand
1 to 0	0.5–1 mm	0.020–0.039	Coarse sand
2 to 1	0.25–0.5 mm	0.010–0.020	Medium sand
3 to 2	125–250 µm	0.0049–0.010	Fine sand
4 to 3	62–125 µm	0.0025–0.0049	Very fine sand

WDOE, 2026)

Forces Driving Bluff Erosion

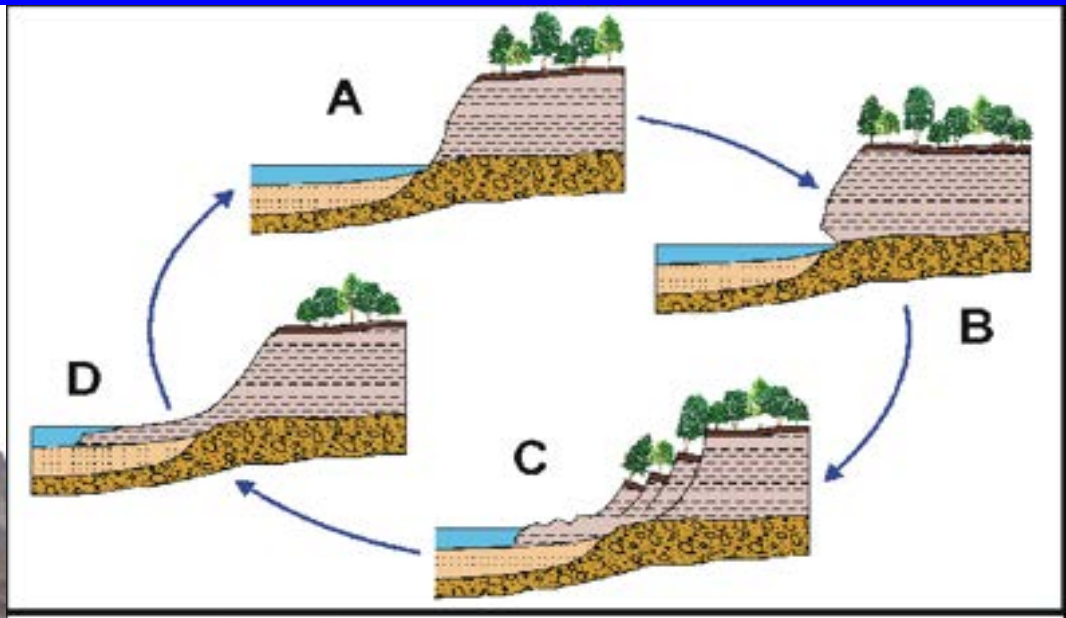
- Wave Run-up at Bluff Toe

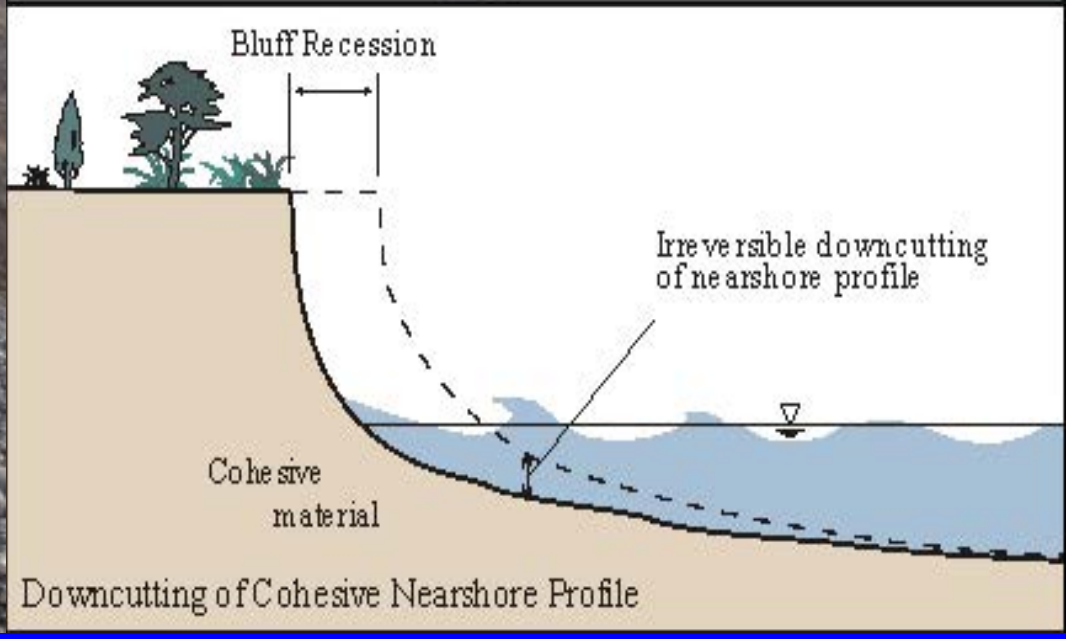
- Hydrologic Inputs at Bluff Top (Rain)

- *Raphael, et. al., 2026. Temporal Evolution of Coastal Cliffs From Weekly to Interannual Timescales. JGR Earth Surface.*

Bluff Erosion Cycle







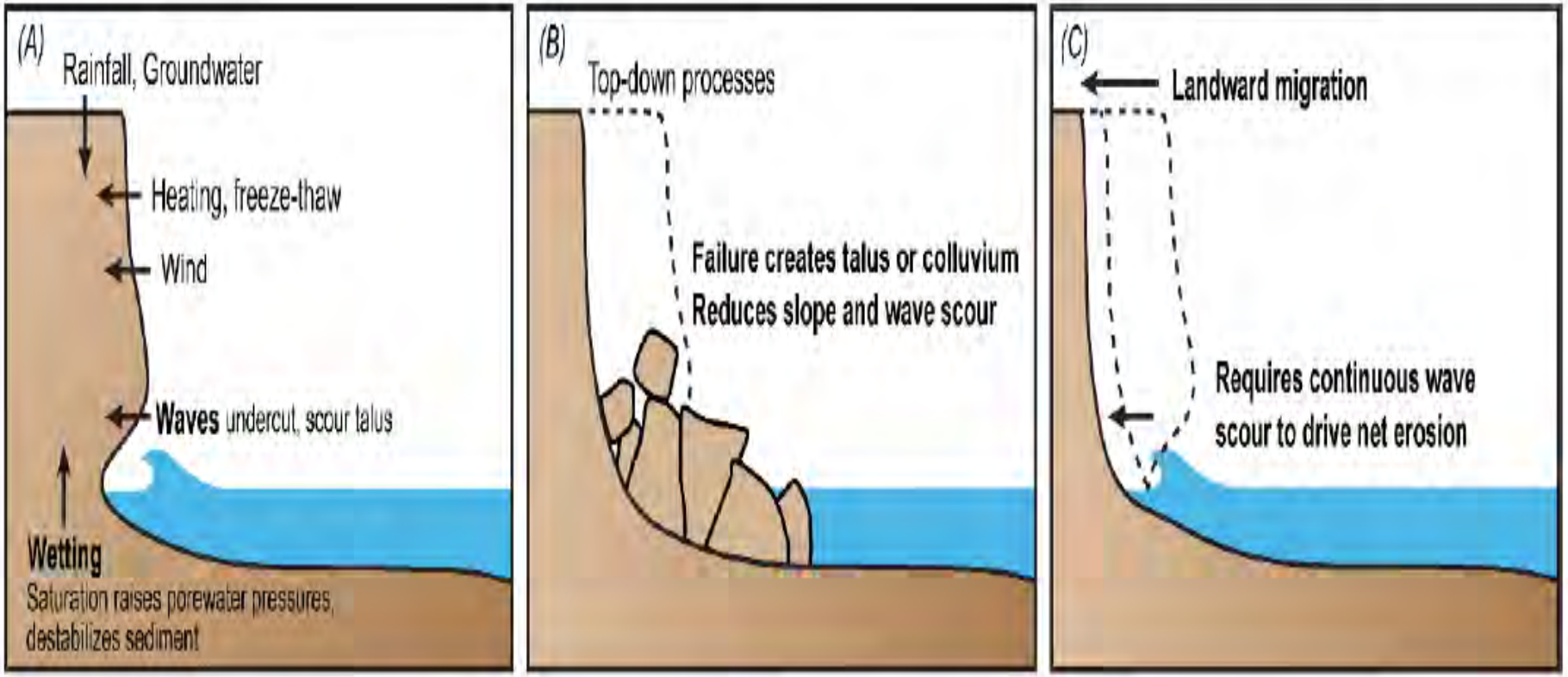
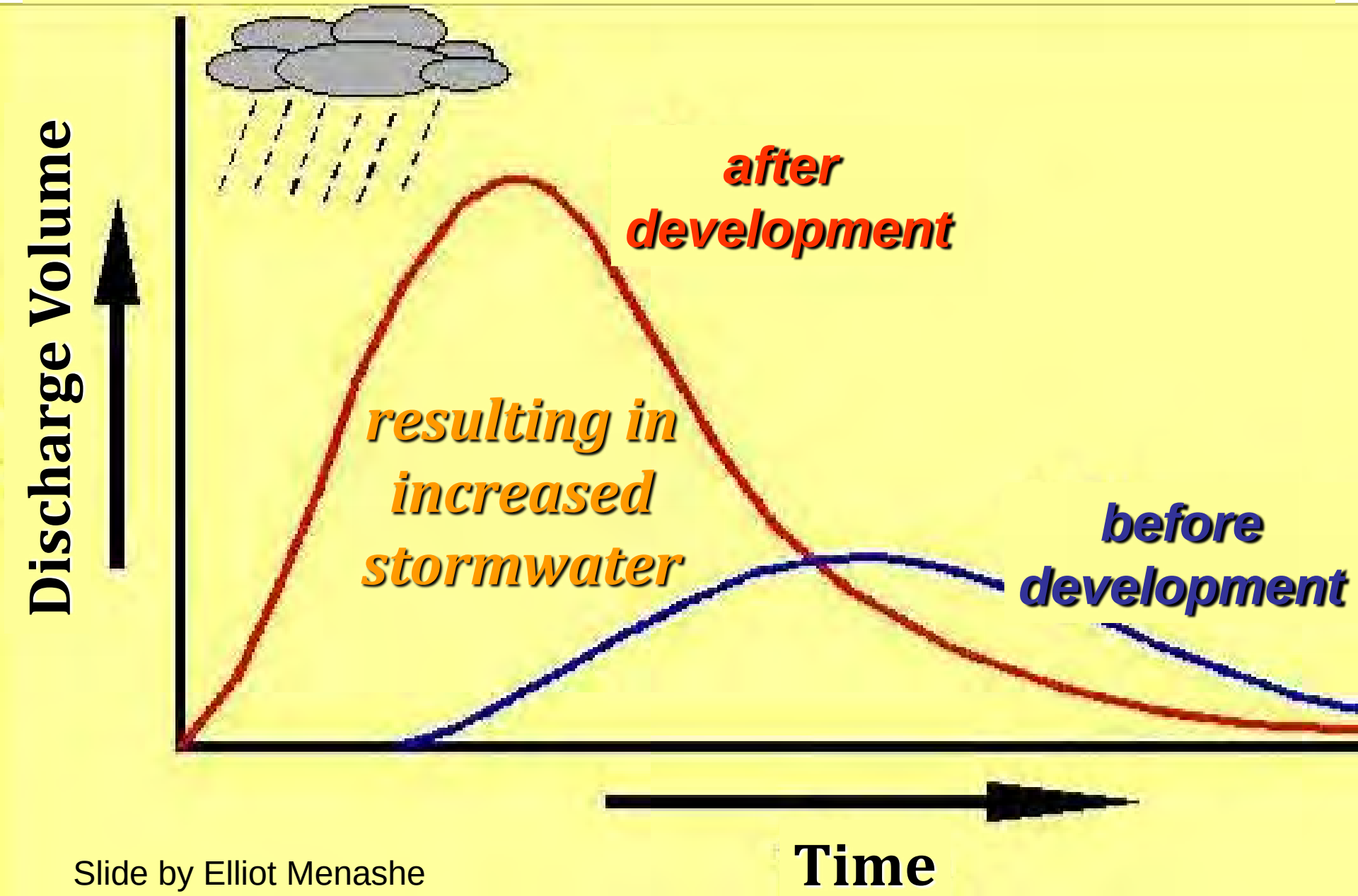


Figure 1. Conceptual diagram illustrating factors that drive bluff retreat and the two factors (bold) accounted for in this study (A), the reduction in slope and erosion with only top-down processes (B), and the requirement for wave scour processes to redistribute colluvium undercut and oversteepen bluffs to drive net landward migration (C).

Grossman et. al., 2026 (In Press)

TIMING OF STORMWATER RUN-OFF



Slide by Elliot Menashe

Geologic History



Geologic Context

- Bluffs are a product of glacial advance/retreat, sea-level change, and wind, water, and wave erosion.
- Modern (5k yr. bpa) bluff erosion driven by:
  - Wave run-up on the beach
  - Precipitation & Groundwater effects
  - Aeolian (wind) erosion
  - Freeze-Thaw (expansion and contraction)
- High degree of spatial and temporal variability in bluff properties and factors driving erosion.

Vashon Glaciation 15.5 K yr bpa



Haugerud, R.A., 2020, Deglaciation of the Puget Lowland, Washington, *in* Waitt, R.B., Thackray, G.D., and Gillespie, A.R., eds., Untangling the Quaternary Period—A Legacy of Stephen C. Porter: Geological Society of America Special Paper 548, p. 279–298, https://doi.org/10.1130/2020.2548(14). © 2020 The Geological Society of America. All rights reserved. For permission to copy, contact editing@geosociety.org.

Relative Sea-Level Changes

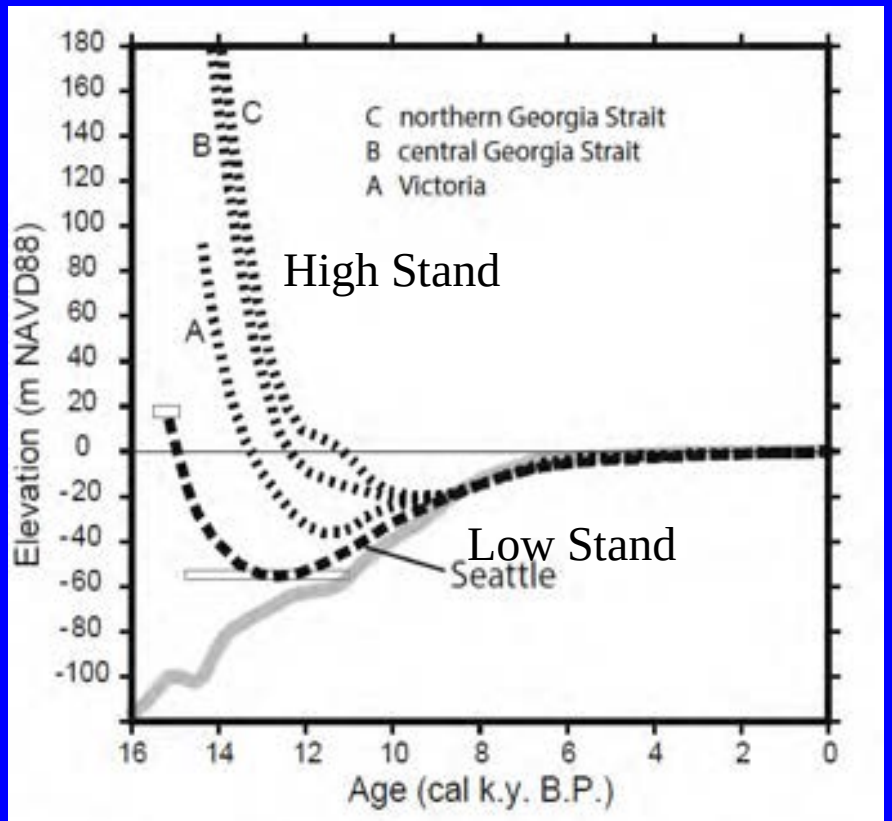
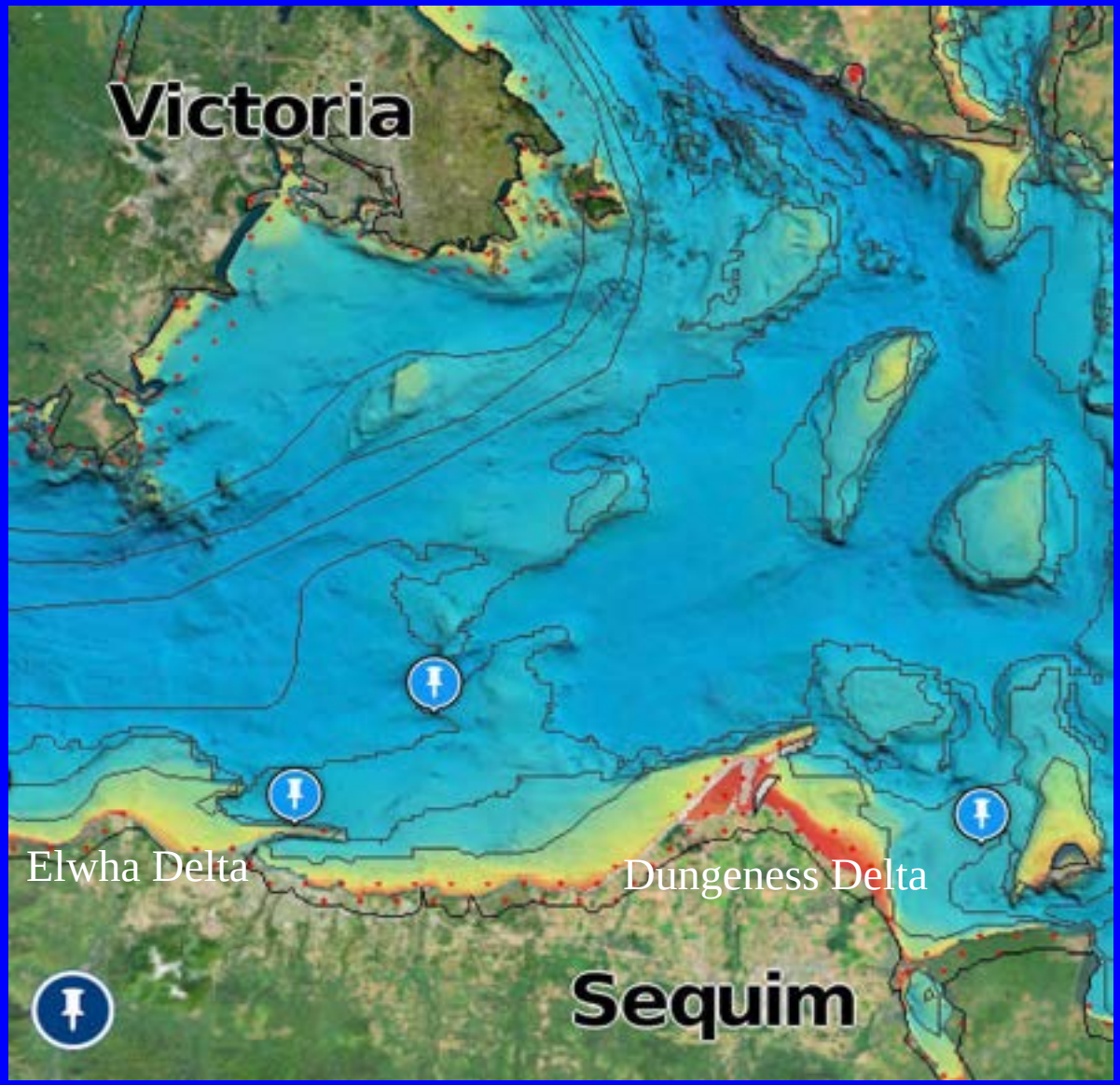


Figure 4. Relative sea-level (RSL) histories. Gray line—global ice-volume–equivalent sea-level history from Lambeck et al. (2014). Dashed line—RSL curve for Seattle. Constraints are shown as boxes: RSL of 15–20 m (elevation by projection from Thorson, 1989; Dethier et al., 1995) at 15.5–15.0 calibrated (cal.) k.y. B.P. (shortly after deglaciation; Fig. 8), and RSL of ~55 m (marine lowstand shoreline) at 15–11 cal. k.y. B.P. (after deglaciation and before global sea level [gray line] rose above ~55 m). RSL for Seattle after 6 cal k.y. B.P. is from Engelhart et al. (2015). Dotted lines—modeled RSL curves for Victoria, central Georgia Strait, and northern Georgia Strait (James et al., 2009). NAVD88—North American Vertical Datum of 1988. Figure is from Haugerud et al. (2017); used with permission.

Sea Level “Low-Stand” Landforms

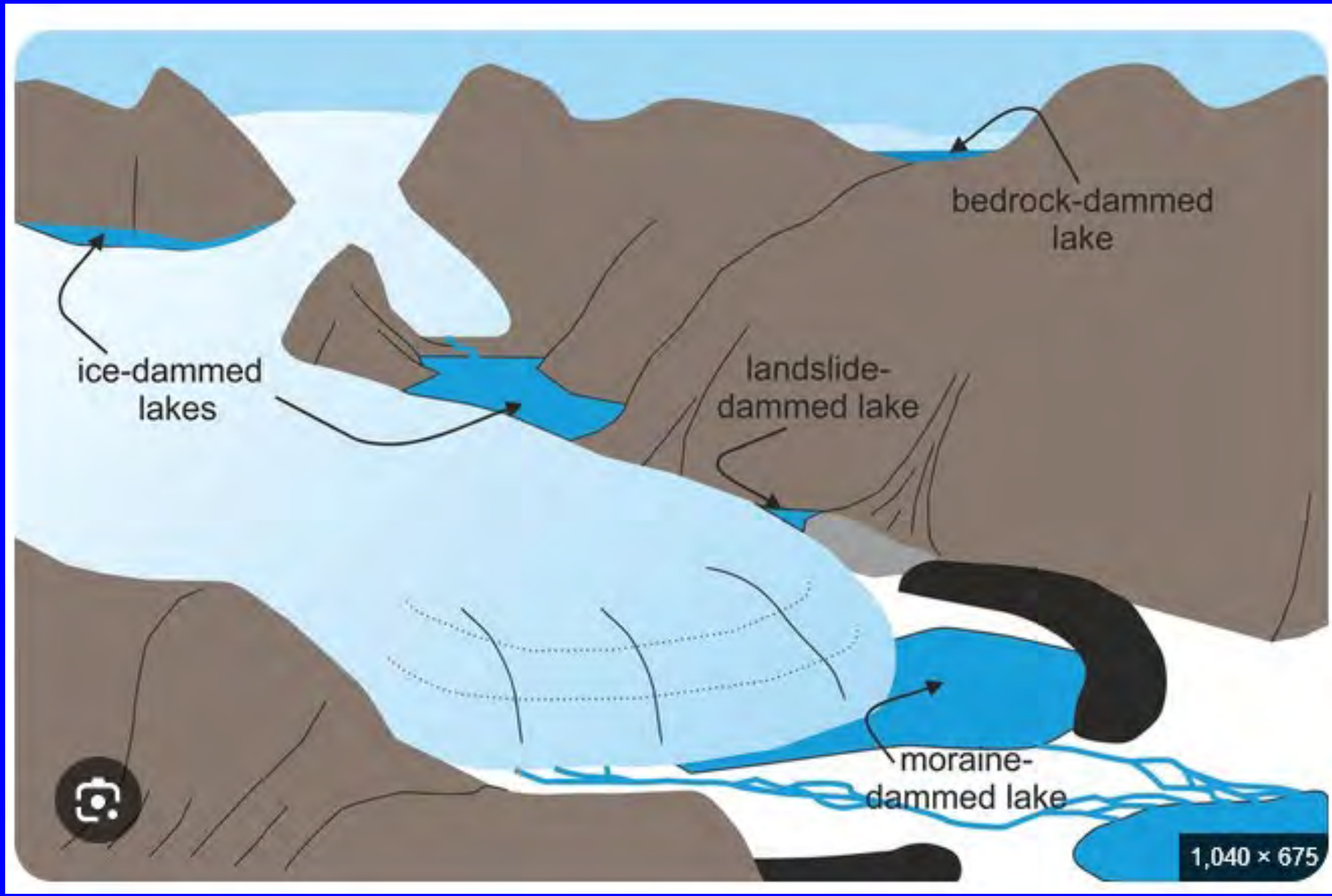


Glacial Bluff-Backed Beaches

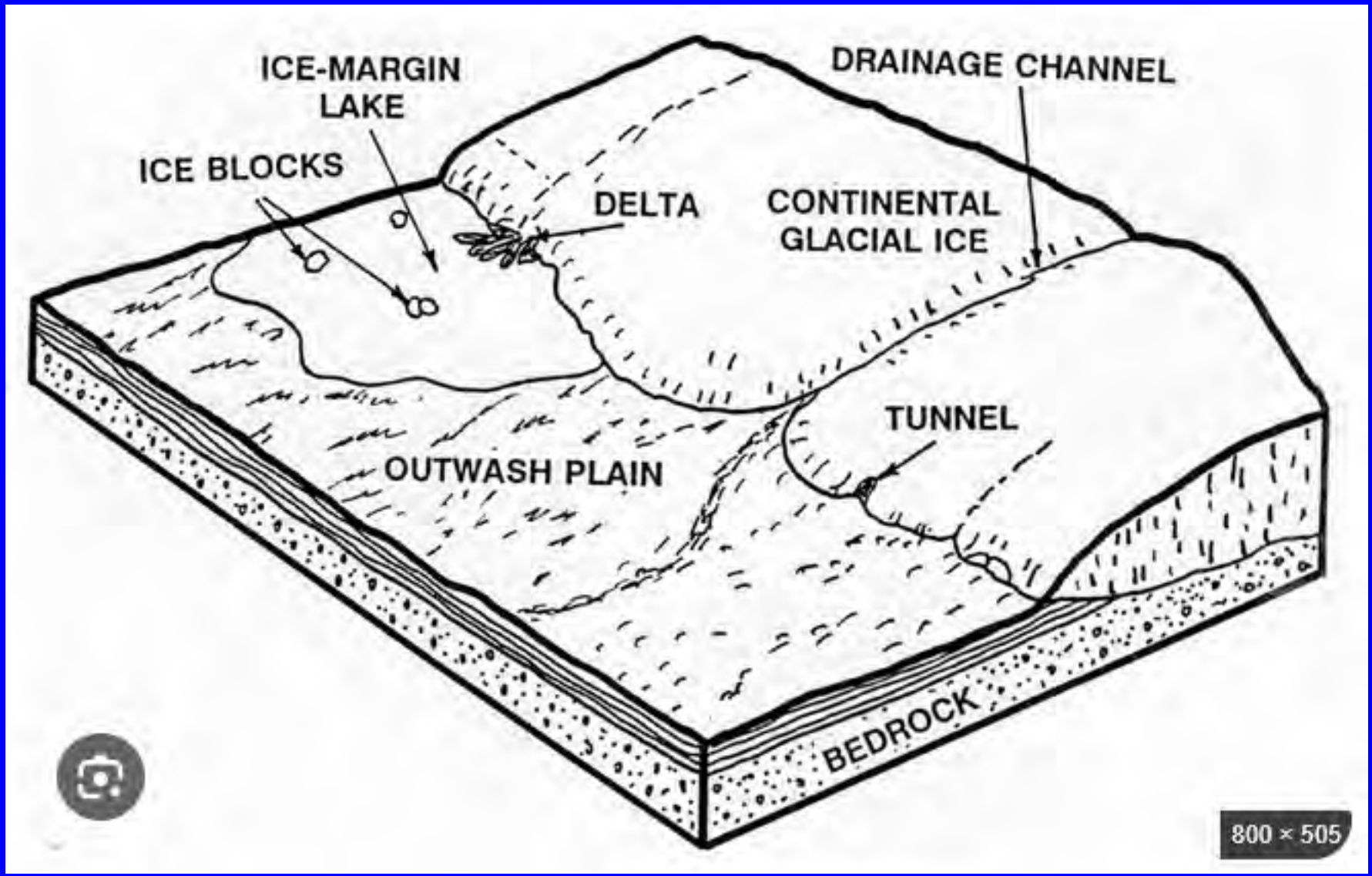


Fraser Glaciation
Sea Level Change
Isostatic Rebound

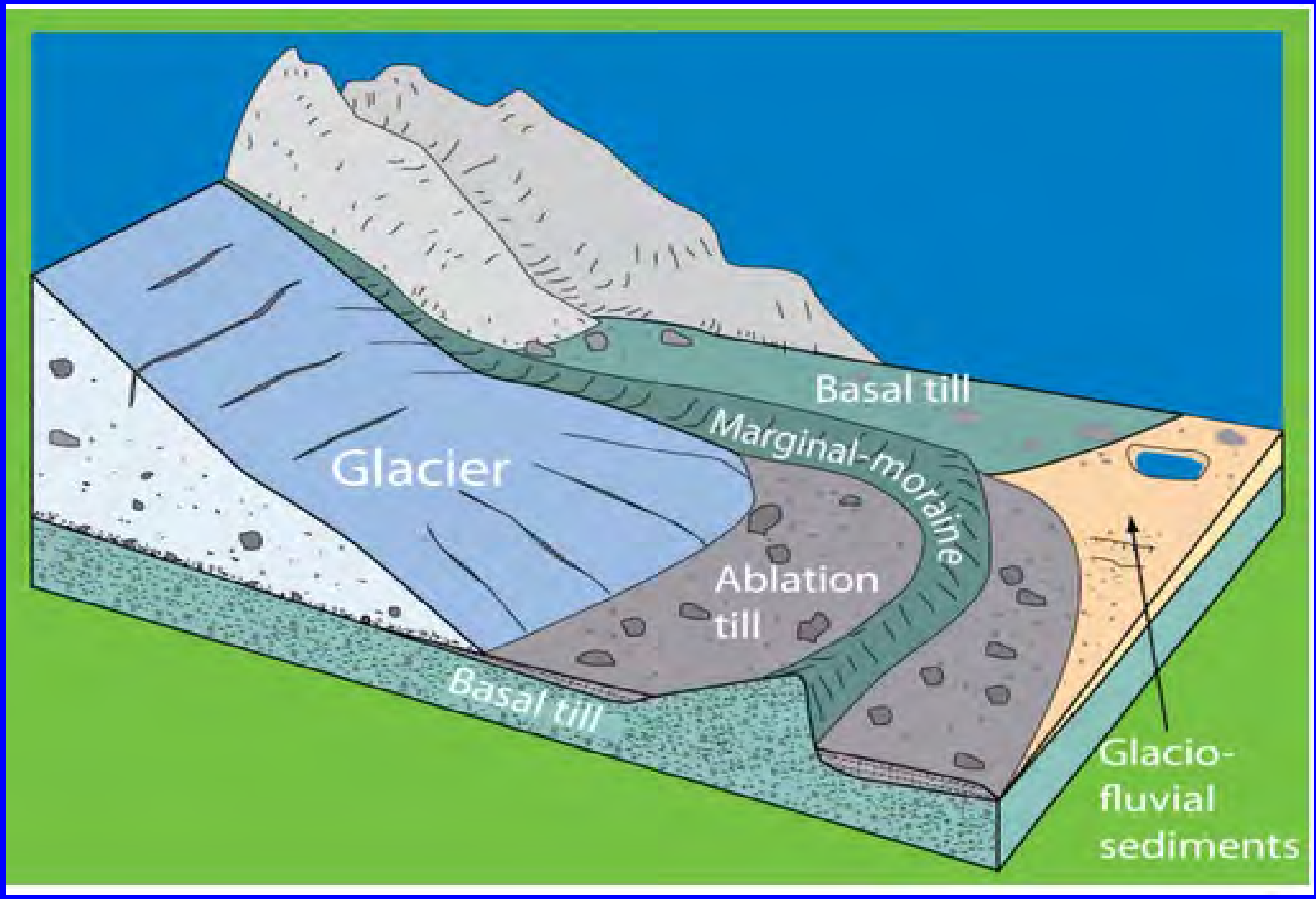
Proglacial Lake Sediments



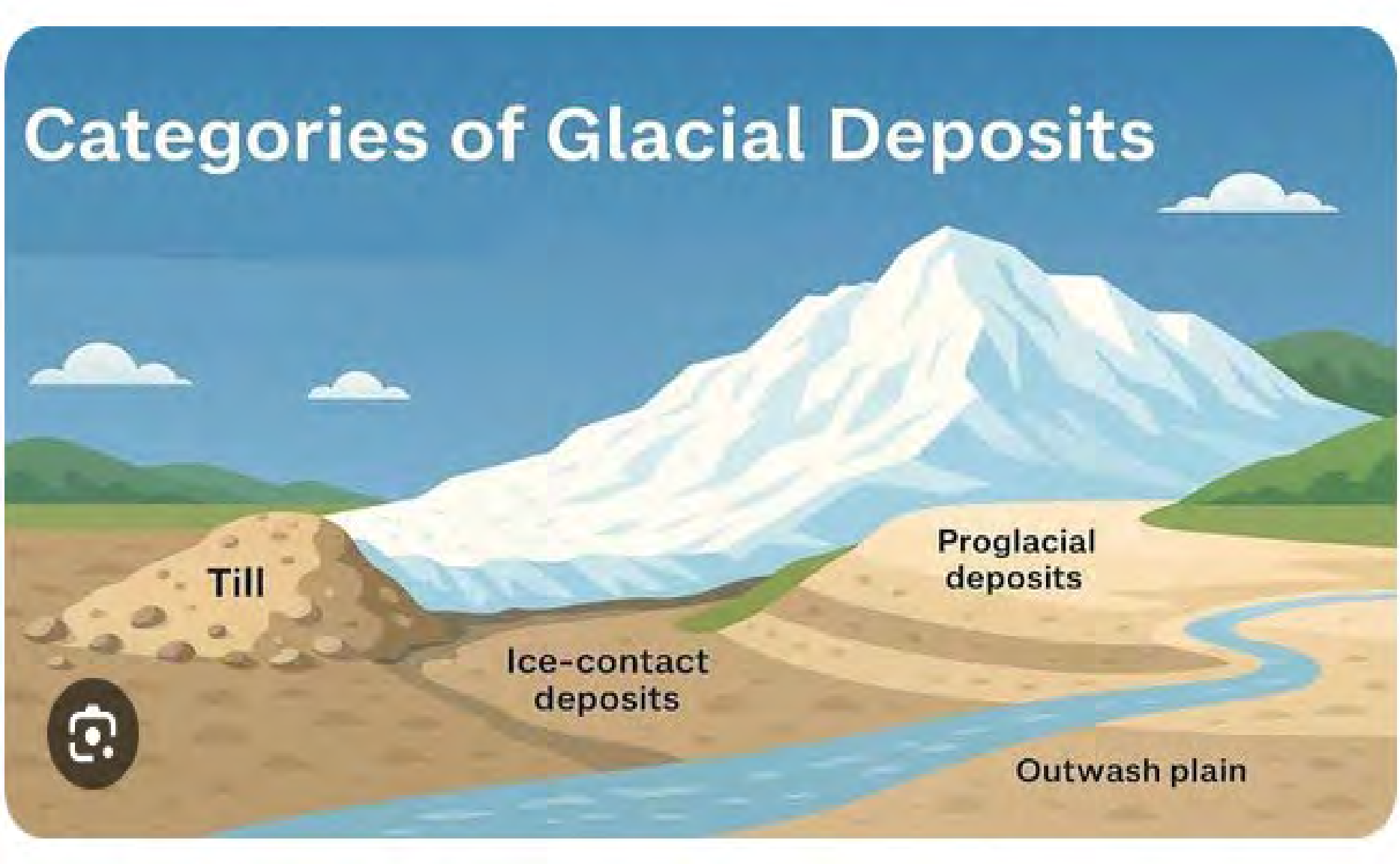
Outwash (Advance/Recessional)



Glacial Till



Ice-Contact Stratified Drift



Glaciomarine Drift

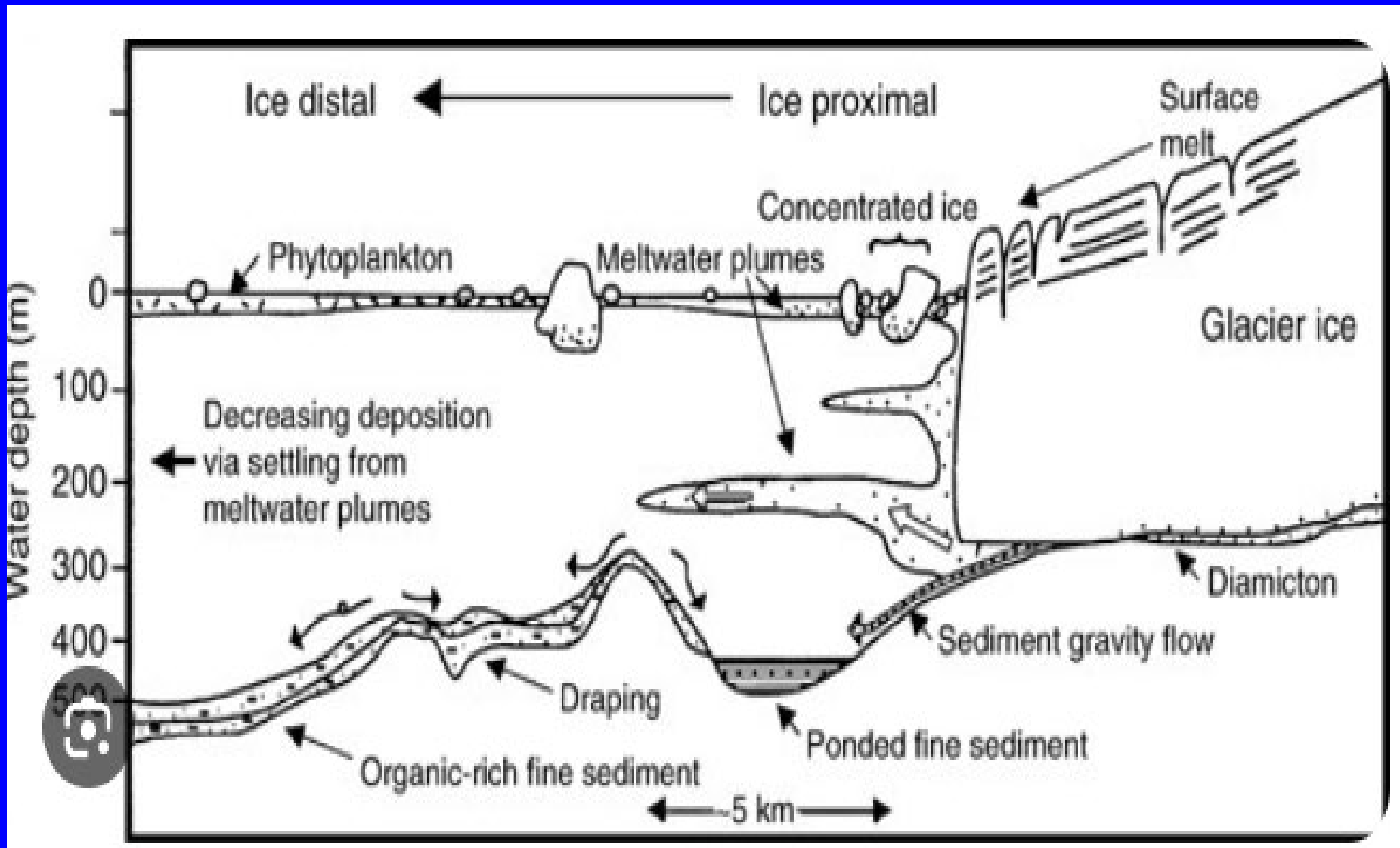




Fig. 1. Study area and selected site locations.

Bluff Profile Locations-Alampay et. al, 2023

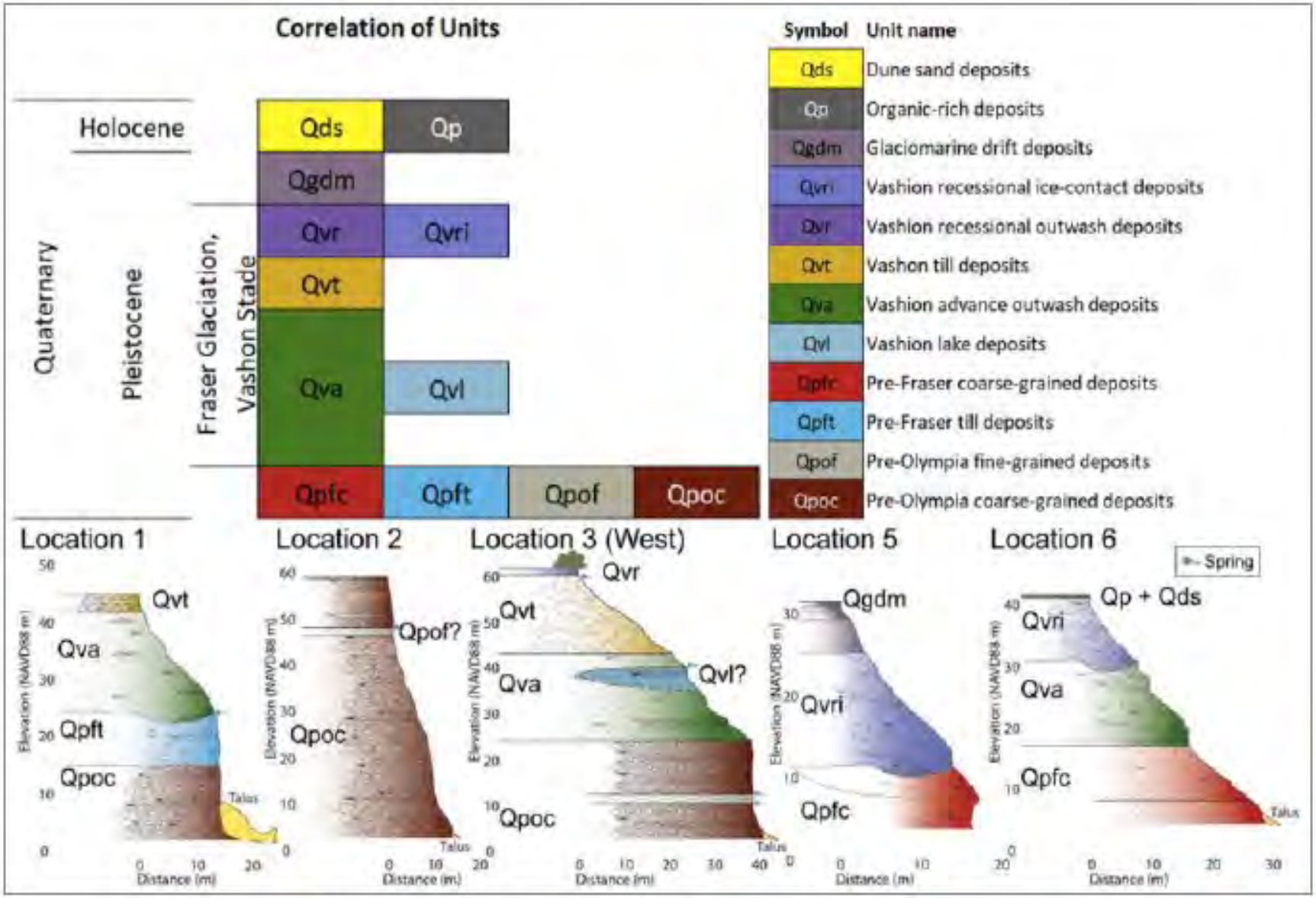


Fig. 3. Geologic units present at the bluff sites.

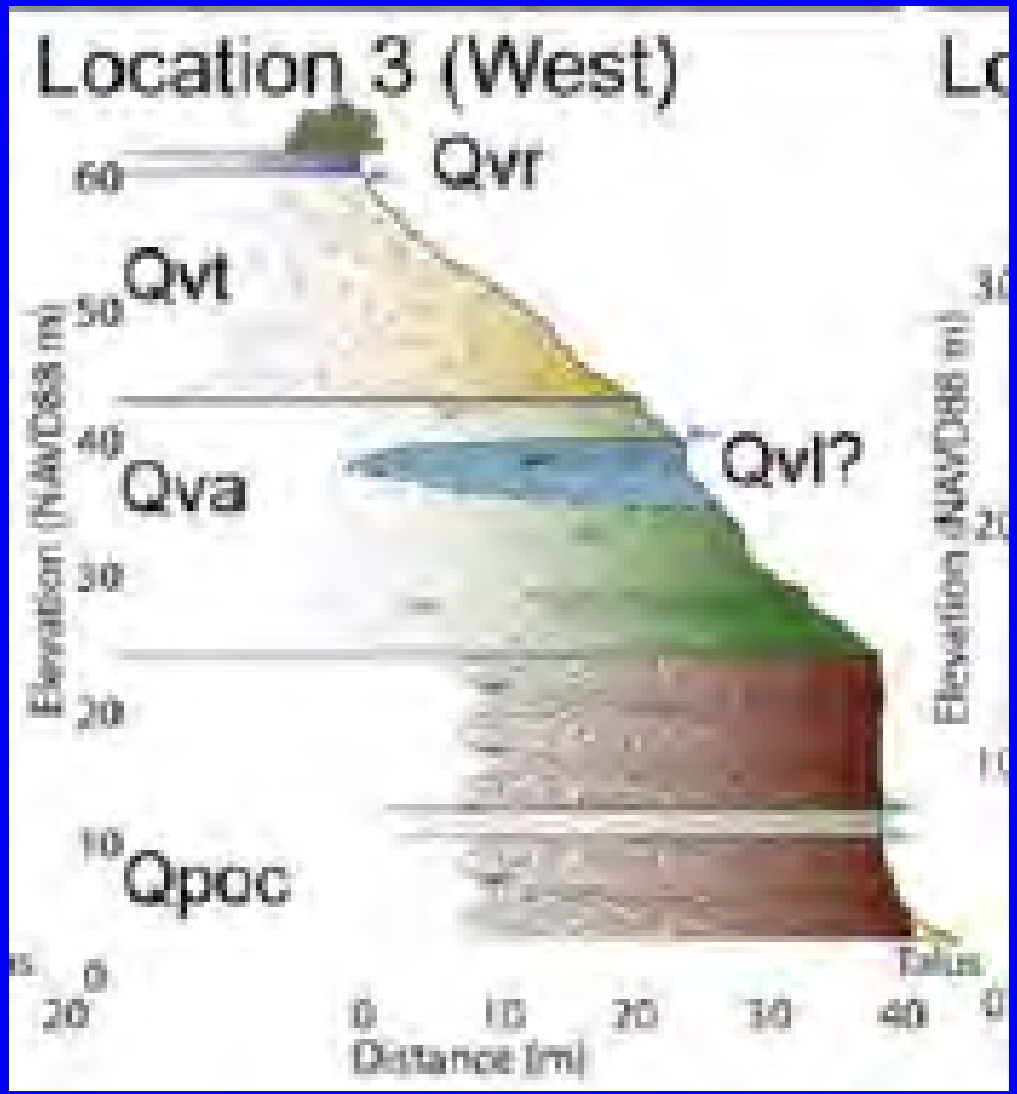
Alampay et. al., 2023

Bagley Creek Area



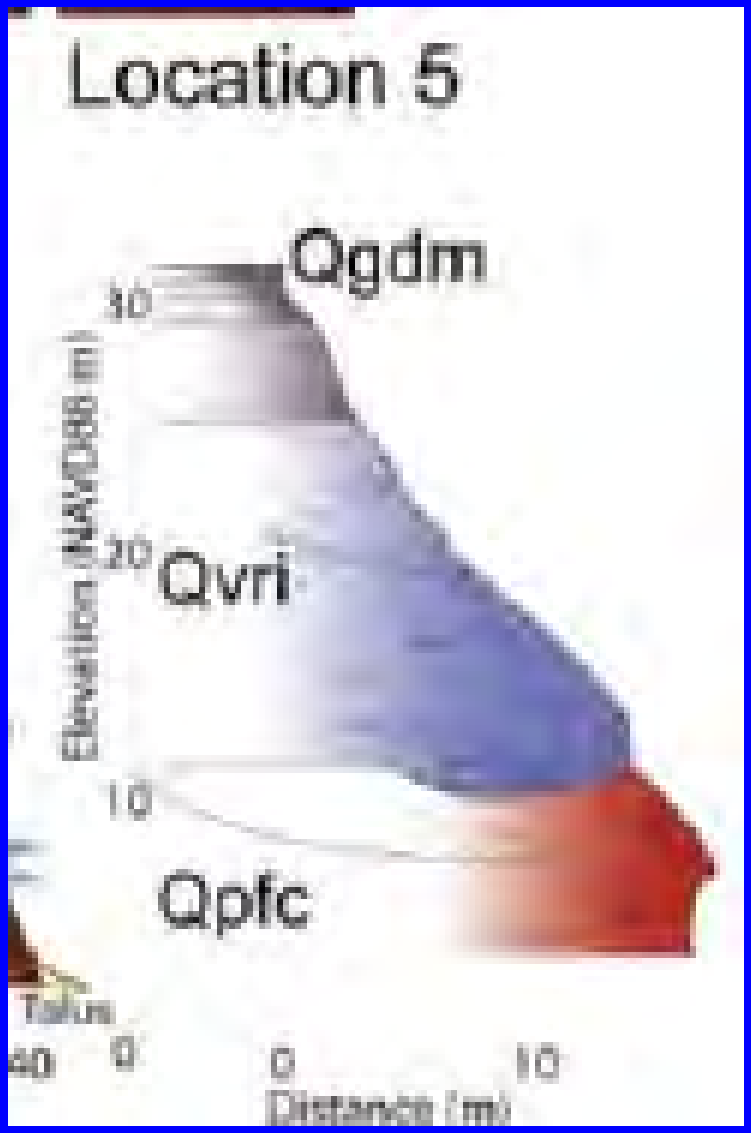


Bluffs Subdivision Area



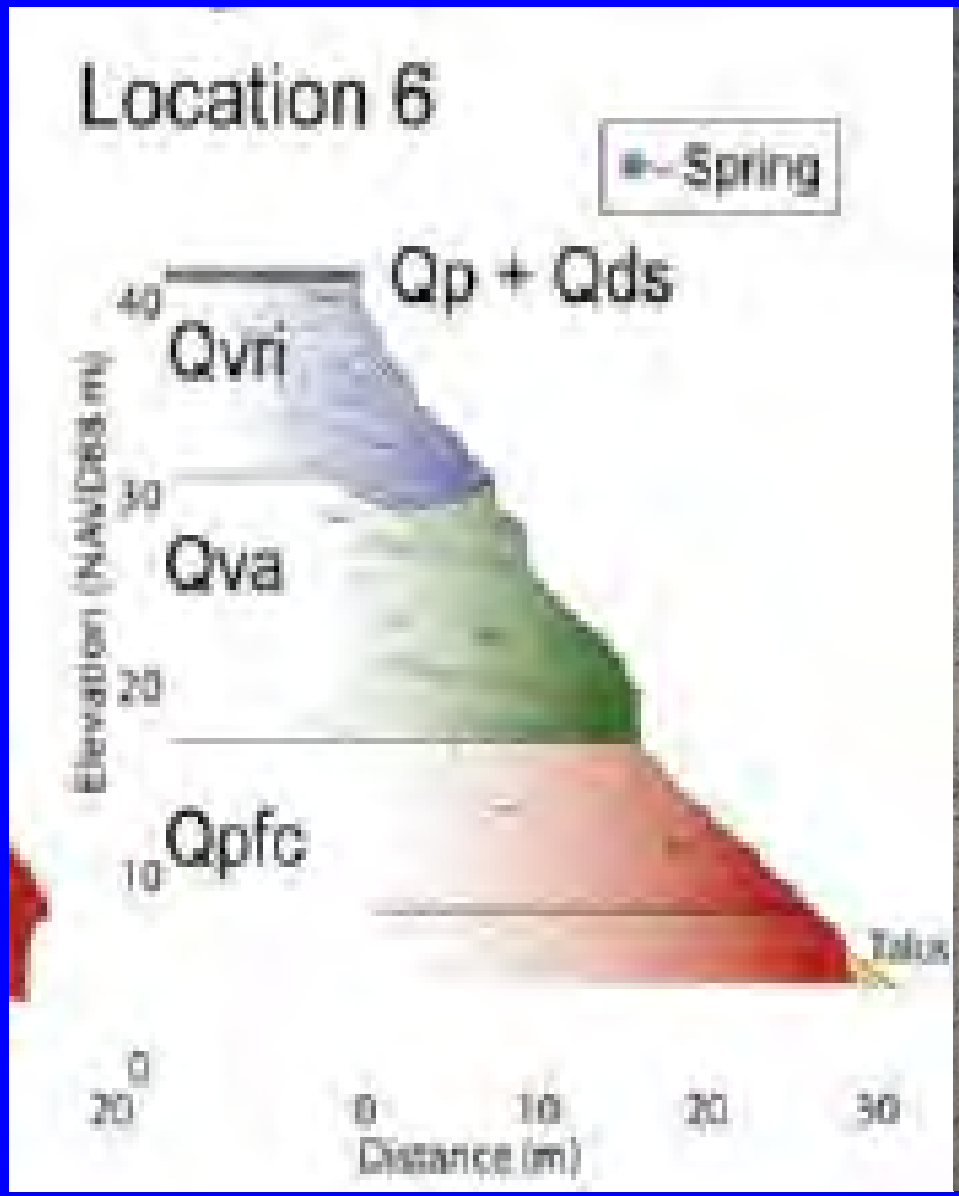


East McDonald Creek Area



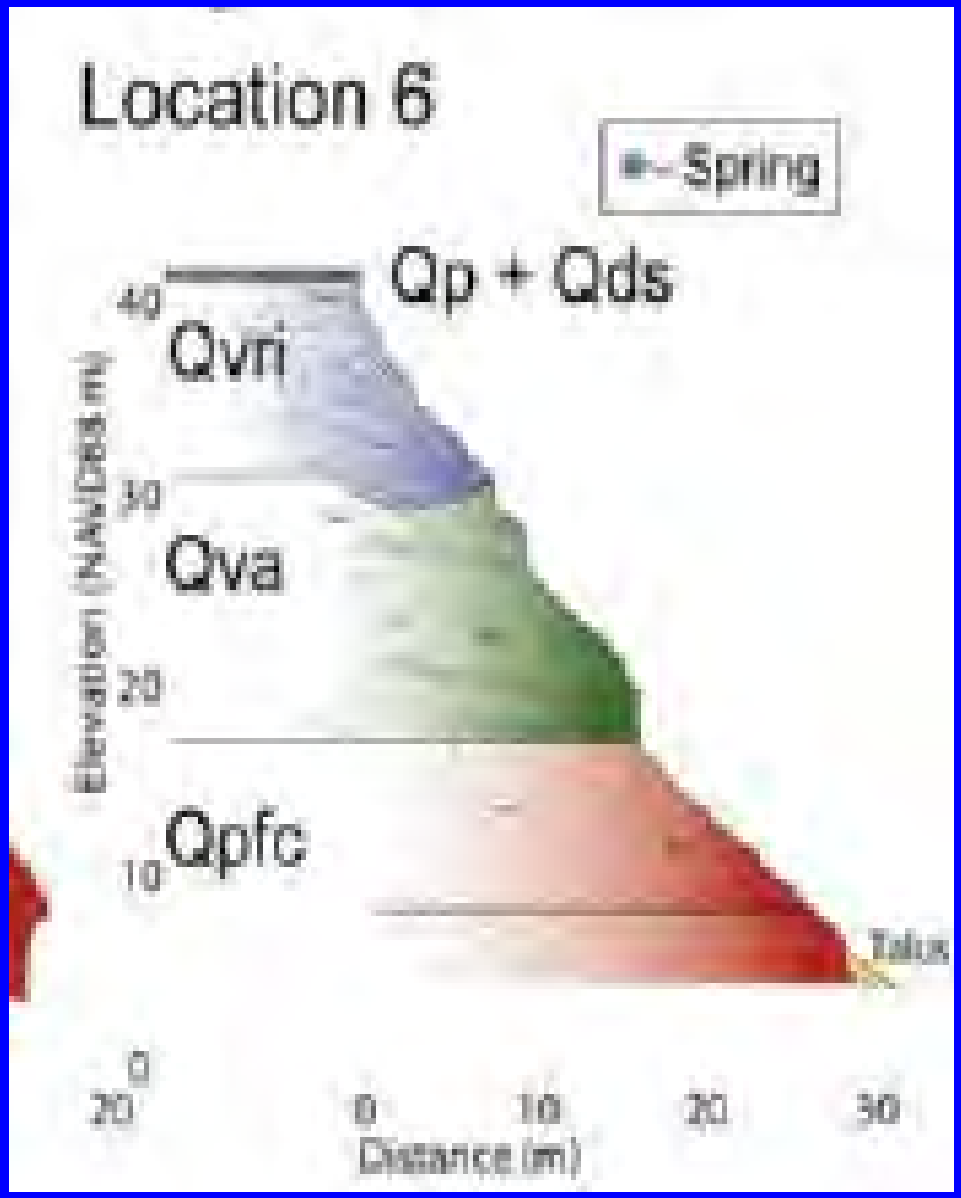


Dungeness Refuge/County Park





Geologic Summary



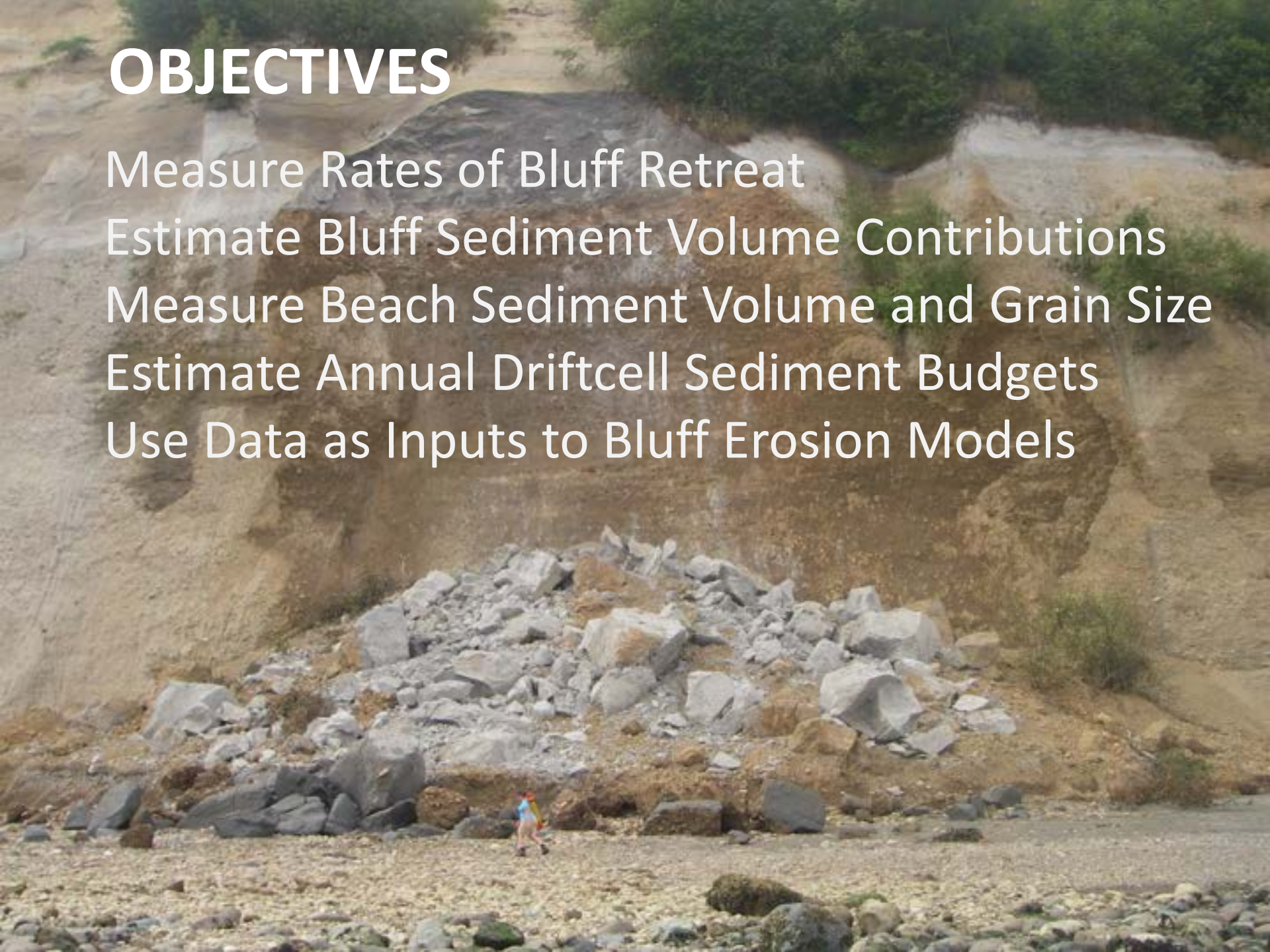
Unconsolidated deposits overlying consolidated deposits

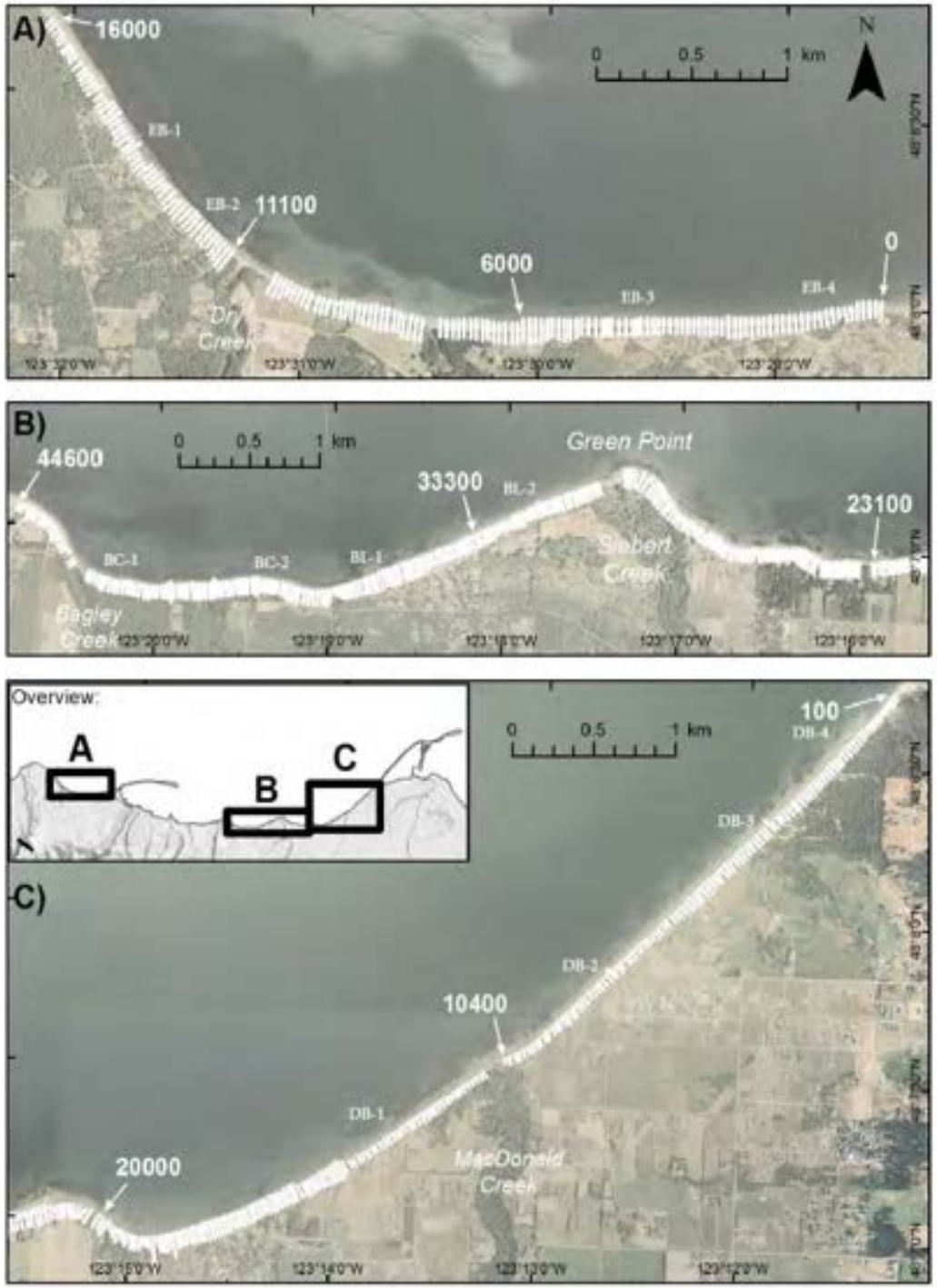
Weak over Strong

Porous overlying Impervious

OBJECTIVES

Measure Rates of Bluff Retreat
Estimate Bluff Sediment Volume Contributions
Measure Beach Sediment Volume and Grain Size
Estimate Annual Driftcell Sediment Budgets
Use Data as Inputs to Bluff Erosion Models





Bluff Transects

Elwha N=152

Dungeness N=423

30 m transect spacing

Beach Transects

Elwha N=5

Dungeness N=8

Elwha=4.9 km

Dungeness =13.6 km



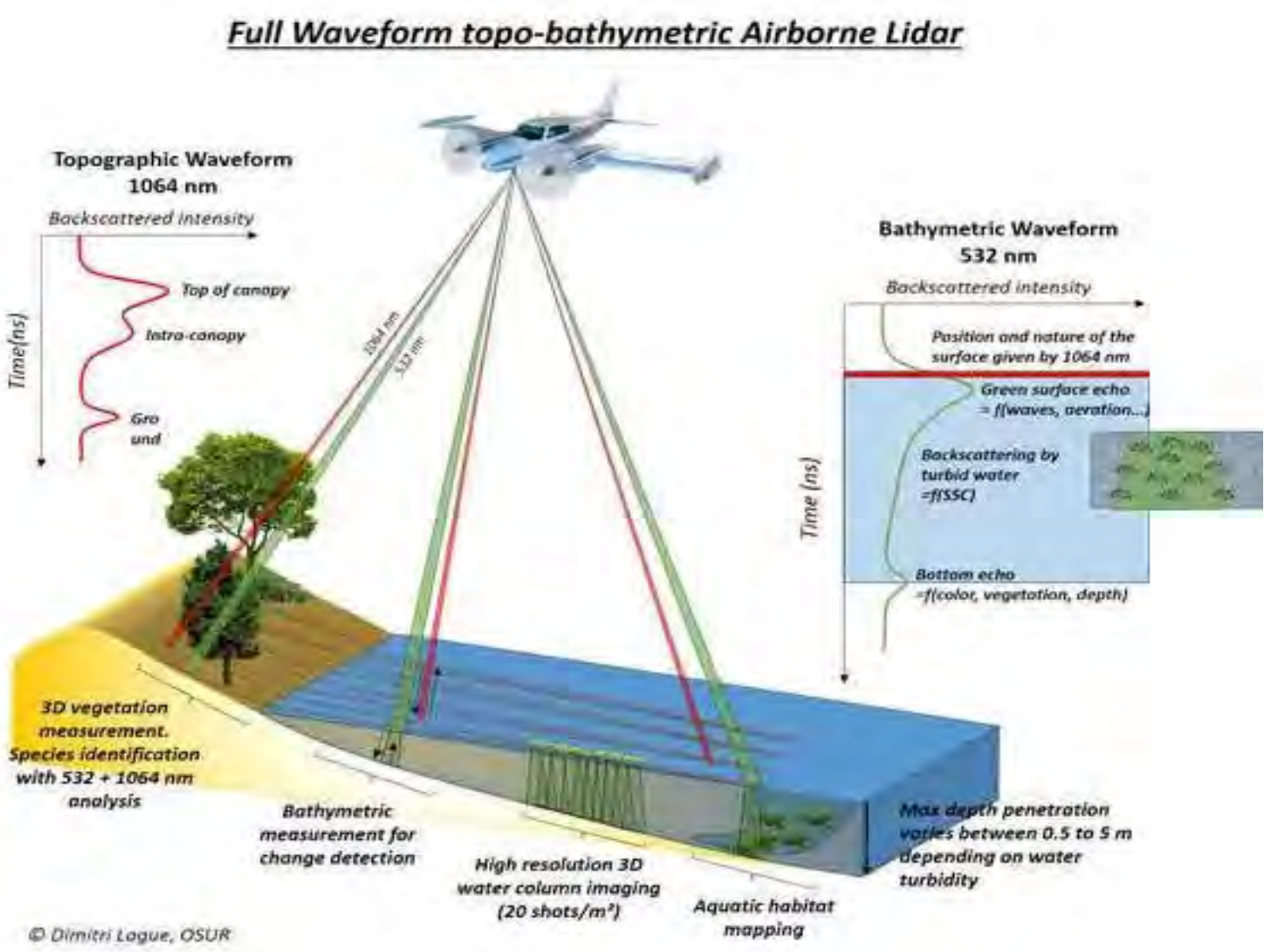




Methods

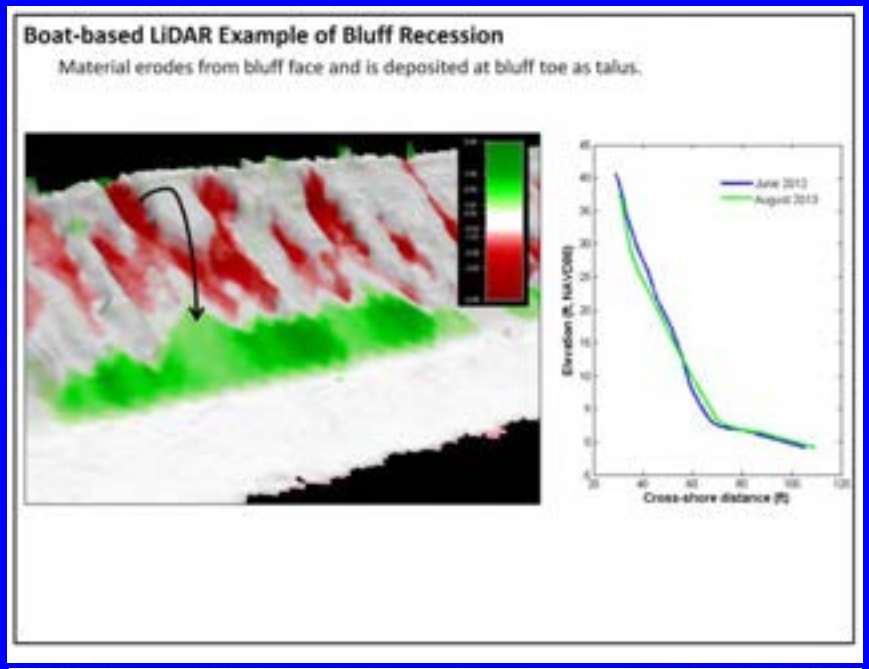
- Digitized historic aerial photography (1939-2001)
- 2-D Bluff Profiles from Airborne LiDAR Digital Elevation Models (DEMs) 2001-2012.
- 2-D Cross Shore Beach Topography (2010-2018) (RTK-GPS)

Airborne LiDAR



Ecology Boat-Based LiDAR









George Kaminsky
Heather Baron
Diana McCandless
Amanda Hacking

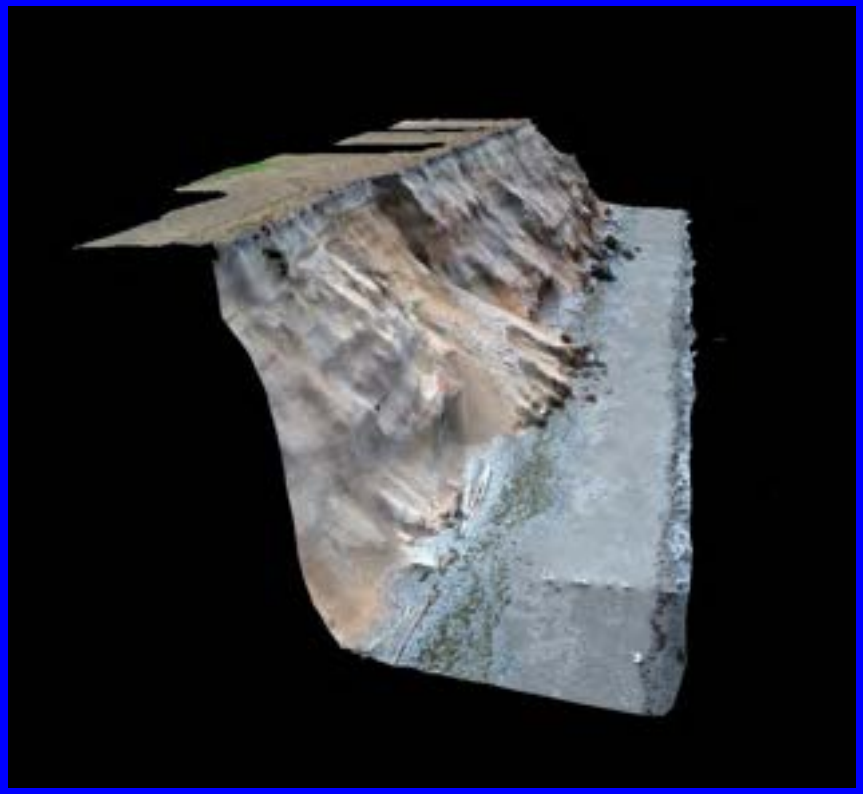
R.V. George Davidson

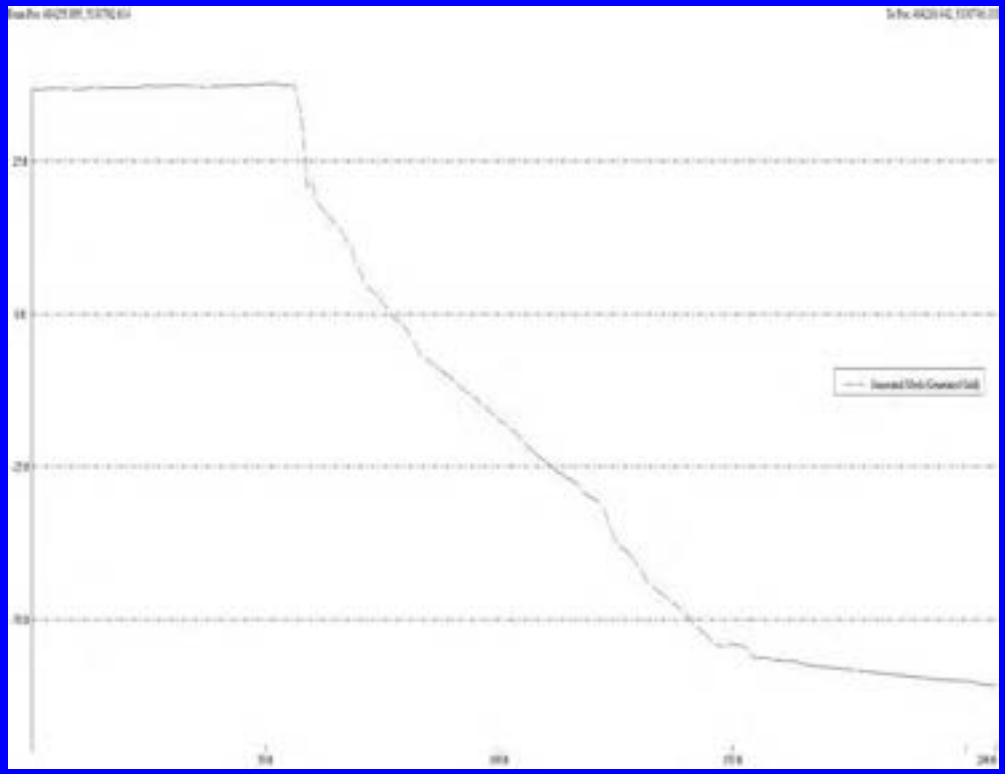
Structure-from-Motion (SfM) Photogrammetry











Bluff Recession Studies

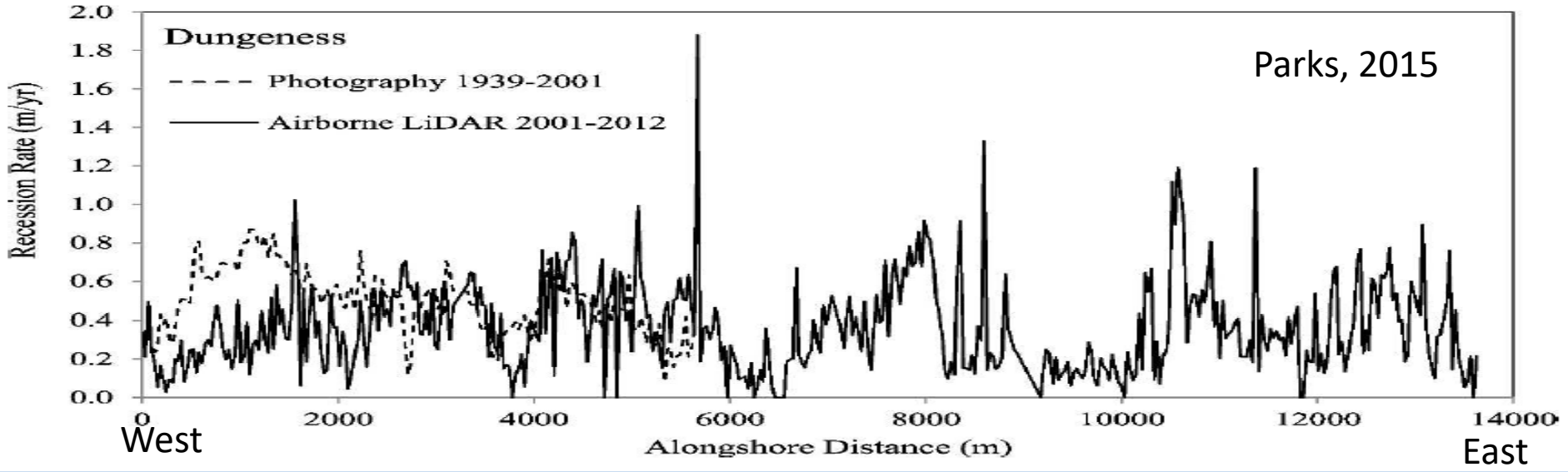


Photo: Ruth Jenkins

AVG. Bluff Recession Rates

	Recession Rate	Sediment Volume
• WDOE, 2014: (2011-2012)	2.5 ft.yr (0.77 m/yr)	NA
• Parks, 2015: (2001-2012)	1.2 ft/yr (0.36 m/yr)	7.5 m^3/m/yr
• Knapp, 2016: (1976-2010)	1.0 ft/yr (0.33 m/yr)	NA
• WDOE, 2026: (2015-2021)	1.2 ft/yr (0.36 m/yr)	8.7 m^3/m/yr

Bluff Recession Rates



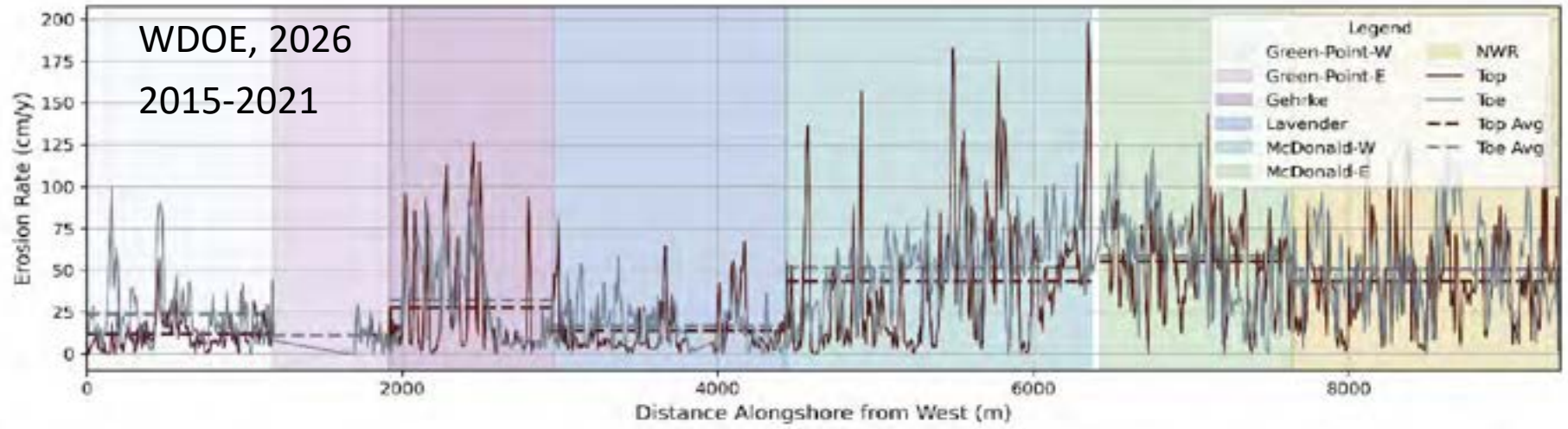


Figure E-22. Alongshore-binned bluff top and toe erosion rates at all sub-cells in Dungeness.

Max Recession Rates

- Parks, 2015 : 5.9 ft/yr (1.8 m/yr)
  (2001-2012)

- Knapp, 2016: 14.6 ft/yr (4.5 m/yr)
  (1976-2010)

- WDOE,2026: 6.6 ft/yr (2.0 m/yr)
- (2015-2021)



Recession Rates Matter!



Land Use Implications

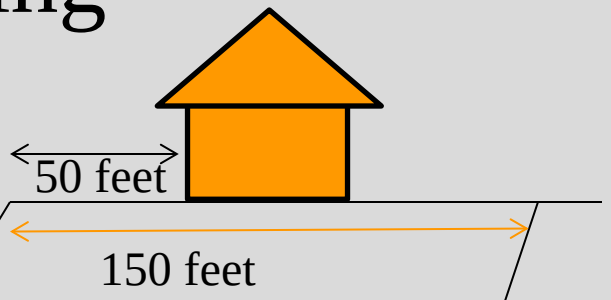
Buyer Beware!



Implications for Land Use Planning

Avg. Rec. Rate 1.5 ft/yr *100 years=150 feet

Avg.+ 1 S.D. Rate 2.0 ft/yr *100 years=200 feet



Or….

50 ft./1.5 ft/yr=33 yrs.

50 ft./2.0 ft/yr=25 yrs.

Standard Setback from Marine Bluffs in Clallam County Title 27.12.415

Managed Retreat



3/2014



10/2014

Abandonment

Gehrke Road 11/2014





Dungeness Bluffs Cabin Removal


Photo: Jamie Michel


Photo: Jamie Michel


Photo: Jamie Michel

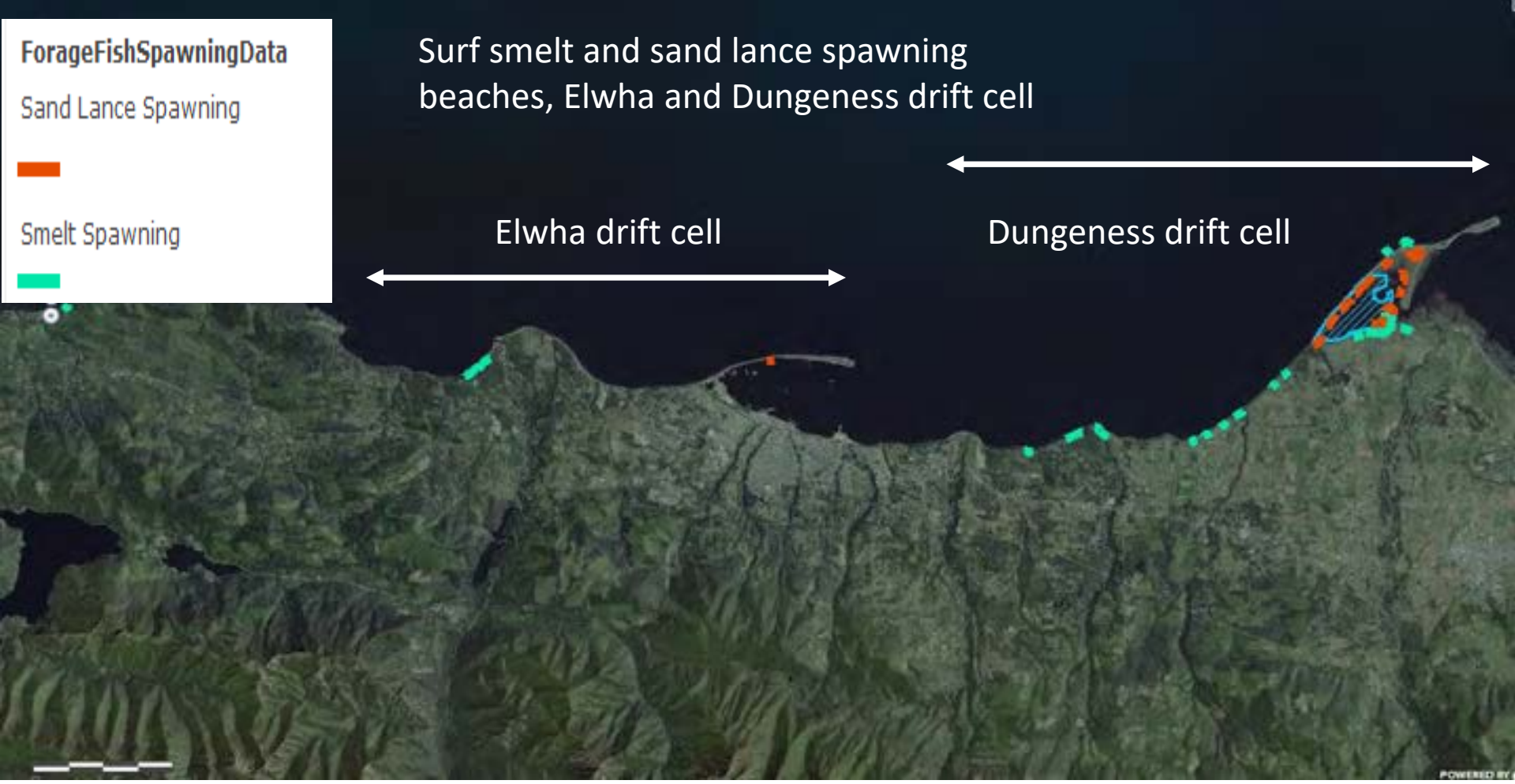
Shoreline Armoring Negatively Affects Forage Fish Spawning Habitat Suitability (Parks et al., 2013).

Elwha Armored



Dungeness Unarmored





* Beach area calculated assuming a 20 foot wide beach

Data source: WDFW http://bit.ly/16eBpJh

Species	Drift cell	Drift cell length (miles)	Total spawning area (square feet)*
Surf smelt	Dungeness	8	404,040
	Elwha	6	66,700
Sand lance			
	Dungeness	8	240,000
	Elwha	6	20,000

Shoreline Armoring Alters Shoreline Processes and Functions
Dethier et al., 2016

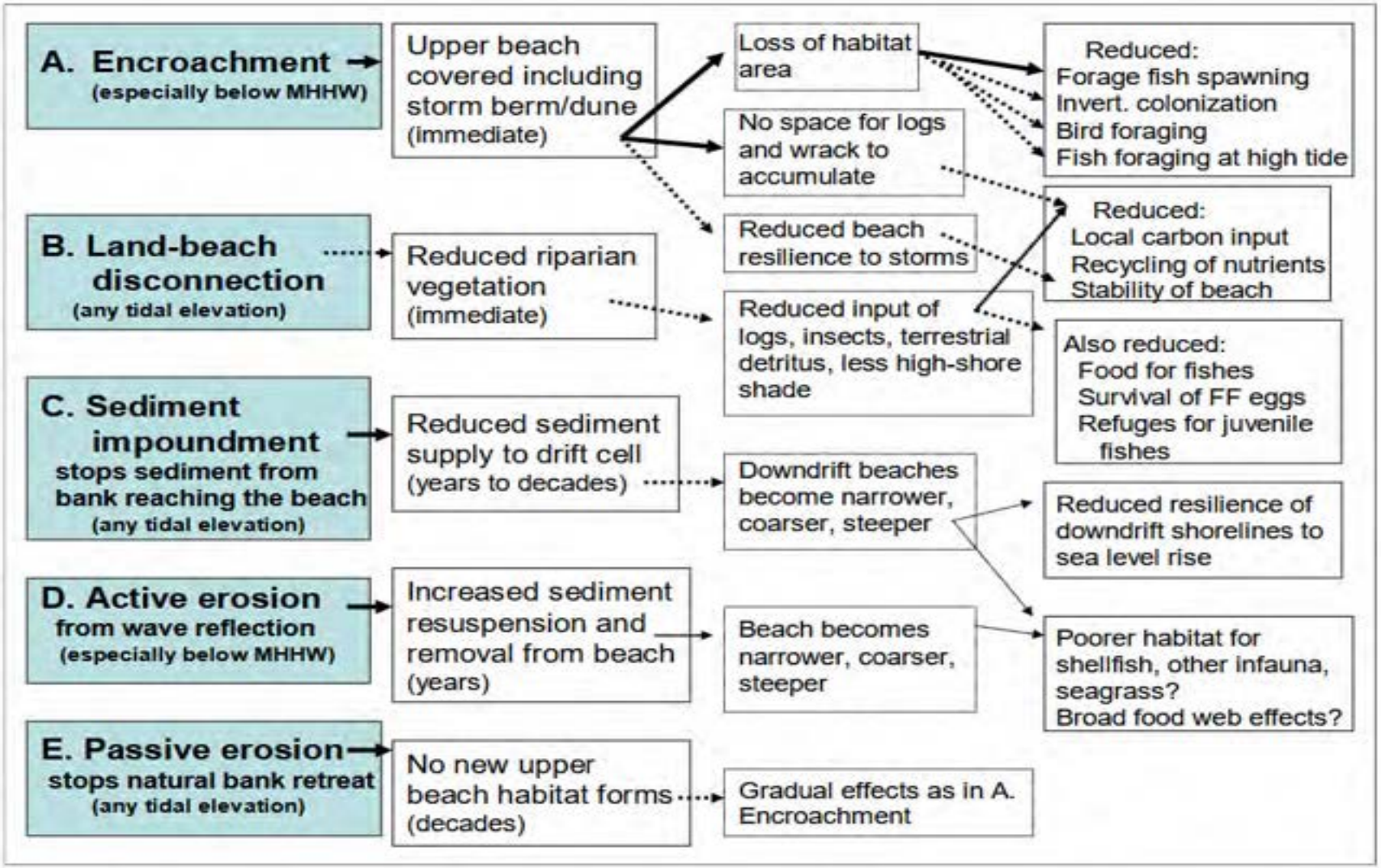


Figure 1. Five mechanisms by which armoring could alter shoreline processes and functions, and their ultimate impacts on nearshore biota. MHHW = mean higher high water. Linkages that are more certain (for Puget Sound) are shown with more solid arrows.

2026 El Nino Record Tides

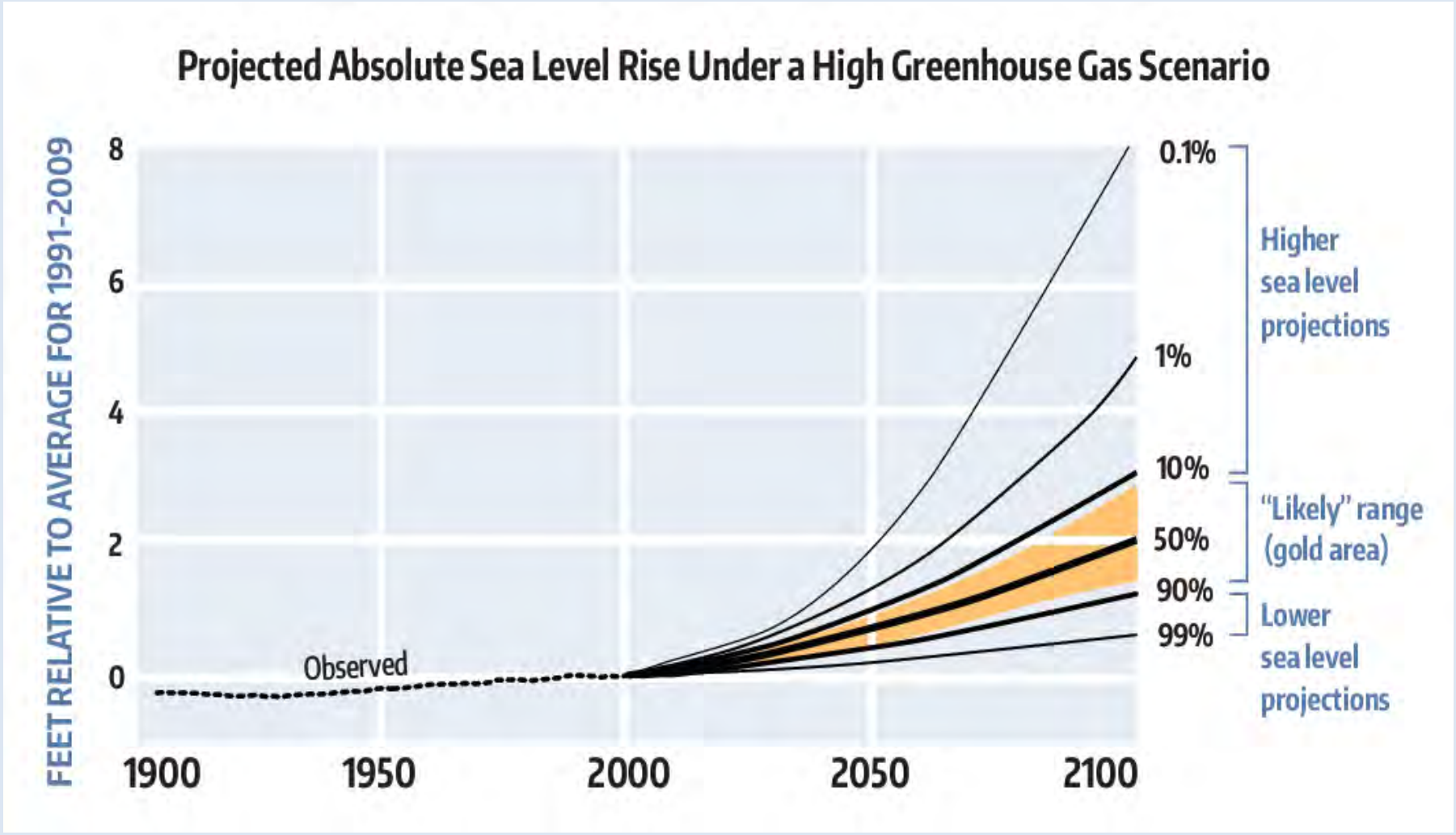


Southern California, October 13, 2026
The Gaurdian.



San Francisco Bay (Marin County) Oct. 29, 2026.
The Gaurdian

Sea Level Rise Scenarios



Miller, et al., 2018. Projected Sea Level Rise for Washington State (WA Sea Grant)

USGS Bluff Model Framework

Bluff recession model accounting for coastal processes and bluff geology (Grossman et al., 2026a)



CoNED topo-bathymetry (Tyler et al., 2020); CFDT (Seymour et al, 2020)

Bluff crest/toe position (MacLennan et al., 2018; Grossman et al., 2026)

Geology (WDNR); cohesion (Badger & D'Ignazio 2018; GeoEngineers 2009, 2013; Harp et al., 2006; Koloski et al., 1989; Savage et al., 2000; WSDOT, 2013)

Tide, surge, waves (NARR, ERA5) (Grossman et al., 2023; Crosby et al., 2023; Parker et al., 2026)

Historical

Future

Tide, surge, waves (Δ CMIP6) (Parker et al., 2026)

Sea Level Rise (cm)
025, 050, 100, 150, 200, 300

Historical bluff recession rates (MacLennan et al. 2018) (site specific)

Validation

Bluff model

Projections

Regional Erosion Rates

Historical (1940-2022)

Multivariate Regression

Future (2020-2100)

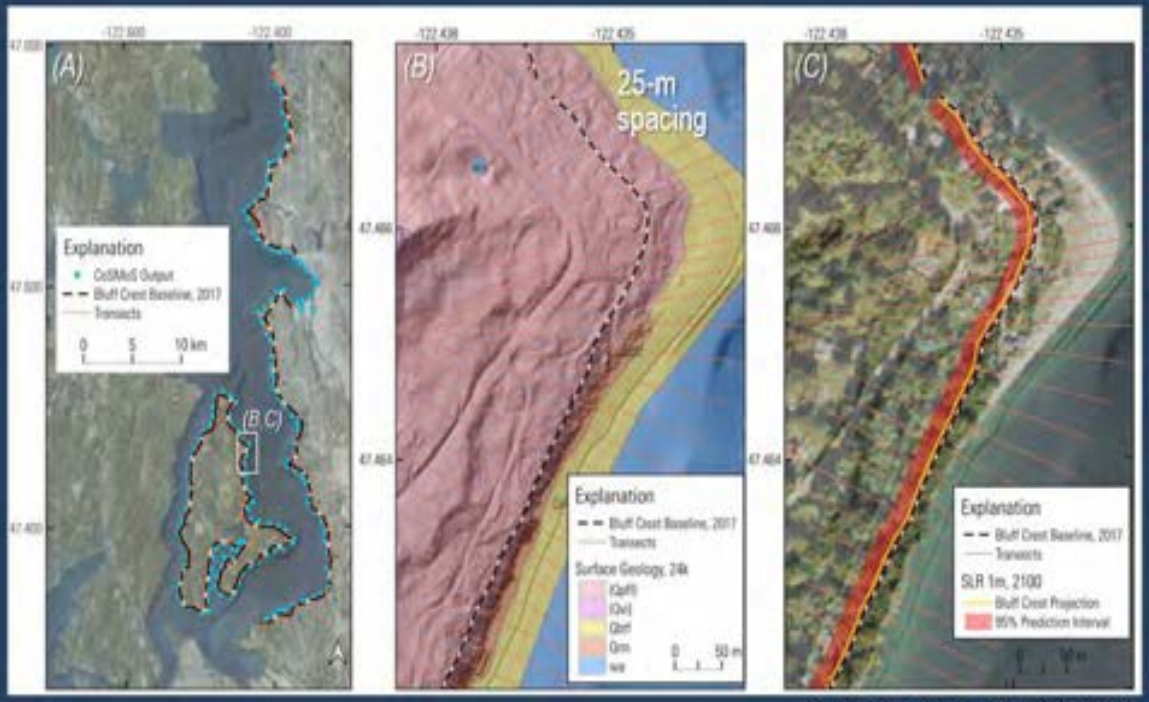
Ensemble Mean of Multivariate Regression, Bruun, Total Water Level, Hackney formulations after Limber et al (2018)

Bluff Model Configuration

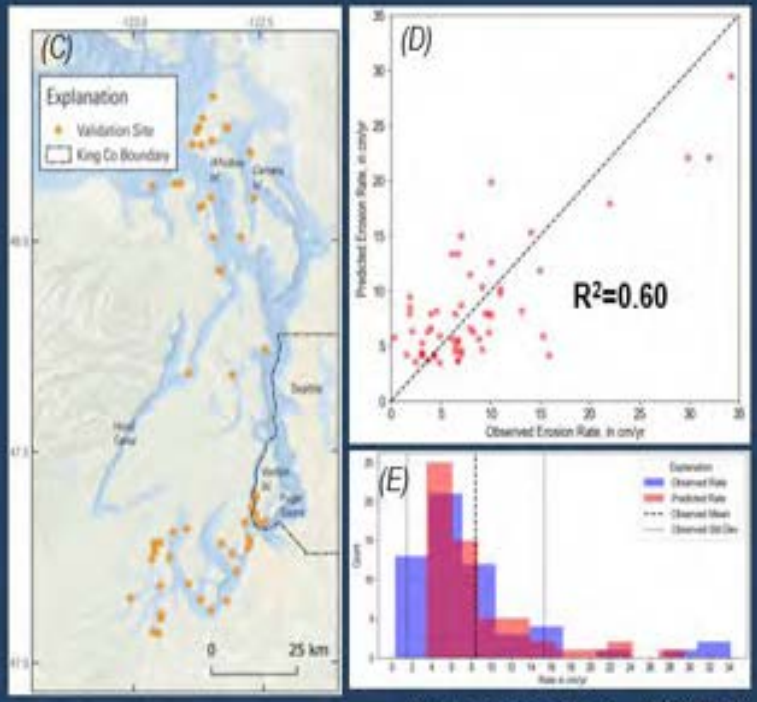
USGS

Attribute model with elevation, bluff crest/toe, geology, water level anomaly normalized by tide range and cumulative wave power.
Compute ensemble weighted mean of four shoreline change models with 1000-bootstrapped uncertainty analyses
Next step to include effects of rainfall intensity/duration

- Explains 60% of historical variability in recession rate
- Accounts for water levels, wave energy, and bluff geology



Grossman et al., (2026b)



Grossman et al., (2026a)

Clallam County Scheduled for February, 2027.

Summary

- Landowners of bluff top properties should plan for retreat now.
- County Land Use Codes should be updated to reflect maximum bluff recession rates (e.g., larger buffers).
- Bluff parcels should be prioritized for conservation easements or purchase.
- Conservation is more cost effective than mitigation.





Thank You!



