

Shoreline Processes

- Tides
 - Independent of weather
- Storm surge
 - Wind-induced water level rise

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Shoreline Processes

- Wave action
 - Waves are created by wind over water
 - Height varies with wind speed, fetch, and duration
 - Waves breaking obliquely against the shore cause longshore sediment transport

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Shoreline Processes

- Wave-induced "littoral" sediment transport
 - Occurs mainly in surf (littoral) zone
 - Longshore transport induced by oblique waves
 - Offshore transport induced by storm waves
 - Onshore transport induced by mild waves

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Arctic Coastal Processes

- Undercutting of glacially deposited bluffs
- Thermal erosion of permafrost bluffs
- Thaw subsidence of permafrost shores

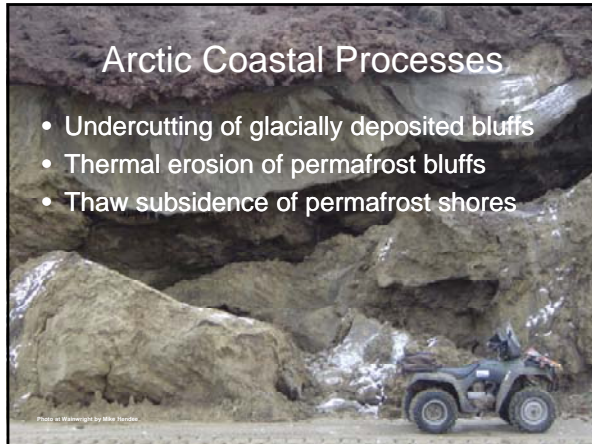



Photo by Waterlight by Mike Tondra

Coastal Erosion

Coastal erosion is a natural dynamic process, mainly caused by

- Storm waves and surges (rapid and dramatic)
- Natural changes to tidal inlets, river mouths, and entrances to bays
 - migration or fluctuation of channels and shoals
 - interruption of longshore sediment transport
- Manmade structures and human activities
 - shore protection structures
 - damming of rivers (trapping sediment)
 - dredging, mining sand from beaches and dunes
 - alteration of vegetation, surface or groundwater drainage at coastal bluffs
 - local scour around structural elements
 - such as pilings and abutments
- Long-term erosion occurs over decades from cumulative effects due to:
 - sea level rise
 - depletion of sediment supply
 - factors mentioned above



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Parameters of Coastal Flooding and Related Hazards

- origin of flooding
- flood frequency
- flood depth
- flood velocity
- flood direction
- flood duration
- wave effects
- erosion and scour
- sediment over-wash
- Flood-borne debris

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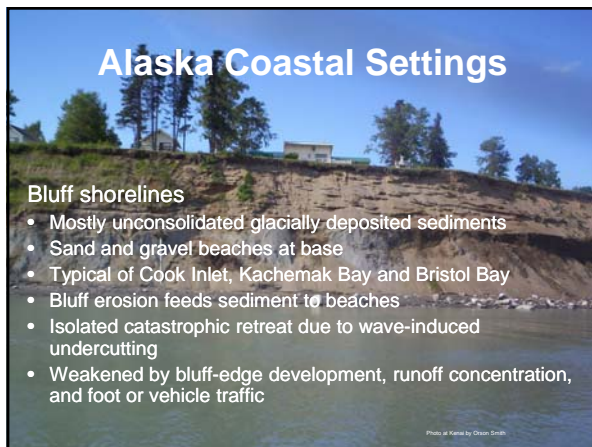
Alaska Coastal Settings



Fjords and rock promontories

- Primarily in Southeast and Southcentral Alaska
- Steep pocket beaches of sand and pebbles
- Subject to high tidal range
- Respond mainly to storms
- Comparatively slow erosion rates

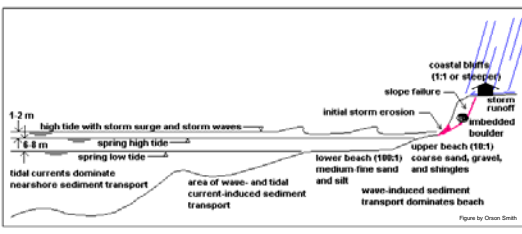
Alaska Coastal Settings



Bluff shorelines

- Mostly unconsolidated glacially deposited sediments
- Sand and gravel beaches at base
- Typical of Cook Inlet, Kachemak Bay and Bristol Bay
- Bluff erosion feeds sediment to beaches
- Isolated catastrophic retreat due to wave-induced undercutting
- Weakened by bluff-edge development, runoff concentration, and foot or vehicle traffic

Cook Inlet Bluff Erosion



The diagram illustrates the cross-section of a bluff and beach system. Key features include:

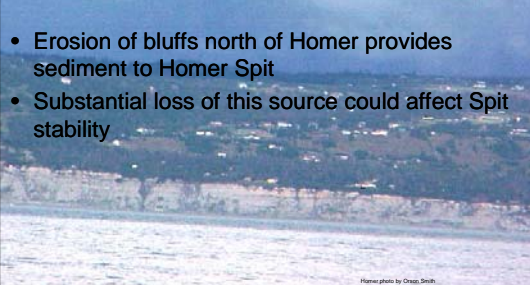
- Bluff Profile:** A steep bluff with a "coastal bluff (1:1 or steeper)" slope. A "slope failure" is indicated at the top. "storm runoff" is shown as blue arrows hitting the bluff.
- Tide Levels:** "1.2 m high tide with storm surge and storm waves" is shown at the top. "spring high tide" and "spring low tide" are marked with horizontal lines.
- Beach Profile:** The beach is divided into a "lower beach (10:1) coarse sand, gravel, and silt" and an "upper beach (10:1) coarse sand, gravel, and shingles". An "embedded boulder" is shown in the upper beach.
- Erosion and Transport:** "initial storm erosion" is shown at the base of the bluff. "nearshore sediment transport" is indicated by arrows near the water's edge. "area of wave- and tidal current-induced sediment transport" is shown in the water. "wave-induced sediment transport dominates beach" is noted at the base of the beach.

Figure by Orson Smith

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Alaska Coastal Settings

- Erosion of bluffs north of Homer provides sediment to Homer Spit
- Substantial loss of this source could affect Spit stability



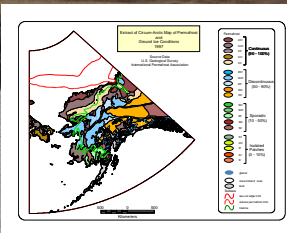
Homer photo by Orson Smith

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Alaska Coastal Settings

Permafrost shorelines

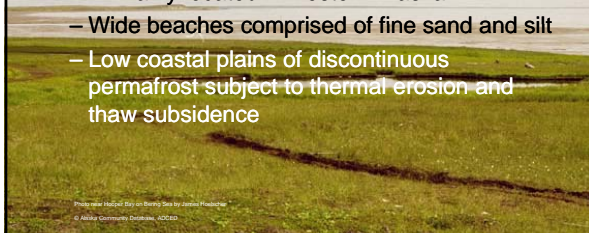
- Northwestern and Arctic Alaska
- Low tide range
- Narrow sand and gravel beaches at base of low bluffs
- Permafrost of ice, organics, and fine-grained sediments
- Subject to thermal erosion
- Most eroded matter lost with little contribution to beaches
- Dramatic erosion during late summer and early fall storms



Photos on Bering Lagoon near Barrow by Orson Smith; map by USGS

Alaska Coastal Settings

- Deltaic shorelines composed of fine-grained sediments covered with tundra
 - Primarily located in western Alaska
 - Wide beaches comprised of fine sand and silt
 - Low coastal plains of discontinuous permafrost subject to thermal erosion and thaw subsidence



Photograph: Richard Dill; map: Orson Smith; map by Orson Smith
© Alaska Communities Database, ACDDB

High Winds on the Alaska Coast

- Values are nominal design 3-second gust wind speeds in miles per hour
- Mountainous terrain, gorges, ocean promontories, and special wind regions may have unusual localized wind conditions

From Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers, (ASCE 1998)

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Tsunamis on the Alaska Coast

KEY
Tsunami Elevations (ft NGVD)

- > 30 ft
- 15 - 30 ft
- 5 - 15 ft
- 0 - 5 ft

From FEMA Coastal Construction Manual (2000)

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Sea Ice

1 - 15 February

From Cook Inlet Marine Ice Atlas

- Variable conditions from year to year
- Long-term reduction in duration, extent, and thickness
- Seldom causes coastal erosion

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Coastal Climate Change in Alaska

- Little or No Sea Level Rise
 - Most of Southeast and Southcentral Alaska shores have net drop in sea level due to ongoing glacial rebound
- Changes in frequency, intensity, & tracking of storms
 - No Alaska trends apparent to date
- Increased winter rain and runoff on unfrozen ground
 - Changes in coastal sediment budgets
- Reduced winter sea ice cover
 - More wave energy reaching the shore
 - Confirmed on Beaufort Sea coast of Alaska
- Melting permafrost and coastal thaw subsidence

Prudhoe Bay photo by Orson Smith

Evaluate before you buy

- Property location
 - City, borough jurisdictions
 - Special zoning, set-backs, building or land use restrictions
 - Hazard area designations
 - Natural resource protection areas

Prudhoe Bay photo by Orson Smith

Evaluate before you buy

- Geometry of property
 - Property shape and acreage
 - Shoreline frontage distance
 - Seaward boundary (MHW or other datum)
 - Depth of property perpendicular to shoreline
 - Useable acreage outside of natural or regulatory restrictions
 - Geometry of adjacent property

(after FEMA Coastal Construction Manual)
Prudhoe Bay photo by Orson Smith

Evaluate before you buy

- Physical and natural characteristics
 - Geology, soils, and vegetation
 - Topography (elevations and slopes of beach, dunes, bluff, uplands)
 - Site drainage (surface and ground water)
 - Littoral sediment source and transport rate
 - Storm flooding and erosion history
 - Existing erosion control structures (type, age, condition, history)
 - Proximity to inlets or river mouths
 - Sea level change (net, including seismic uplift or settlement)

(after FEMA Coastal Construction Manual)

US Army Corps of Engineers photo

Evaluate before you buy

- Applicable regulations
 - Building codes and related restrictions
 - Flood hazard elevation and construction requirements
 - Erosion-related construction setbacks and restrictions
 - Hazard disclosure requirements for property transfer
 - Subdivision covenants, easements and rights-of-way
 - Local, State, and federal permitting requirements
 - Riparian (stream bank or seashore) rights
 - Habitat for endangered, depleted or sensitive species

(after FEMA Coastal Construction Manual)

Photo by Orson Smith

Consider Erosion before Building

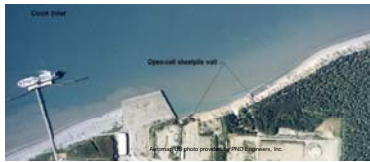
Proper planning, siting, and design of coastal residential buildings require:

1. basic awareness of erosion processes,
2. erosion rate information,
3. appreciation for uncertainty in prediction of future shoreline positions, and
4. knowing buildings landward of a setback line are not guaranteed safe from erosion.

Karek photo by Orson Smith

Evaluating Erosion Risk

1. Define landward shoreline location expected during life of building
2. Define lowest expected ground elevation during life of building
3. Define highest expected Base Flood Elevation during life of building



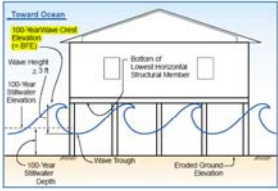
Erosion is usually expressed as a rate, in terms of:

- Linear retreat (e.g., ft shoreline recession per yr) or
- Volumetric loss (e.g., cubic yards eroded sediment per ft of shoreline frontage per yr)

Topographic and hydrographic site surveys and study of historical aerial photographs are useful to determine these parameters

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FEMA V-zone requirements



In Coastal High Hazard Areas (V-zones), buildings must be elevated on an open foundation (e.g., pilings, posts, piers, or columns) so that the bottom of the lowest horizontal structural member is at or above the Base Flood Elevation (BFE).

From FEMA Coastal Construction Manual (2000)

“...A registered engineer or architect must develop or review the structural design, construction specifications, and plans for construction and must certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the building elevation and foundation design standards described above...”

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More FEMA Guidelines


All newly constructed buildings must be located landward of the reach of mean high tide (i.e., the mean high water line). In addition, manmade alterations of sand dunes or mangrove stands are prohibited if those alterations would increase potential flood damage. Removing sand or vegetation from, or otherwise altering, a sand dune or removing mangroves may increase potential flood damage; therefore, such actions must not be carried out without the prior approval of a local official.

From FEMA Coastal Construction Manual (2000)

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Retreat

- Move (or demolish and rebuild) infrastructure inland
- Pros
 - Favors natural coastal environment
 - Prevents future economic loss
- Cons
 - Difficult to predict future erosion rates



Kiritshov photo © Alaska Community Database, ACDDB

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Reasons for Shore Protection


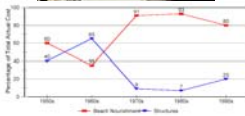
- Prevent damage to property from
 - Coastal floods and salt-water intrusion
 - Waves and wave runup
 - Coastal erosion
- Prevent retreat of shoreline
- Preserve beaches
- Preserve coastal habitat

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Non-Structural Responses

Beach nourishment

- Place fill material typical of natural shore
 - Dune, beach, and submerged profiles
 - Offshore mounds
 - Up-drift feeder beaches
- Most popular solution in lower 48


Graph provided by Dr. David Hughes, US Army Corps of Engineers

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Non-structural Responses

Vegetation

- Effective against wind and runoff erosion on mild slopes
- May survive brief inundation and modest currents
- Long lead time for vegetation to become established
 - Vegetation grows slowly in Alaska's climate
- Usually ineffective against direct ocean wave exposure
 - Best as supplement to seaward shore protection



US Army Corps of Engineers photo

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Shore Protection Structures

- **Revetments**
 - Good method for dissipating wave energy
 - Requires quarrystone, concrete shapes, articulated mats, or other heavy interlocking armor
 - Requires toe protection and splash apron to prevent failure
- **Seawalls**
 - Massive monolithic vertical structures comprised of concrete or stone masonry
 - Need solid foundation base
- **Bulkheads (often also called "seawalls")**
 - Most commonly are steel sheetpile retaining walls
 - Increase reflective wave energy
 - Require toe protection to prevent scour

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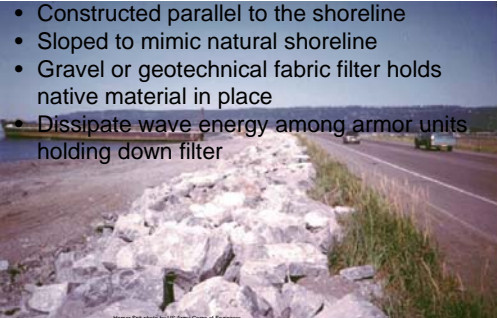
Shore Protection Structures

- **Offshore Breakwaters**
 - Constructed offshore to dissipate incoming wave energy.
 - Requires resilient material (rock or concrete).
 - May accelerate erosion at margins.
- **Beach Groins**
 - Constructed perpendicular to shore to trap sediment moving longshore.
 - Affects material transport
 - Accretes sediment on up-drift side
 - starves areas immediately down-drift

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Revetments

- Constructed parallel to the shoreline
- Sloped to mimic natural shoreline
- Gravel or geotechnical fabric filter holds native material in place
- Dissipate wave energy among armor units holding down filter




Orson Smith photo by US Army Corps of Engineers
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Seawall and Bulkheads

Seawalls


- vertical structures
- parallel to shoreline
- designed to prevent erosion, wave damage, and flooding



US Army Corps of Engineers photo

Bulkheads (also called "seawalls")

- vertical structures parallel to shore
- often steel sheetpile
- retain fill behind
- protect upland areas from wave damage and flooding




02/21/2005
Homer photo by Orson Smith

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Levees and Dikes

- Mounded structures parallel to shore
- Usually made of clay and other natural fill material
- built around low lying areas to prevent flooding
- Often have seaward toe and lower slope protected with a revetment
- Vegetation of upper slope and crest is common




US Army Corps of Engineers photo

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Beach Groins




Nisibak photo by Orson Smith
US Army Corps of Engineers photo

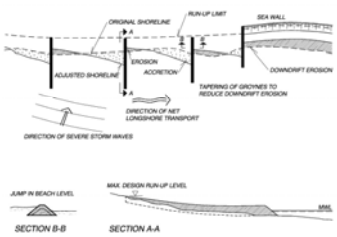
- Constructed perpendicular to the shoreline
- create or widen beaches by capturing sand moving longshore

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Beach Groins




US Army Corps of Engineers photo



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Beach Groins

- **Materials**
 - Stone
 - Concrete
 - Timber
 - Steel sheetpile
 - Geotextile tubes
- **Design Considerations**
 - Functional
 - Crest elevation, groin length, groin spacing, orientation
 - Wave diffraction, overtopping, and transmission
 - Structural
 - Armor stability
 - Foundation
 - Toe scour
 - Flanking
 - Potential impacts
 - Nearshore habitat
 - Adjacent shoreline



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Beach Groin Design

From USACE, Coastal Engineering Manual

- Beach nourishment should be incorporated
 - Plan for renourishment
- Choose dry beach width for effective shore protection
- Taper offshore ends to reduce impacts to adjacent shores
- Monitor performance
 - Periodic inspections, photographs, and surveys

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Offshore Breakwaters

- constructed seaward of and usually parallel to the shoreline
- break incoming waves before they reach the shore

US Army Corps of Engineers photo

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Offshore Breakwaters

US Army Corps of Engineers photo

Materials

- Stone
- Concrete
- Geotextile tubes

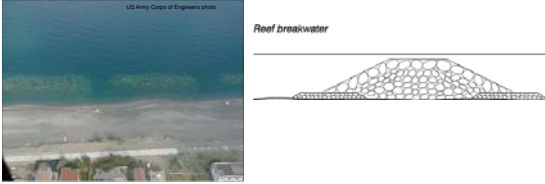
Design Considerations

- Functional
 - Crest elevation, gap width, distance offshore, orientation
 - Wave diffraction, overtopping, and transmission
- Structural
 - Armor stability
 - Foundation
 - Toe scour
- Potential impacts
 - Nearshore habitat
 - Adjacent shoreline

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Reef Breakwaters

- Offshore breakwaters with submerged crests
- Same considerations apply

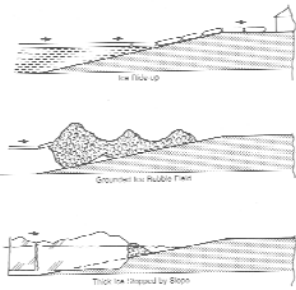


US Army Corps of Engineers photo

Reef breakwater

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Arctic Considerations



Ice Ride-up

Grounded Ice Rubble Field

Traps ice stripped by Storm

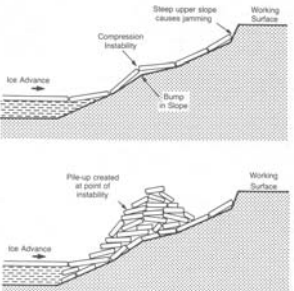
Ice Ride-up and Pile-up

- Generally thin ice on a shallow slope leads to *ride-up*
- Ice fails in bending
- Greater slope angles result in pile-up formation or grounded rubble fields

From ACEC Monograph 'Arctic Coastal Processes and Shore Protection Design'

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Arctic Considerations



Steep upper slope causes jamming

Working Surface

Compression Instability

Bump in Slope

Ice Advance

Pile-up created at point of instability

Working Surface

Ice Advance

Beach profile to reduce ride-up

- Changes in bank slope induce pile-up
- Ice rubble piles provide shore protection
- Arctic artificial islands often include a convex bank area to encourage ice rubble pile-up development


From ACEC Monograph 'Arctic Coastal Processes and Shore Protection Design'

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Arctic Considerations

Freeze/Thaw Processes


- Rock, concrete and other materials can fail from freezing of internal moisture
- Winter construction can introduce ice in fill that will thaw and subside in summer



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Questions or Comments?



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