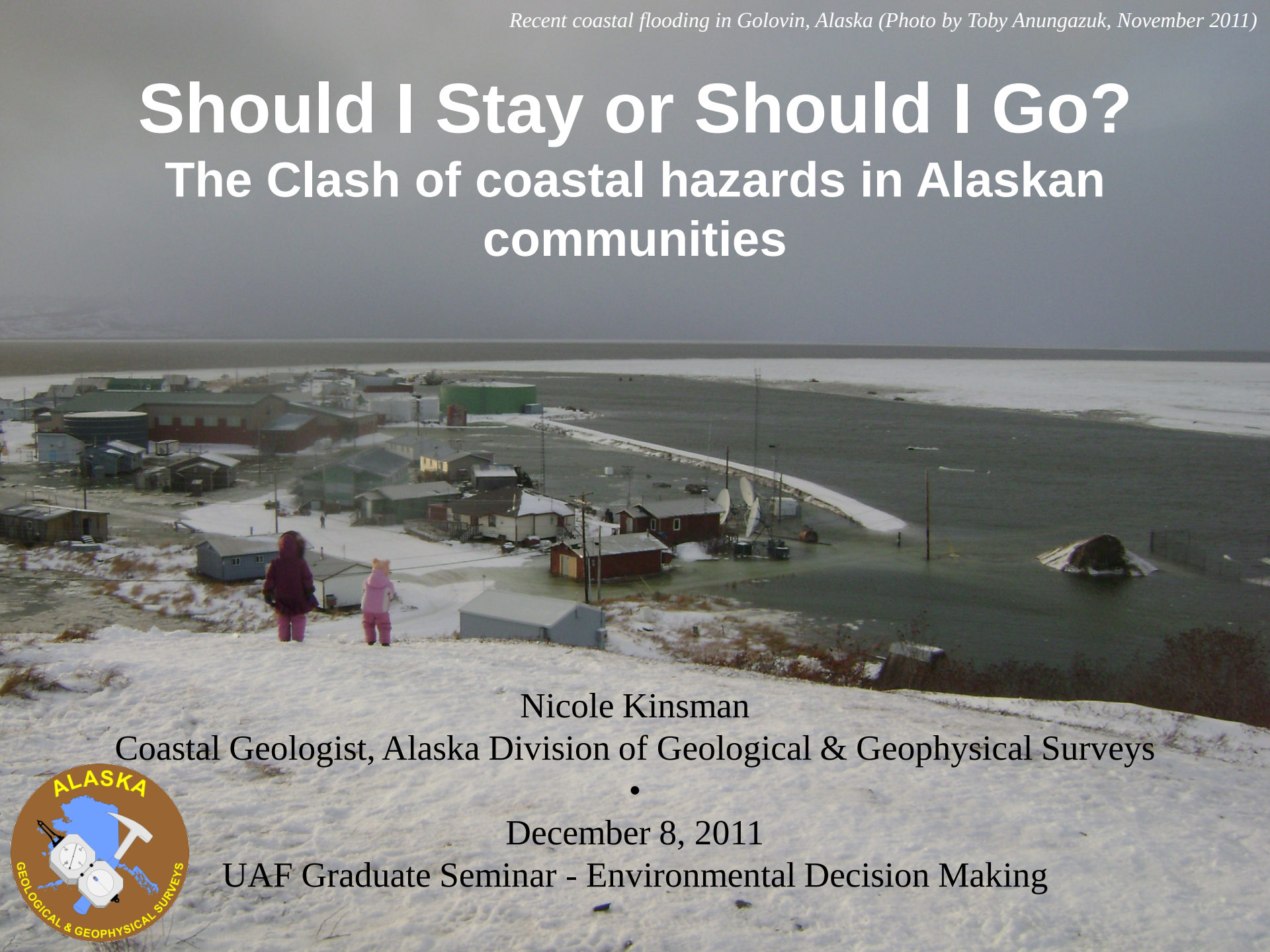


Recent coastal flooding in Golovin, Alaska (Photo by Toby Anungazuk, November 2011)

Should I Stay or Should I Go?

The Clash of coastal hazards in Alaskan communities

Nicole Kinsman

Coastal Geologist, Alaska Division of Geological & Geophysical Surveys

•

December 8, 2011

UAF Graduate Seminar - Environmental Decision Making

Overview of today's talk:

Coastal process intro

Monitoring

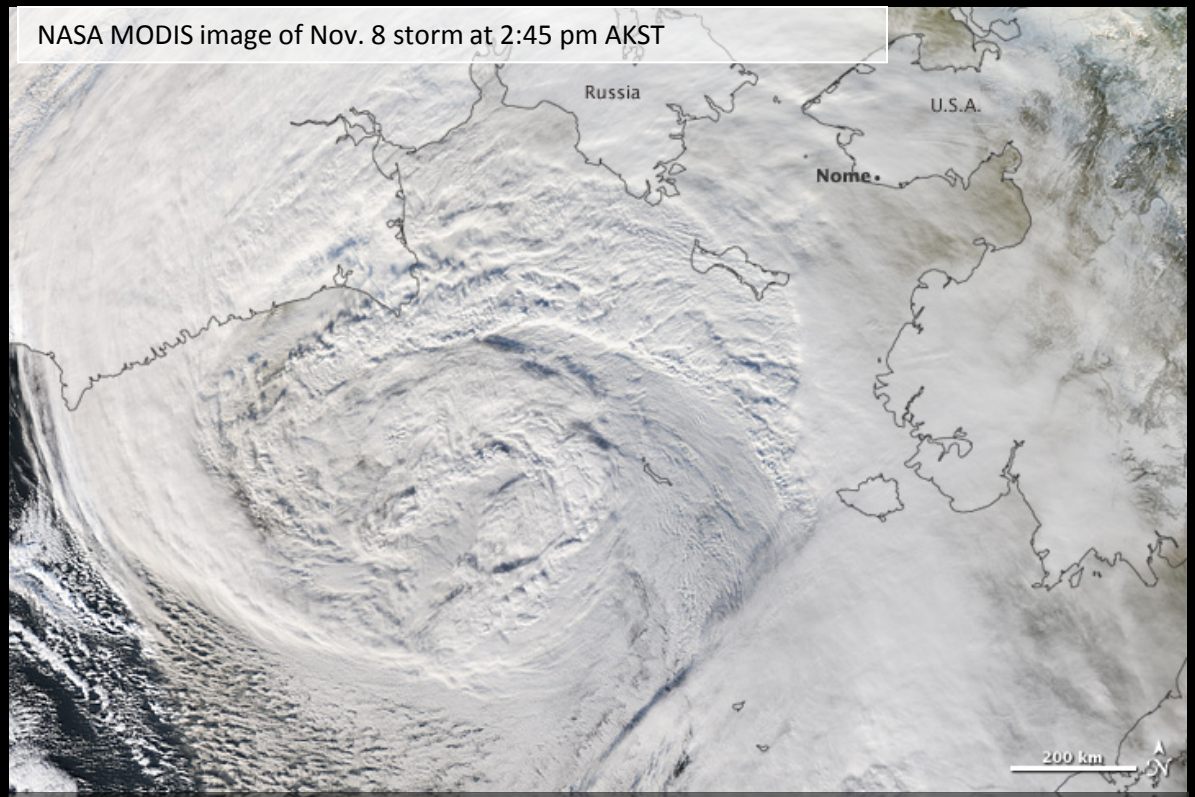
Mapping

Mitigation

Coastal hazards in Alaska

What are

COASTAL HAZARDS?



NASA MODIS image of Nov. 8 storm at 2:45 pm AKST

Coastal Hazard List

- Beach erosion
- Landslides
- Wave attack
- Storm surge
- Cyclones (& hurricanes)
- Tsunami
- Relative sea level rise (inundation & salination)
- Ice push (ivu)
- Salt spray

Coastal ~~Hazard~~ Process List

- Beach erosion
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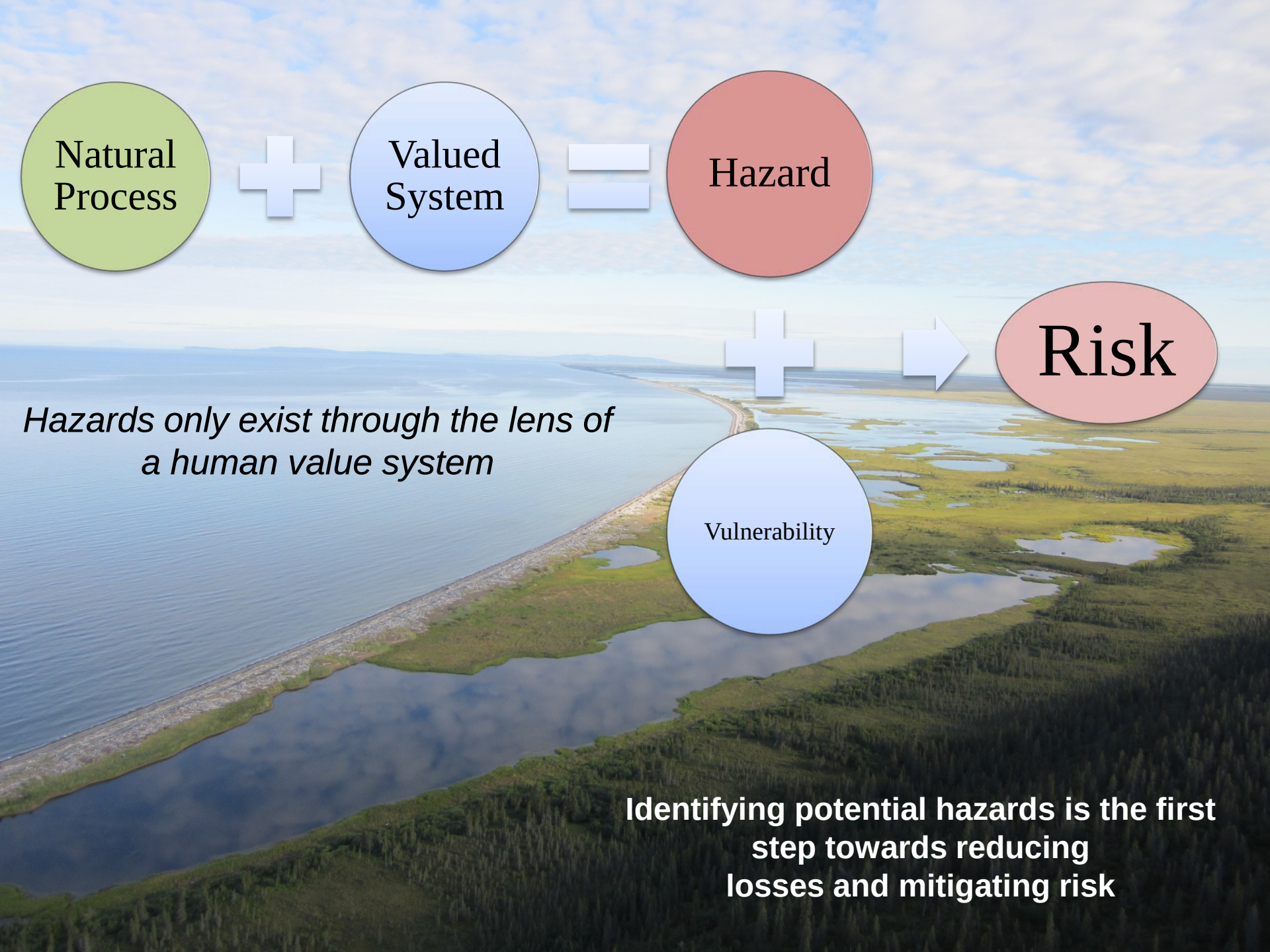
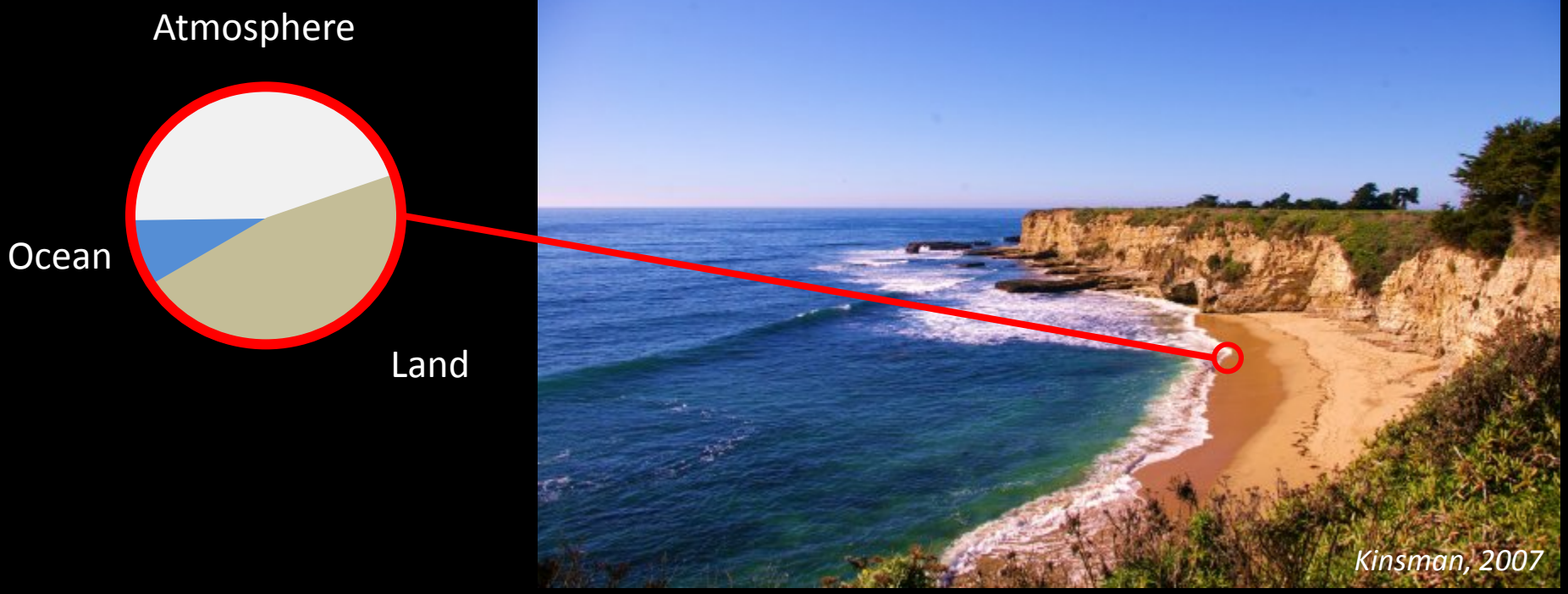
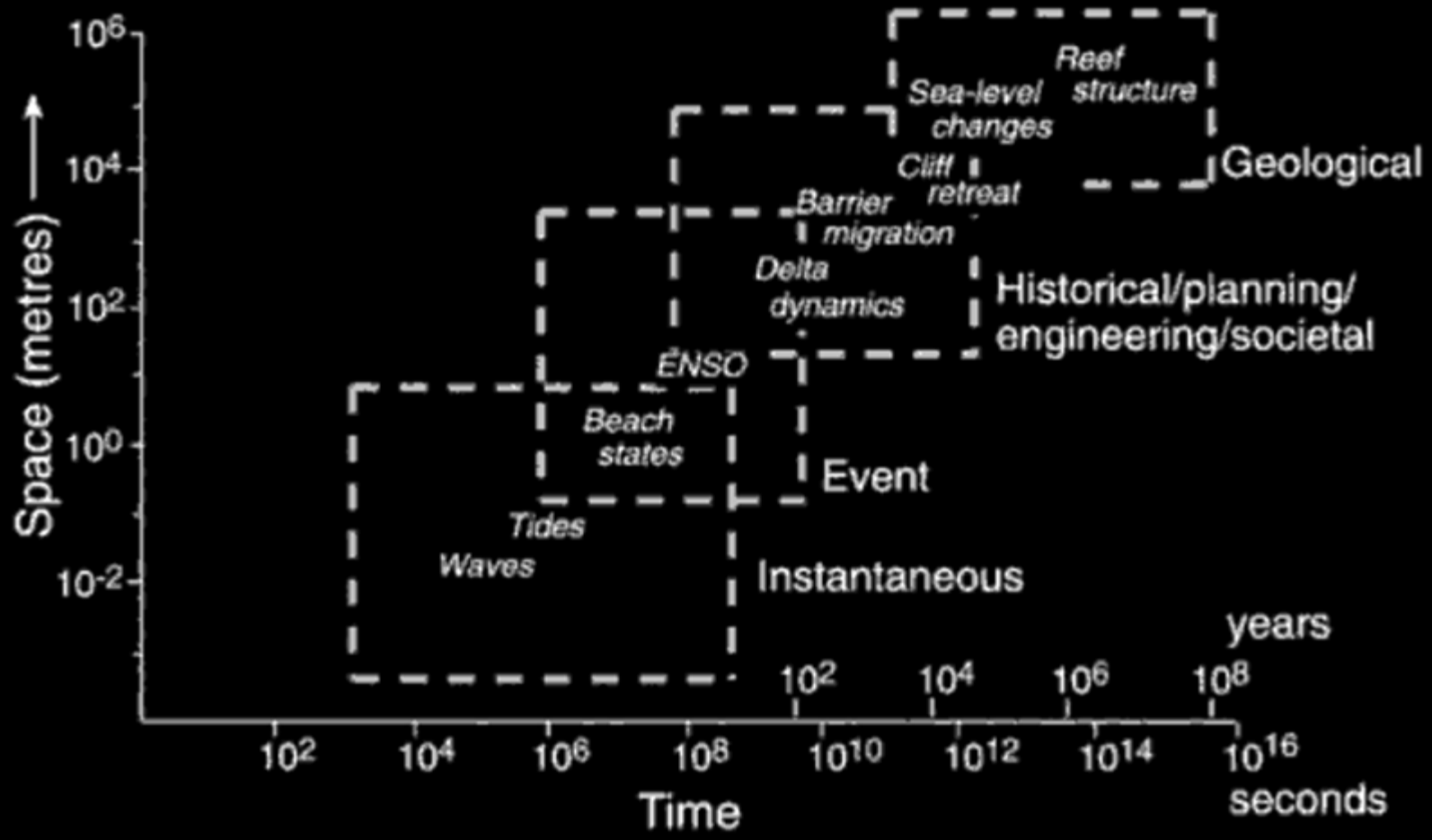

Natural Process
Valued System
Hazard
Risk
Vulnerability
Hazards only exist through the lens of a human value system
Identifying potential hazards is the first step towards reducing losses and mitigating risk

“The Triple Junction”



The concept of dynamic equilibrium shapes all coastlines

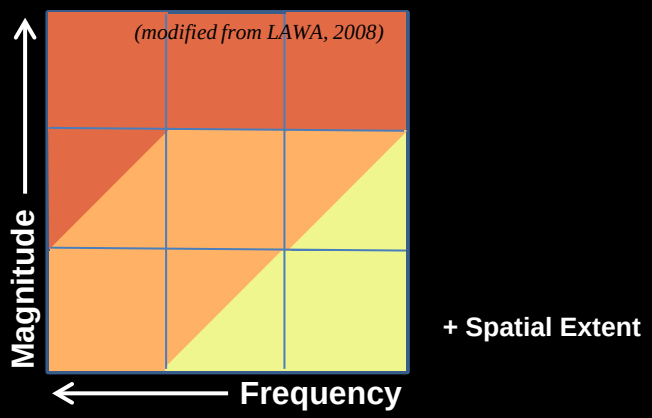
Coastal Process Timescales



Woodroffe, 2002

Coastal Hazard Timescales

Hazard Classification

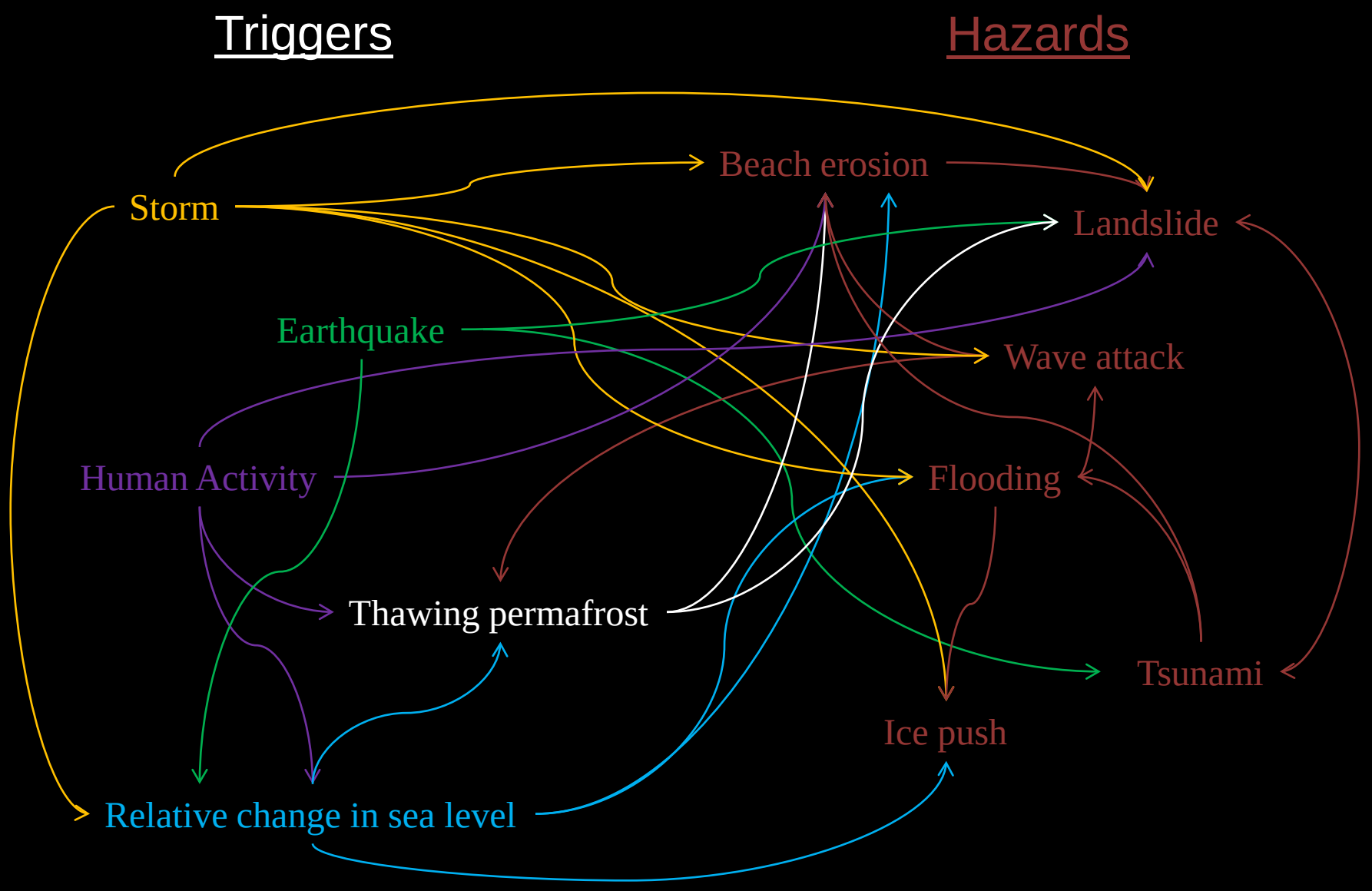


Catastrophic
- Storm Surge
- Tsunami

vs.

Gradual
- Permafrost melt
- Gravel mining
- ATV use on dunes

Coastal Hazards are Interconnected



EROSION

The primary mechanism of erosion in the coastal zone is wave action

Beaches undergo cyclic patterns of erosion and accretion

Coastal erosion is highly episodic

Erosion of bluffs and cliffs is irreversible on a human timescale

This coastal hazard can be most directly linked with human actions

- Beach mining
- Vegetation removal
- Altered sediment sources
- Blocked sediment paths

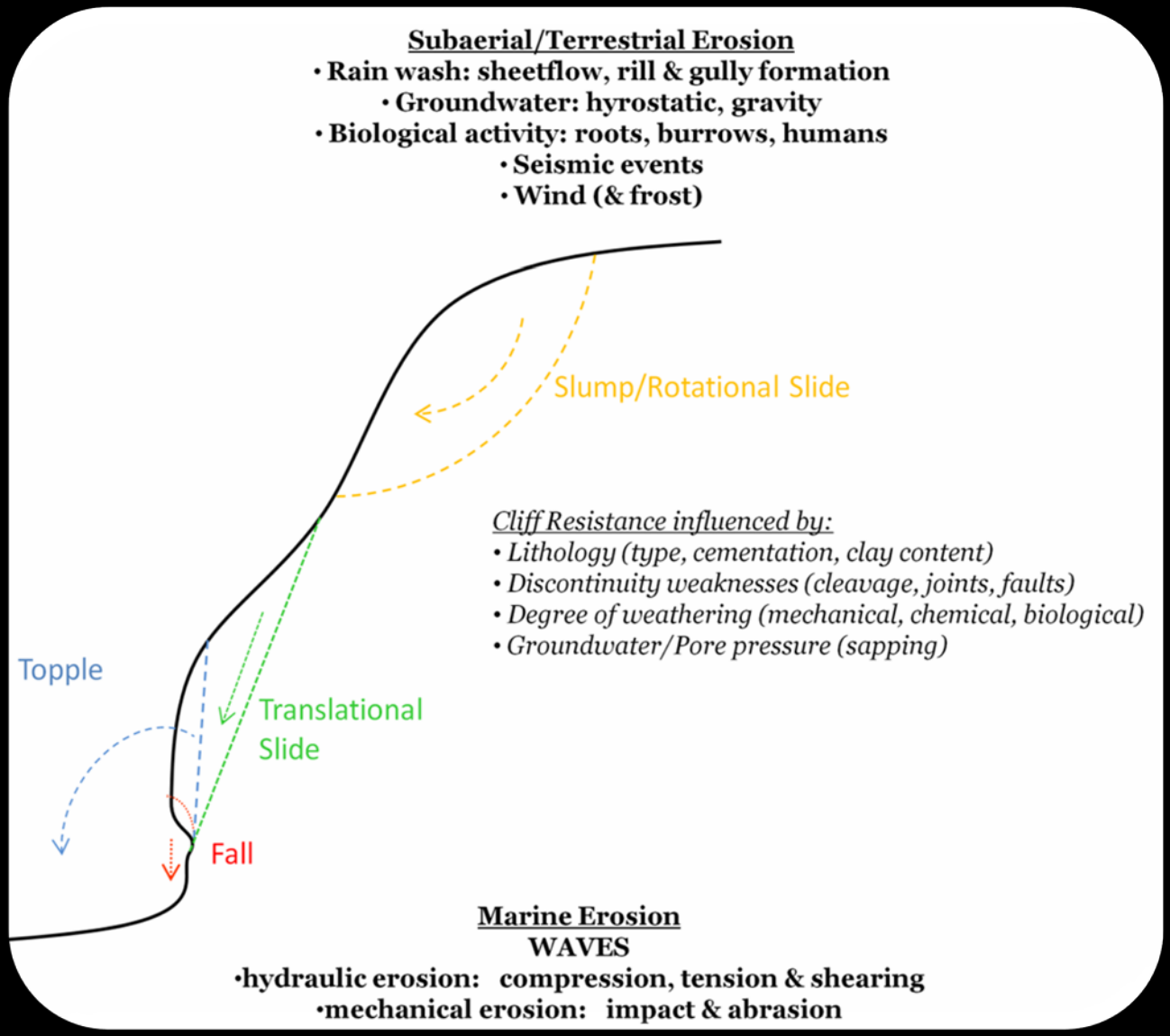
Reversible

Irreversible

LANDSLIDES & SLOPE FAILURE

Bluff Failure
Kivalina,

Slumping Bluff
South of Unalakleet



ARCTIC BLUFF EROSION

Thermal erosion – warm sea water against permafrost rich bluffs

Bluffs on North Slope = 50-70% ice

Characterized by catastrophic failures

Average retreat rates can be >10 m/yr

USGS on North Slope (Erikson et al., 2008)

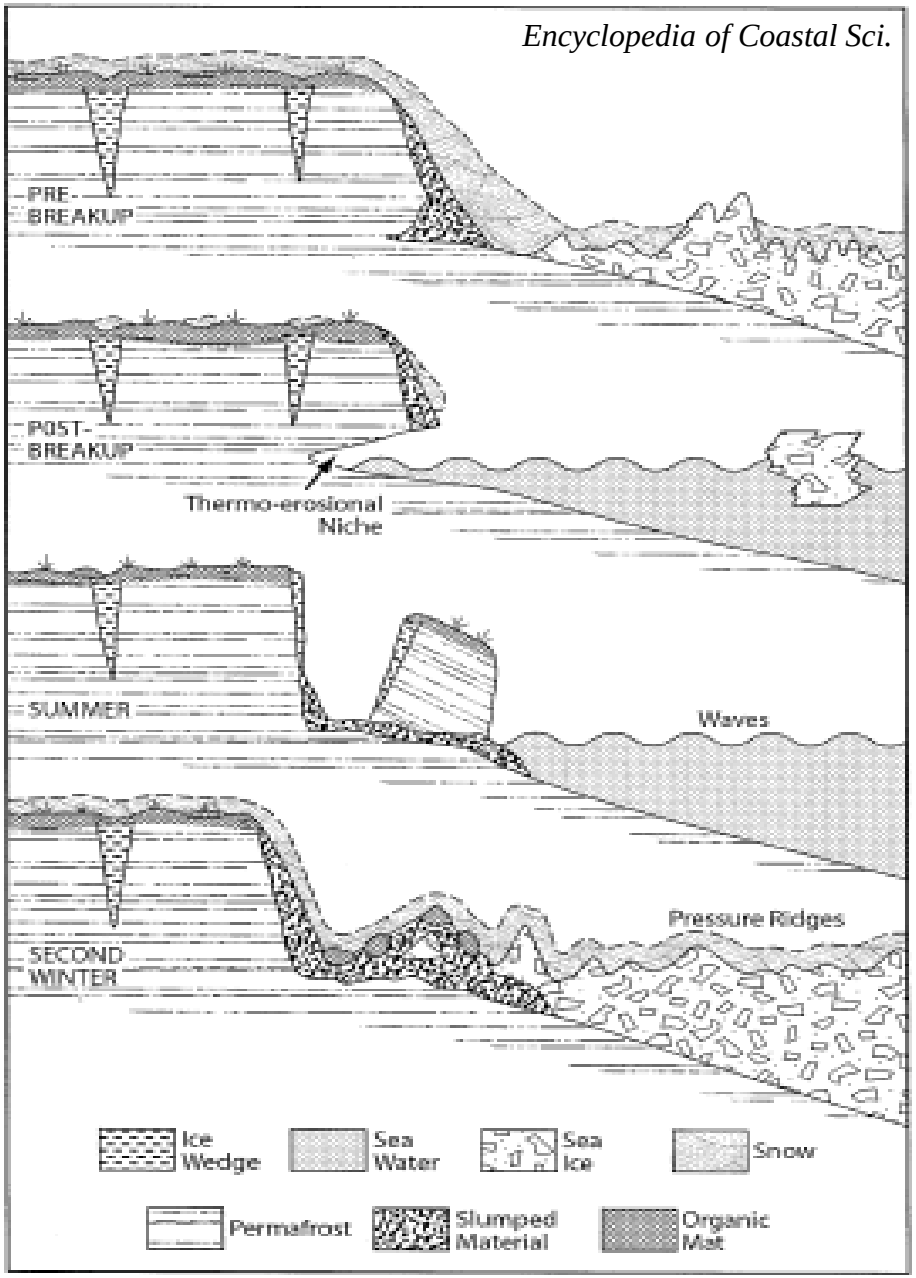


Figure A32 Block collapse and erosion along permafrost coastlines.

WAVE ATTACK

Poses enhanced danger when debris is present

- Ice
- Driftwood
- Man-made objects

The elevation that water can reach on the shore is called the run-up height

Overtopping & overwash

Breaking waves exert an incredible amount of force on the coast

Video by Shawn Hulse – November 2011

STORM SURGE

Total surge level =

Tide

+ Barometric bulge

+ Wind-driven pile

+ Waves

8-12 feet is a typical large surge in AK

30 feet = Katrina surge

43 feet = max. documented (Australia)

Storm surges do not necessarily occur at the same time as high winds

The effects of a storm surge can be enhanced in small ocean basins, sounds

Elevated water levels allow for the translation of other coastal hazards further inland during surges

Shaktoolik, AK – July 2011 *(Kinsman 2011)*

NPS, March 2011

TSUNAMI

A long period wave - behaves like a shallow water wave

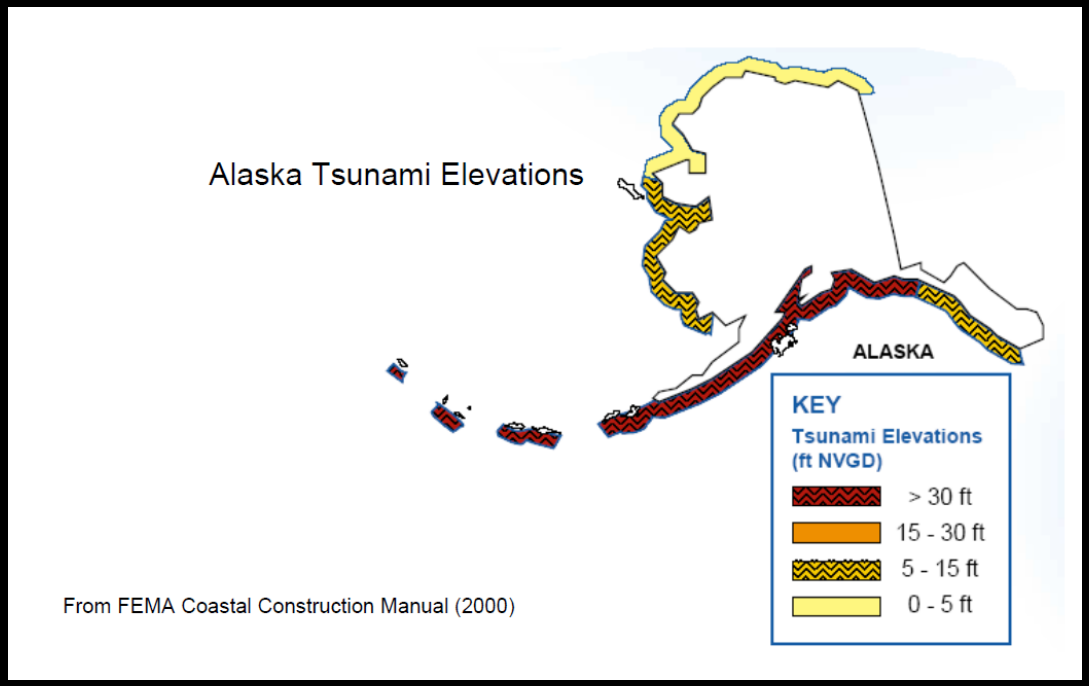
- Steepens rapidly on shelf
- Faster than a commercial jet airplane in open ocean

Triggered by seismic activity, landslide or submarine landslide

May be preceded by a drawdown

1958 Lituya Bay event had an inundation elevation of >500m

1964 Good Friday EQ tsunami caused extensive damages along the southern coast



Tsunami Damage
Kodiak, AK – March 1964 *(noaa.gov)*

SEA LEVEL RISE

Eustatic SL rise:

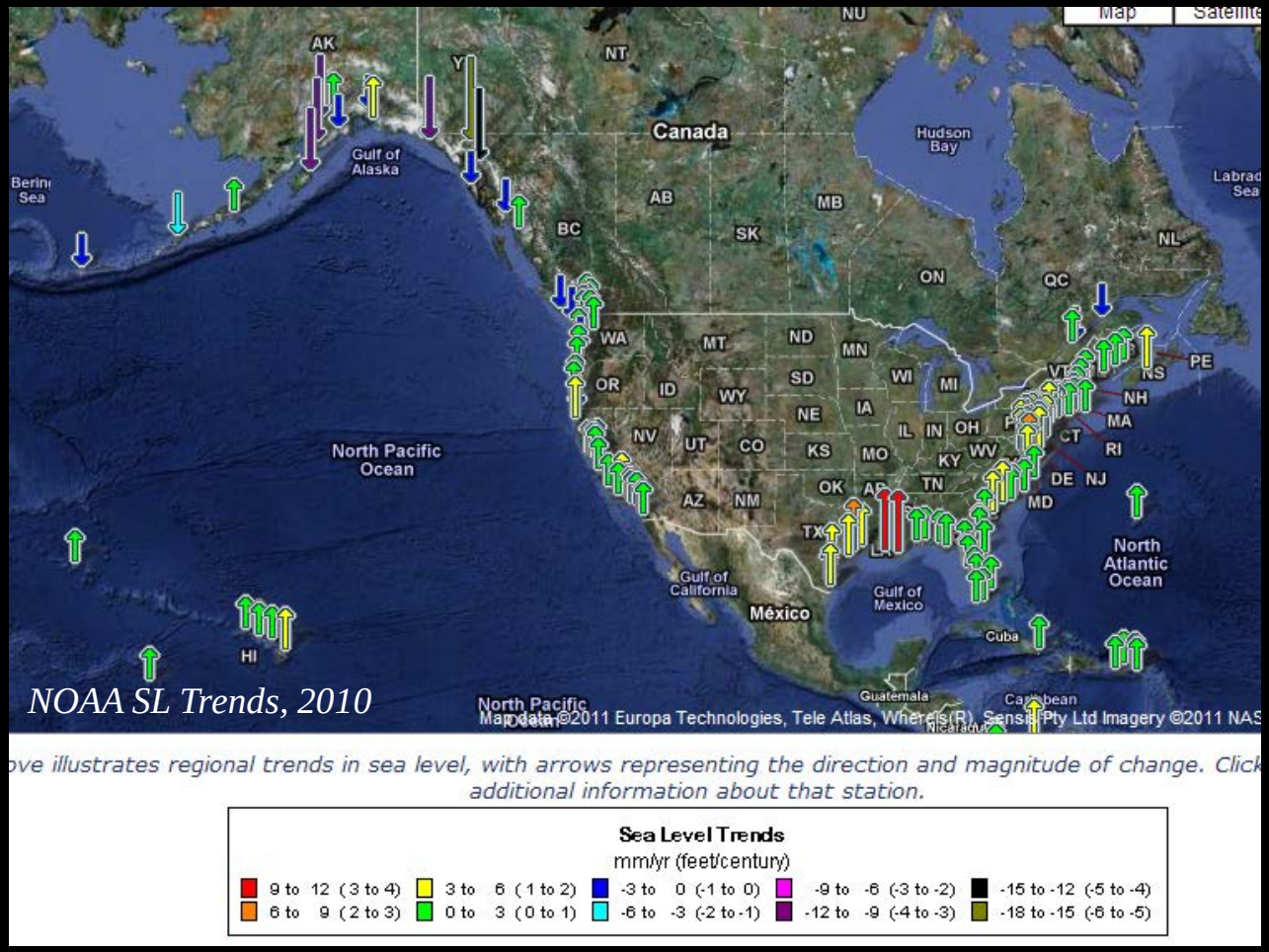
- Steric expansion
- Ice melt

Relative SL:

- Isostatic rebound./subsidence
- Seismic activity
- Extraction subsidence

Relative sea level trend information is limited

The role that sea level trends need to play in coastal hazard planning differs greatly throughout the state



NOAA SL Trends, 2010

IVU

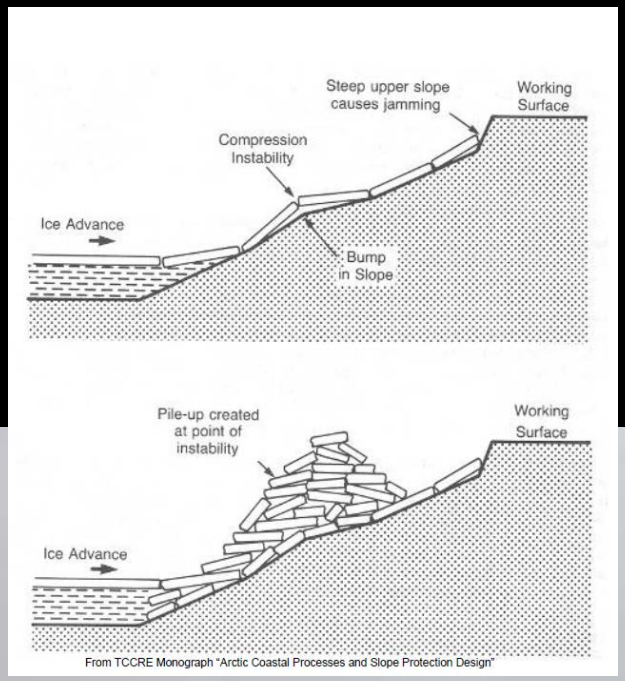
A ride-up & accumulation of ice on the coast

Typically occur atop slope breaks or other irregular coastal features

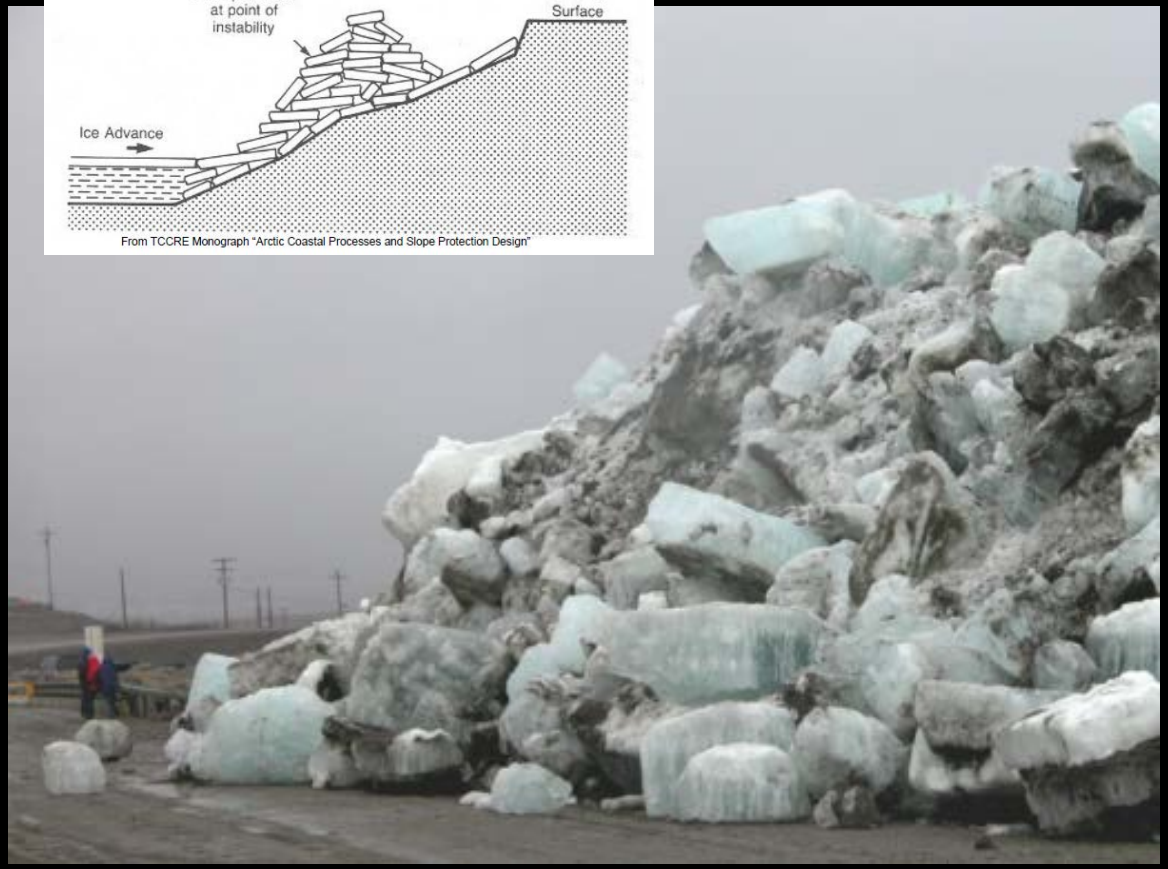
Often wind-driven during storm surge events

Extremely destructive to man-made structures

Not well studied & very difficult to predict



From TCCRE Monograph "Arctic Coastal Processes and Slope Protection Design"



Ivu (Ice Push)
Nome, AK - May 2004

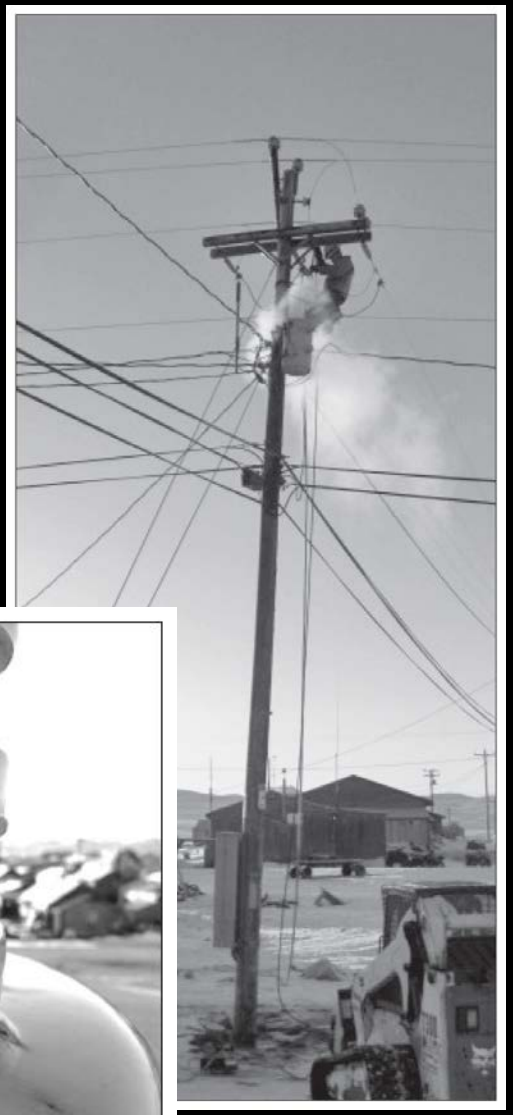
(Tom Busch 2004)

SALT SPRAY

December 2010
Power outage in Savoonga

"Winter storms are not at all a rare occurrence in village Alaska, and especially on St. Lawrence Island. In this particular instance however, a severe winter storm occurred with high wind from the northeast and salt spray was picked up from the ocean that is normally covered with sea ice. The extreme cold caused the salt spray to freeze on electrical equipment. Initial outages were caused by line slap from iced-up conductors, but later problems were caused by electrical arcing through conductive salt. We are concluding that the lack of sea ice was a major contributor to this situation."

- Meera Kohler, CEO for Alaska Village Electric Cooperative Inc.



Conductive salt spray caused arcing to burn this transformer and bushing. Burns similar to this occurred on other transformers and bushings, especially those closest to the ocean.

How do we quantify

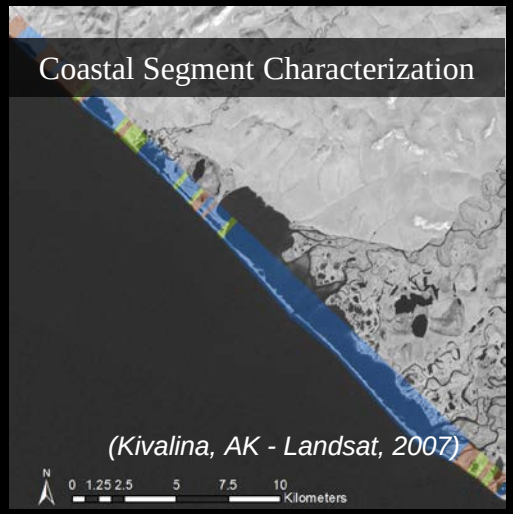
COASTAL PROCESSES?

Baseline Data

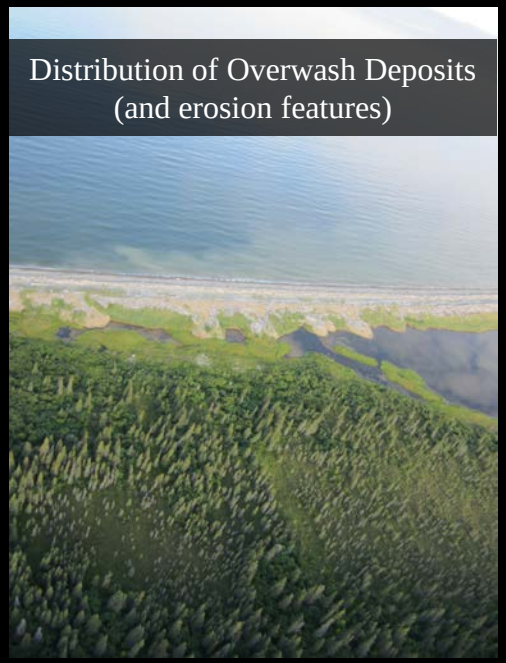
An assessment of coastal hazards benefits from extensive baseline data including:

- Rates of erosion/accretion
- Littoral cell information
- Bathymetry & elevation data
- Knowledge of dominant processes & landforms
- Geologic context
- Records of historic hazard events
- Tidal cycles & water level data
- Storm recurrence intervals
- Wind & wave records

Inlet Bathymetry and Dynamics

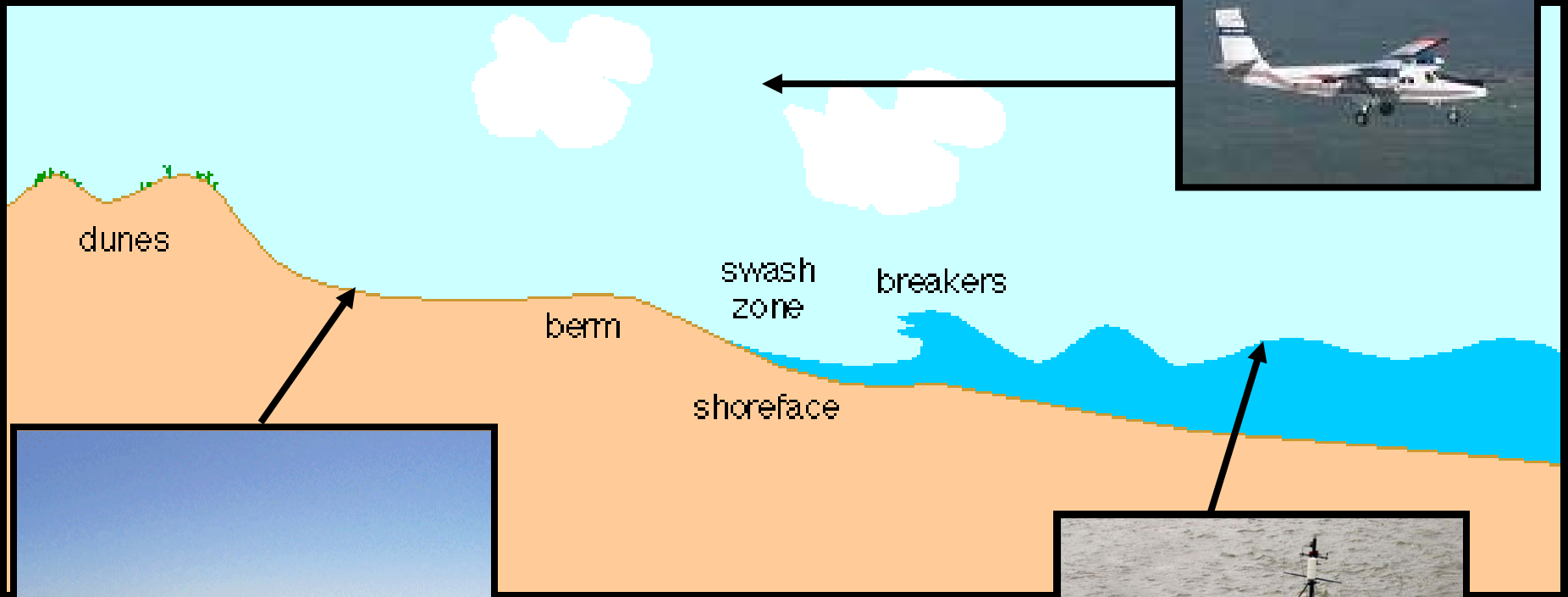


Coastal Segment Characterization



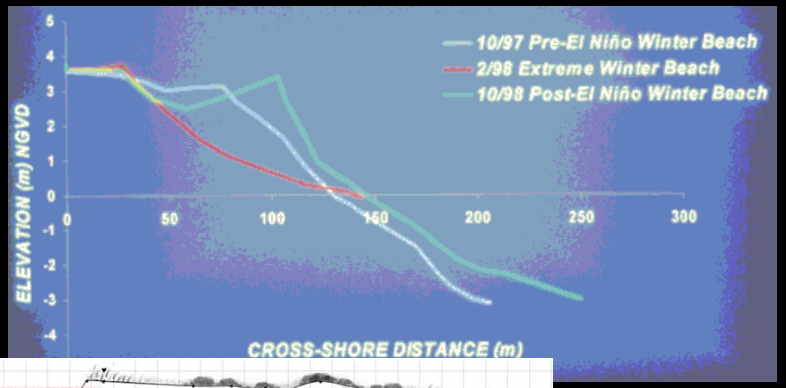
Distribution of Overwash Deposits (and erosion features)

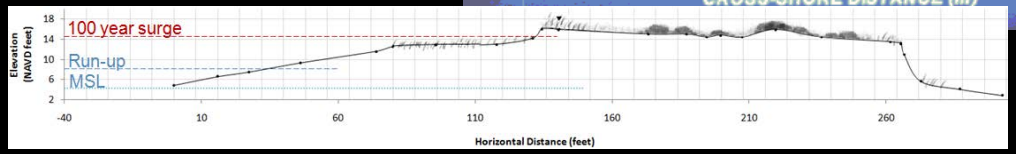
Measuring Erosion & Accretion



Measuring Erosion - in the Field

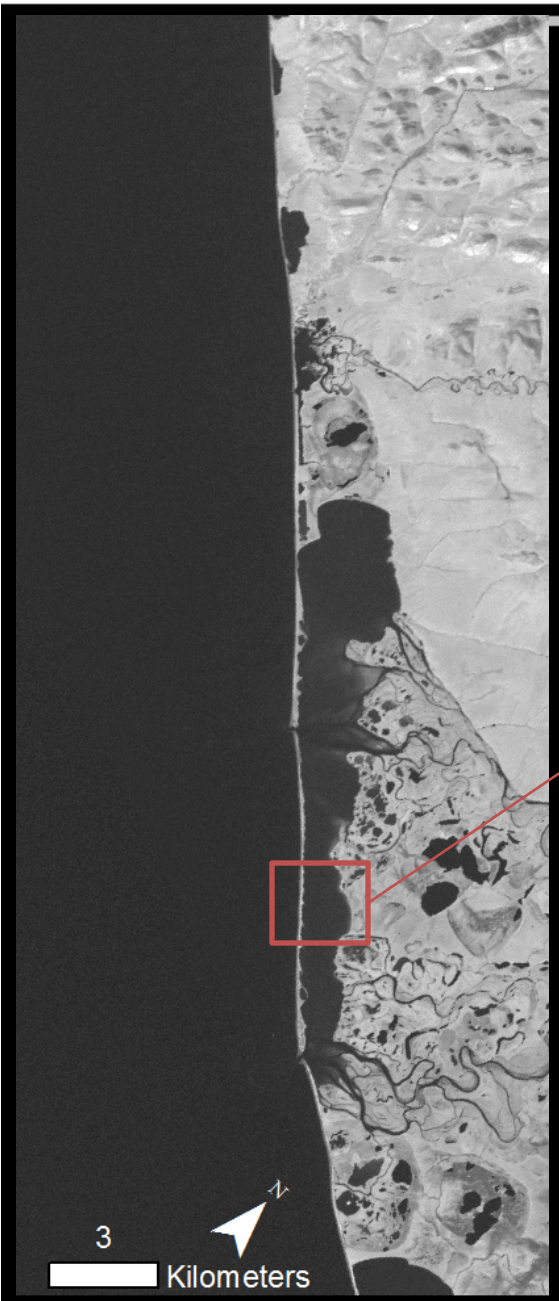
- Rod & Transit
- Laser theodolite
- Precision GPS

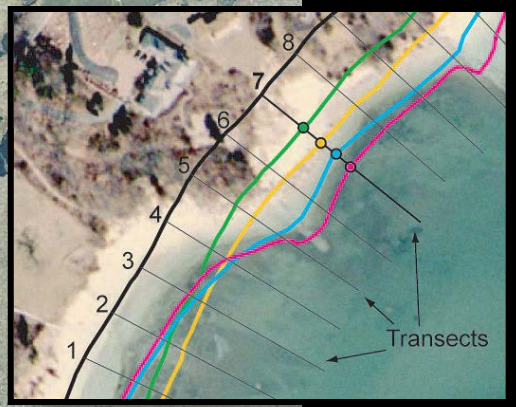




Gridded collection methods

Measuring Erosion - Aerials





1952

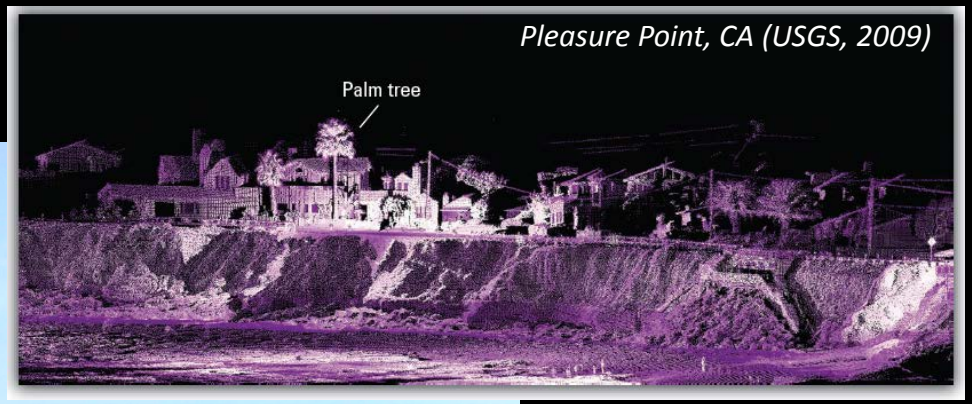
1980

2003

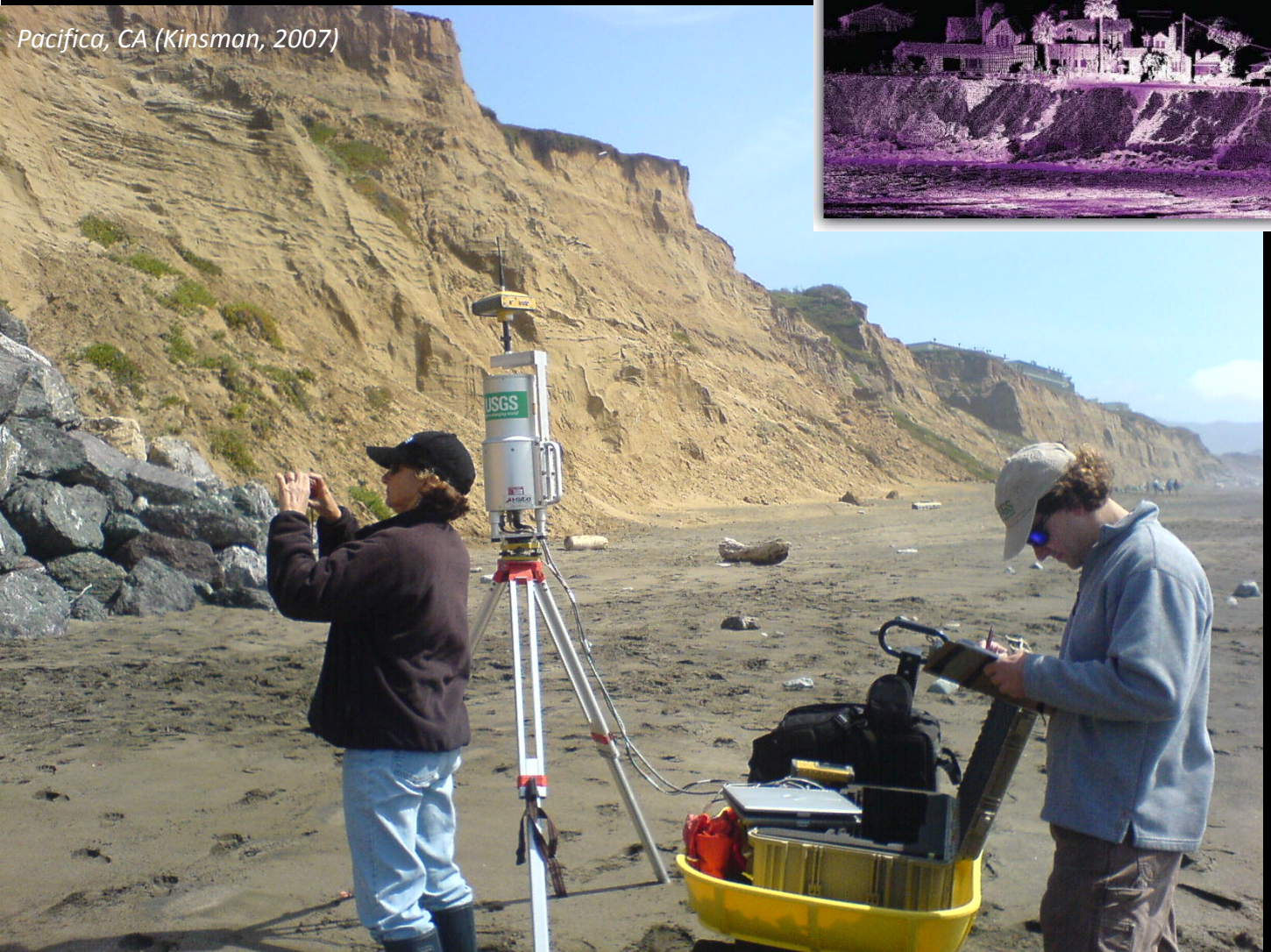
USGS Digital Shoreline Analysis System

Measuring Erosion – Lidar

Ground Based



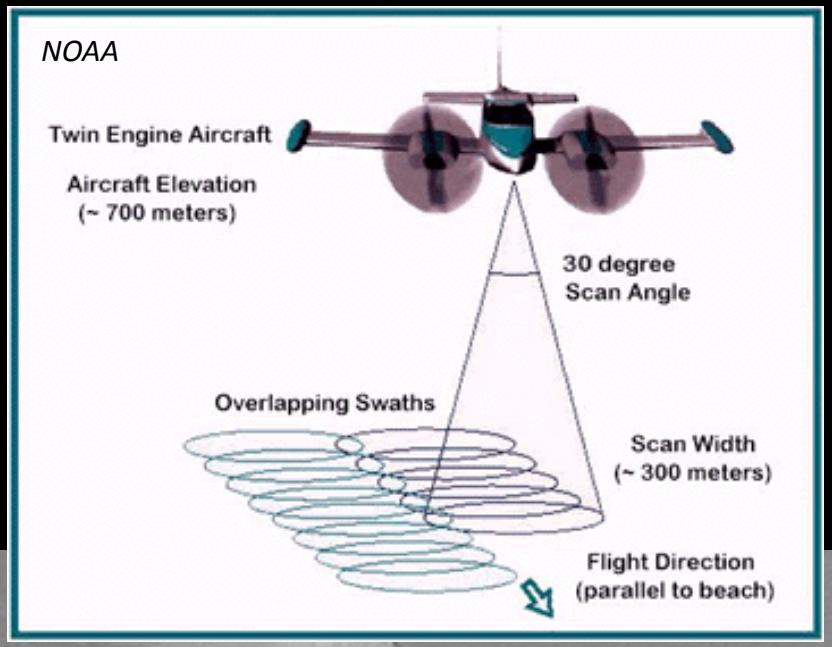
Pleasure Point, CA (USGS, 2009)

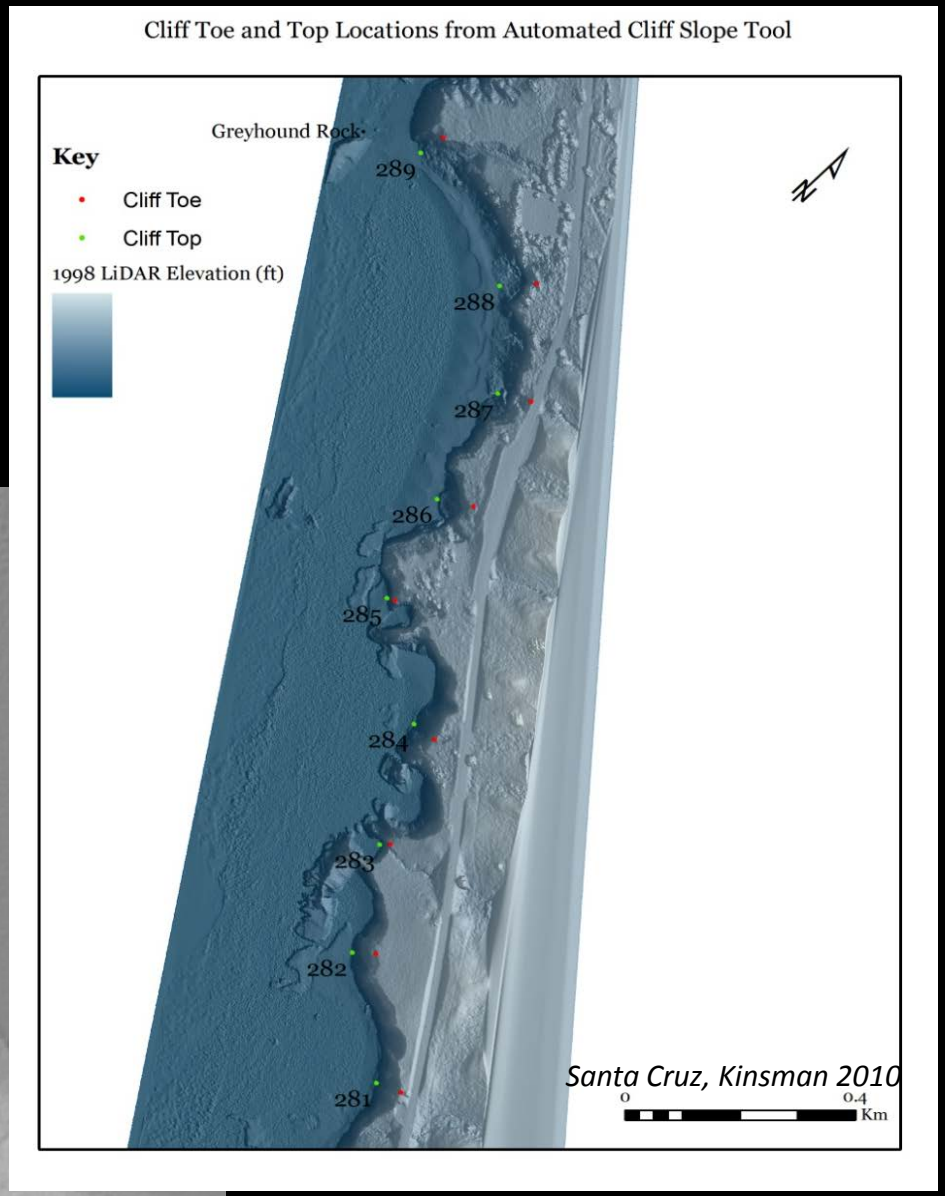


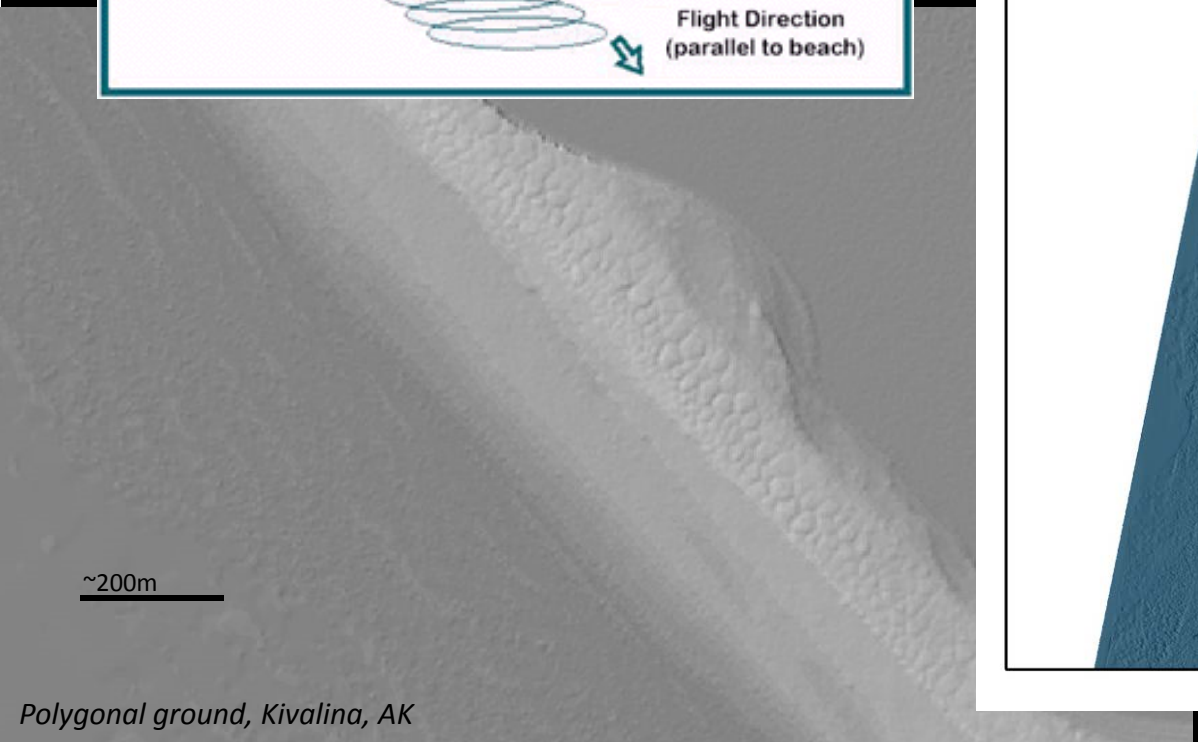
Pacifica, CA (Kinsman, 2007)

Measuring Erosion – Lidar

Aerial







Polygonal ground, Kivalina, AK

Coastal Sediment Characterization

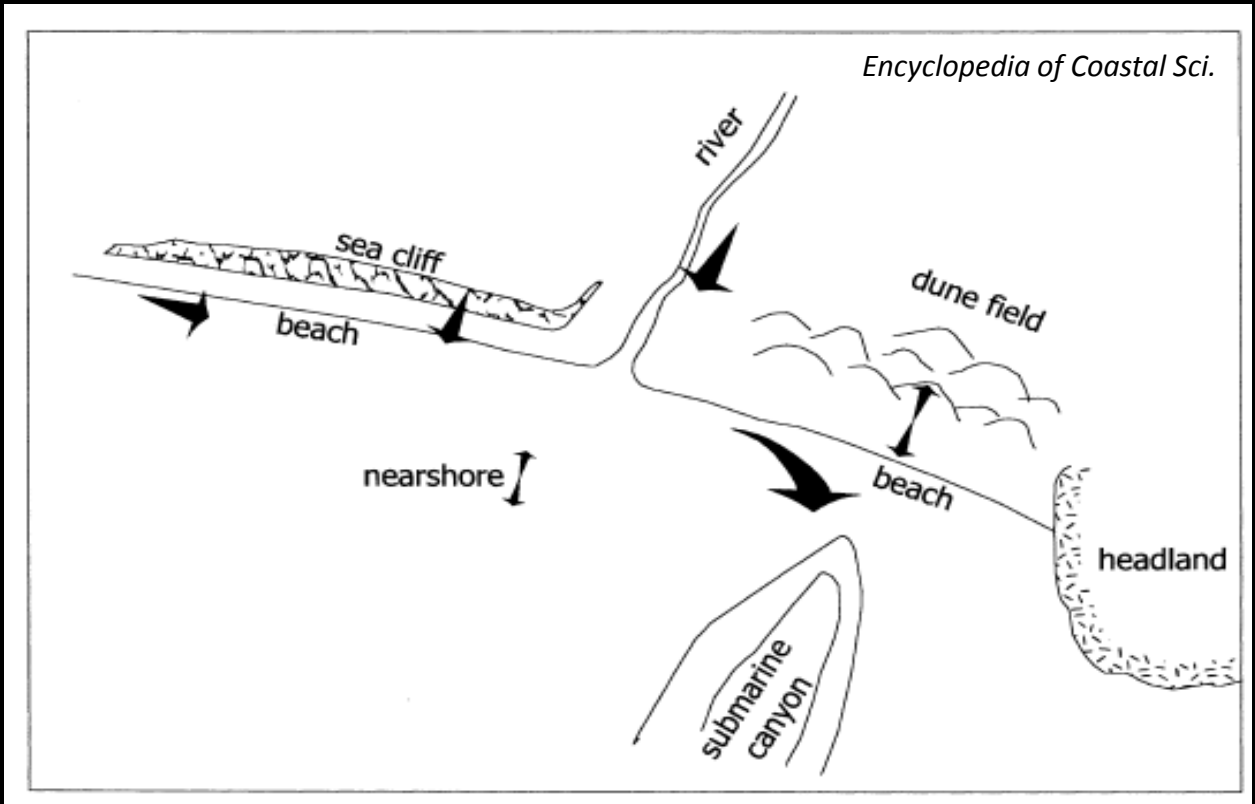
Identification of sources & sinks

Grain size & mineral composition

Littoral Cells

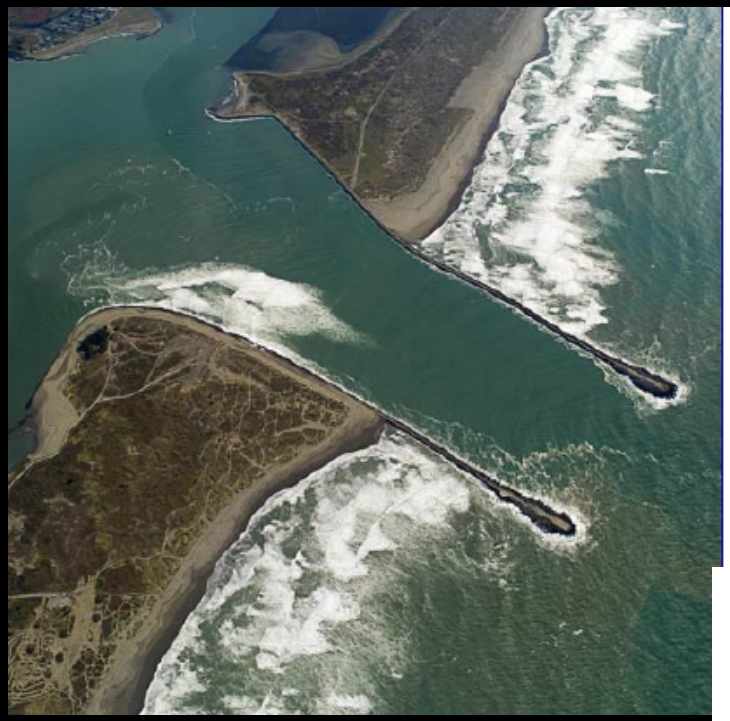
Sources:
- Fluvial
- Cliffs/Bluffs
- Dunes
- Nearshore
- Biogenic deposition
- Human nourishment
- (Alongshore)

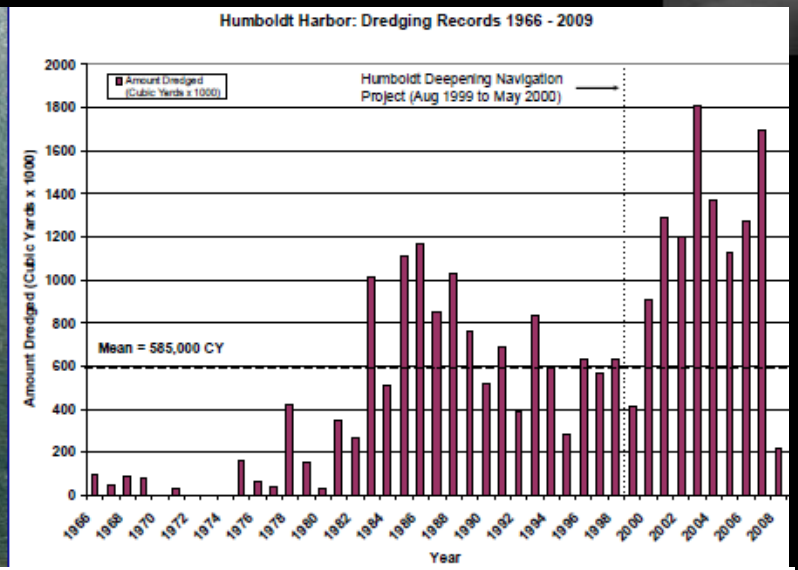
Sinks:
- Offshore (canyons)
- Nearshore
- Dunes
- Inlets & lagoons
- In situ abrasion
- Sand/gravel mining
- (Alongshore)

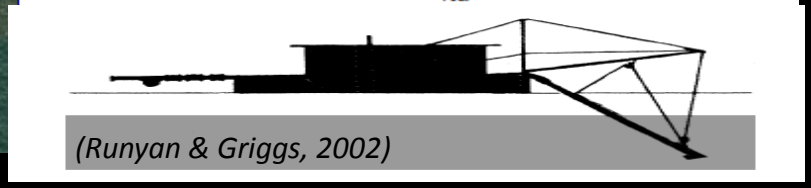


When quantified = sediment budget

Measuring Sediment Movement





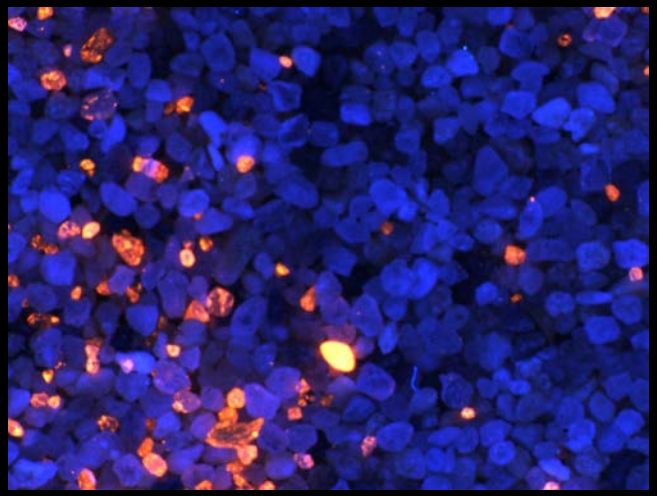


1. Dredge Records

2. Accretion/Infill Rates

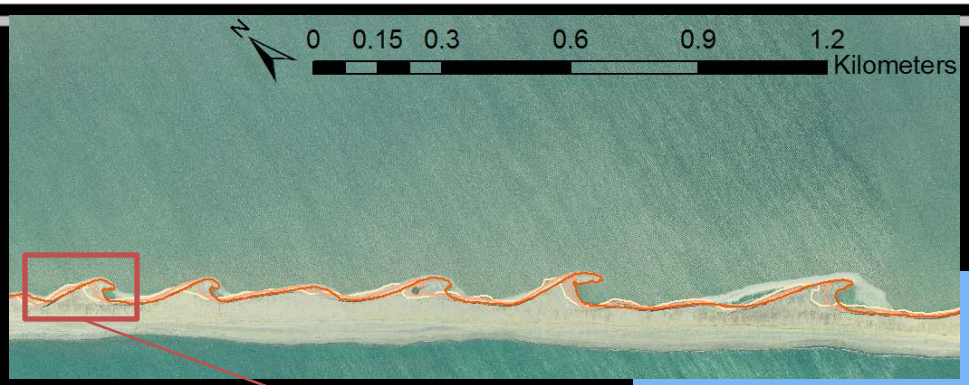
Measuring Sediment Movement

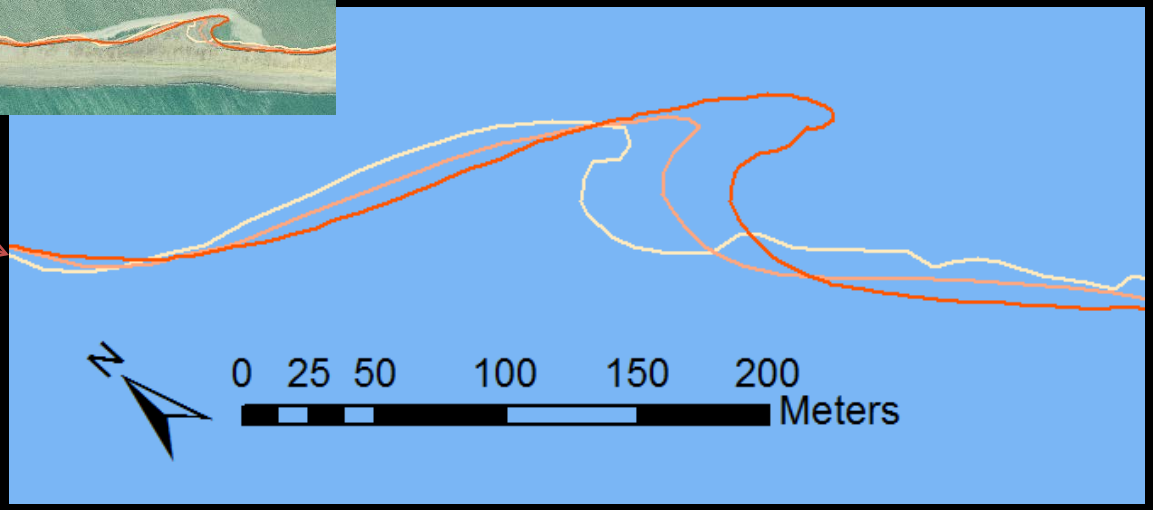
2. Tracers

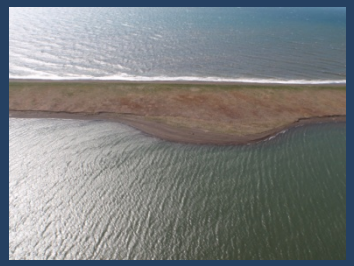


Kinsman & Xu, 2010

Measuring Sediment Movement







Evolution: Salient → Spurred → Looped

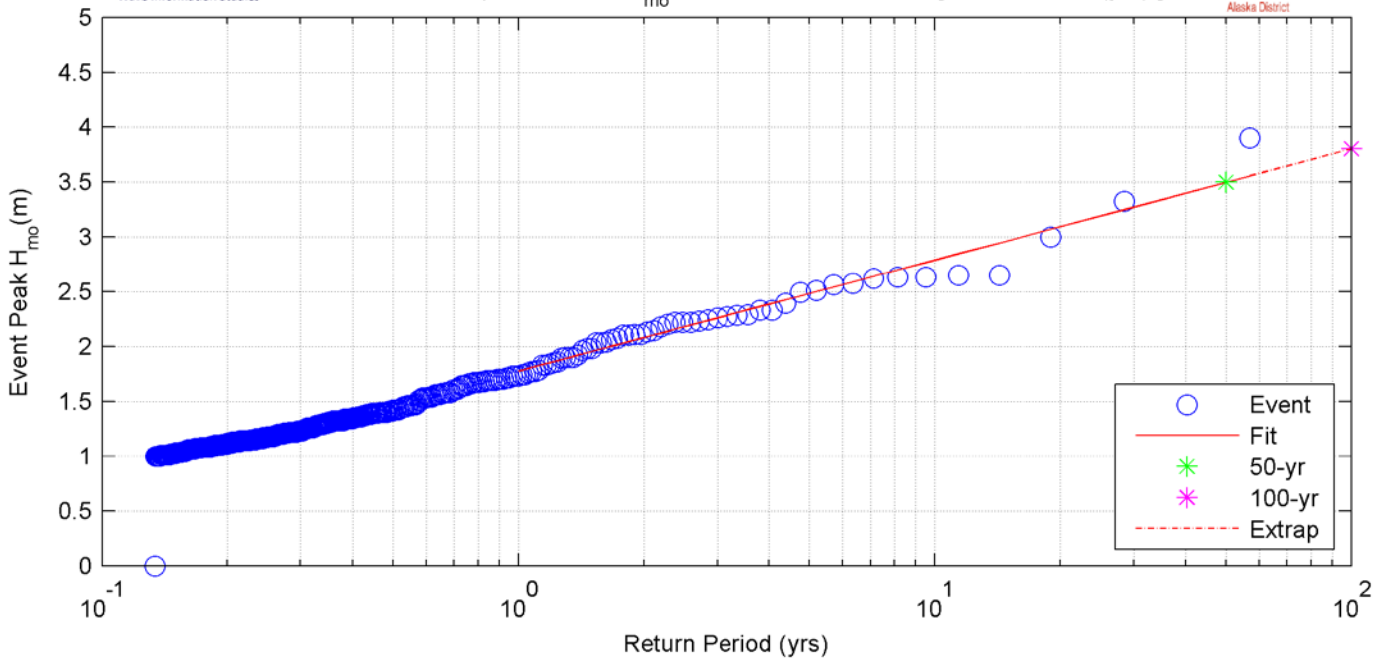
Landform Migration Rate: ~1m/year (example from Kivalina Lagoon)

Wave Hindcasting

Wave Information Studies

Storm Event Return Period of 56-yr (1954-2009) Wave Hindcast
Alaska Station 82126 : Lat: 64.000° Lon:-161.750° , Depth: 8m
Linear Fit to top 56 events: H_{mo} = 1.7769 + 0.43947 • ln [Return Period(yrs)]

Alaska District



Top 10 events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}	Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}
1	1978/11/04 01:00	3.90	7.63	290.0	6	2003/11/09 01:00	2.63	7.63	236.0
2	1960/10/03 01:00	3.32	8.39	49.0	7	1965/11/12 01:00	2.63	6.93	20.0
3	1965/11/15 01:00	3.00	6.93	350.0	8	1975/08/26 01:00	2.62	6.93	26.0
4	1985/10/15 01:00	2.65	6.30	115.0	9	1989/11/16 01:00	2.57	6.30	117.0
5	1966/11/16 01:00	2.65	6.93	342.0	10	2009/11/12 01:00	2.56	10.15	85.0

An event is defined as any period when H_{mo} > 1.00m

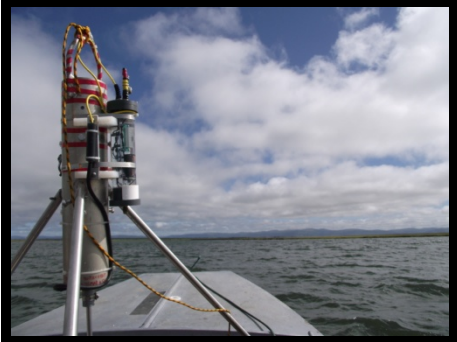
θ_{mean} is direction that waves are arriving from

ERDC US Army Engineer Research & Development Center

20-May-2011 09:22:59

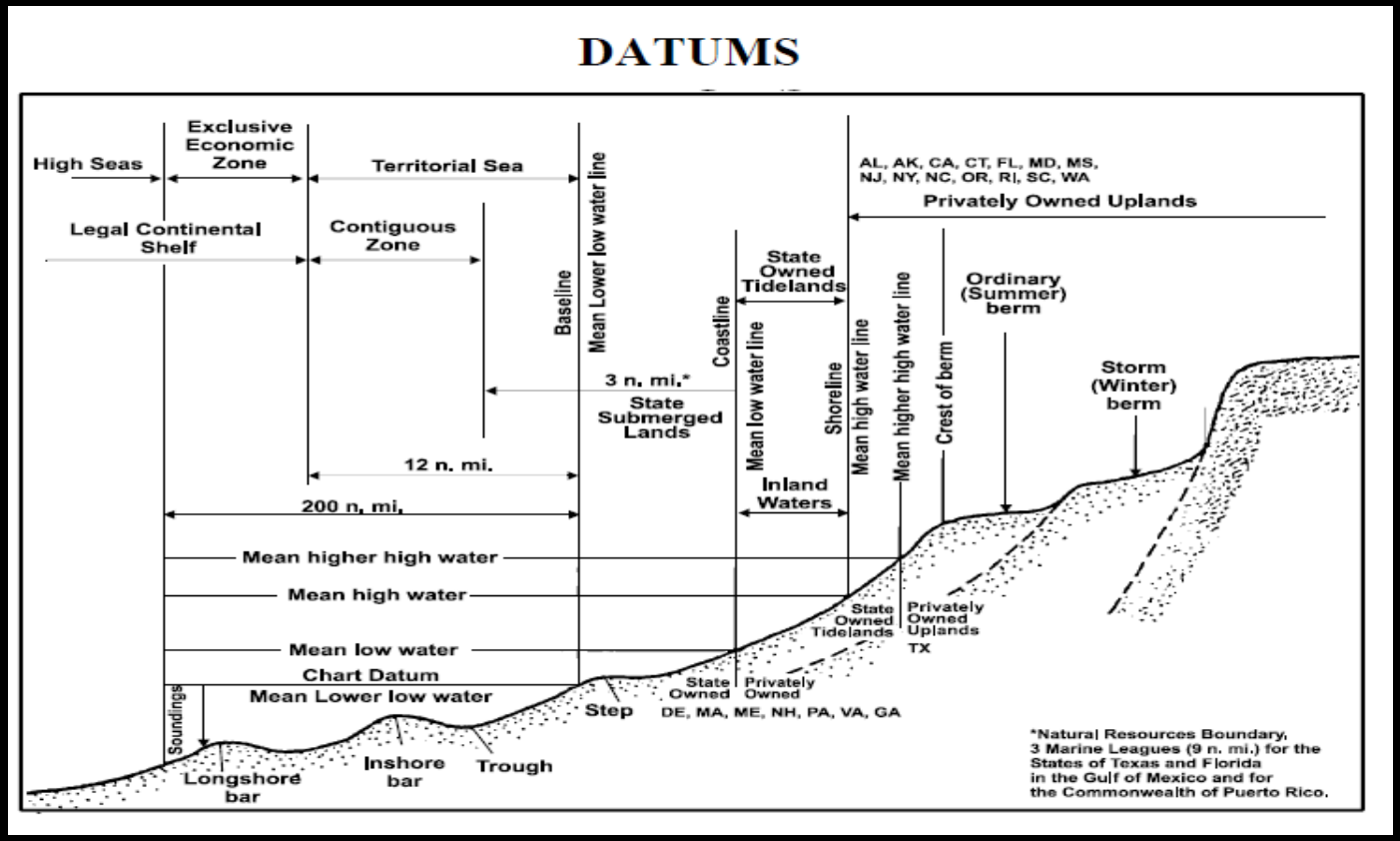
Water Levels & Currents

Pressure Transducers



Current Meters

Delaware Coastline: 30 mi – 4 tide gauges
NW Alaska Coastline: 2,000+ mi – 3 tide gauges

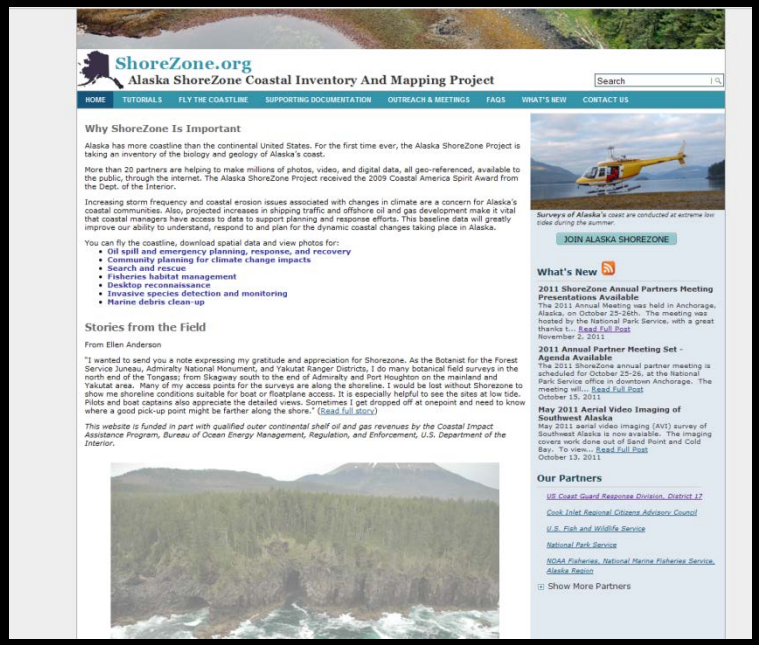


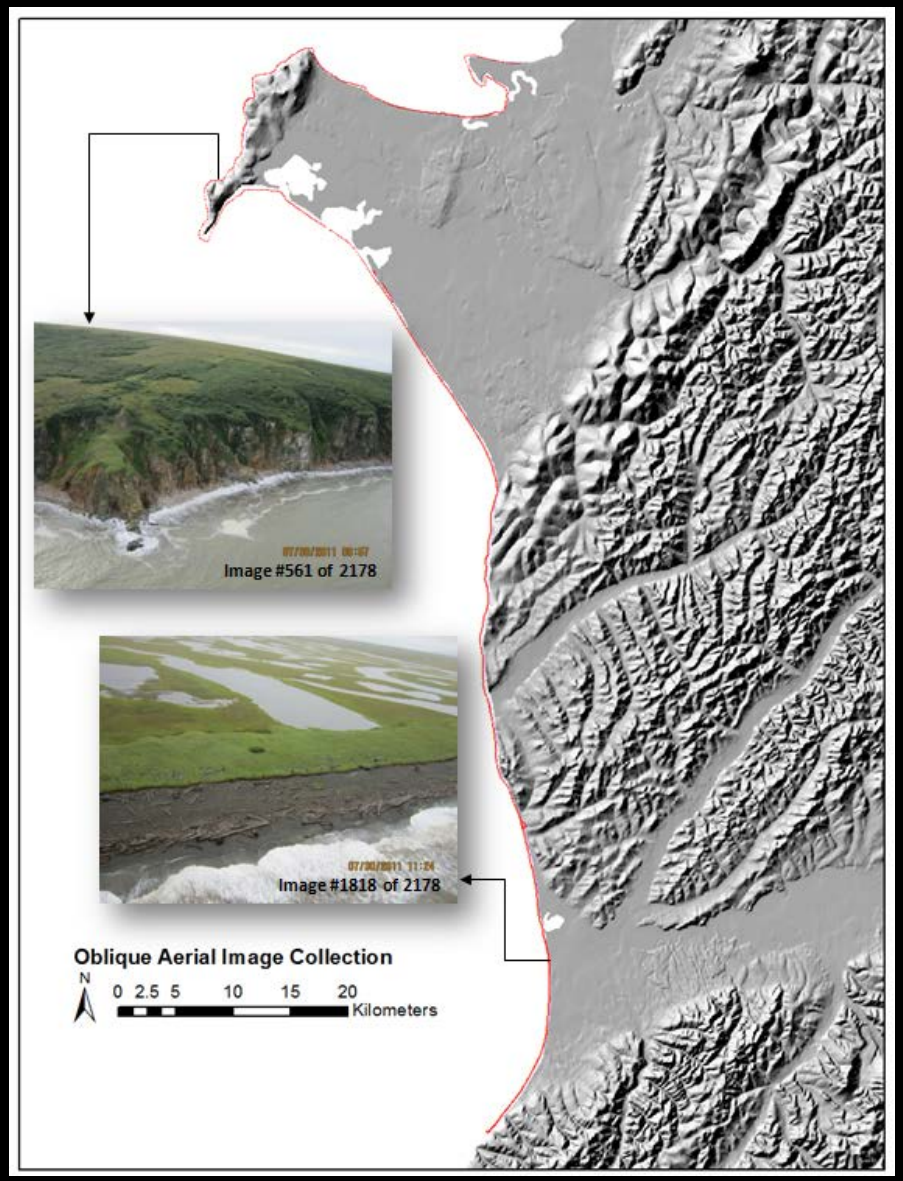
Oblique Image Collection

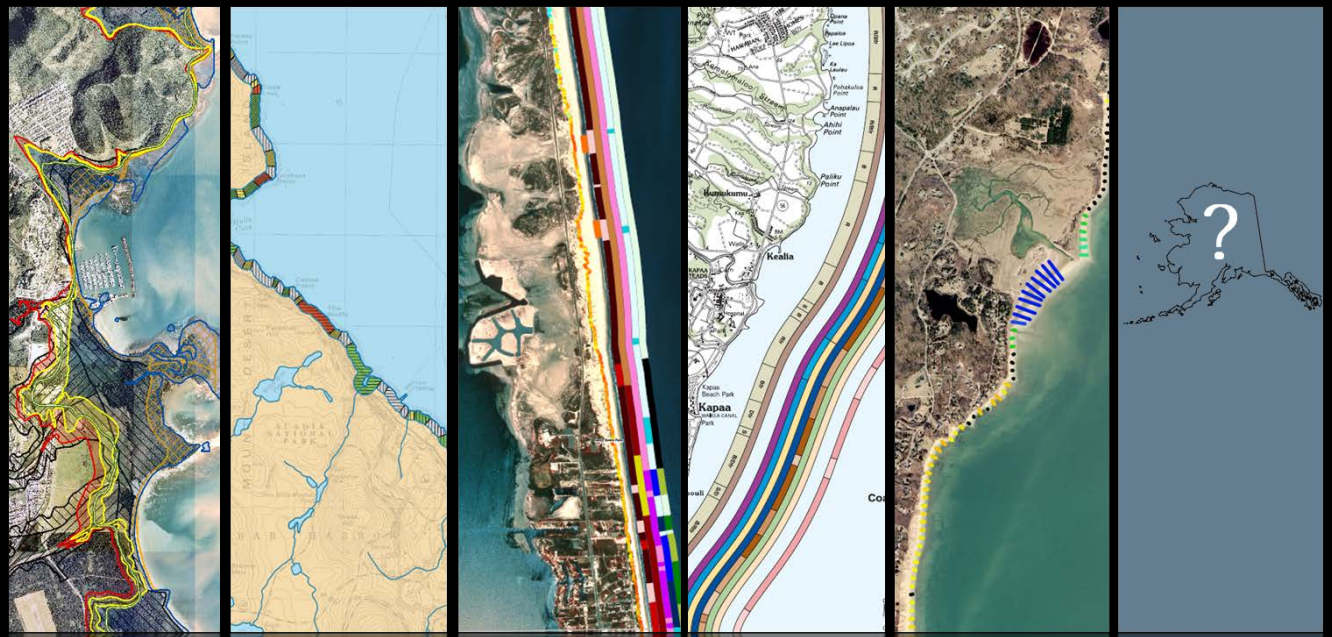
Alaska ShoreZone Project

Visual record of coastline

Useful for a wide range of applications & to many types of end users





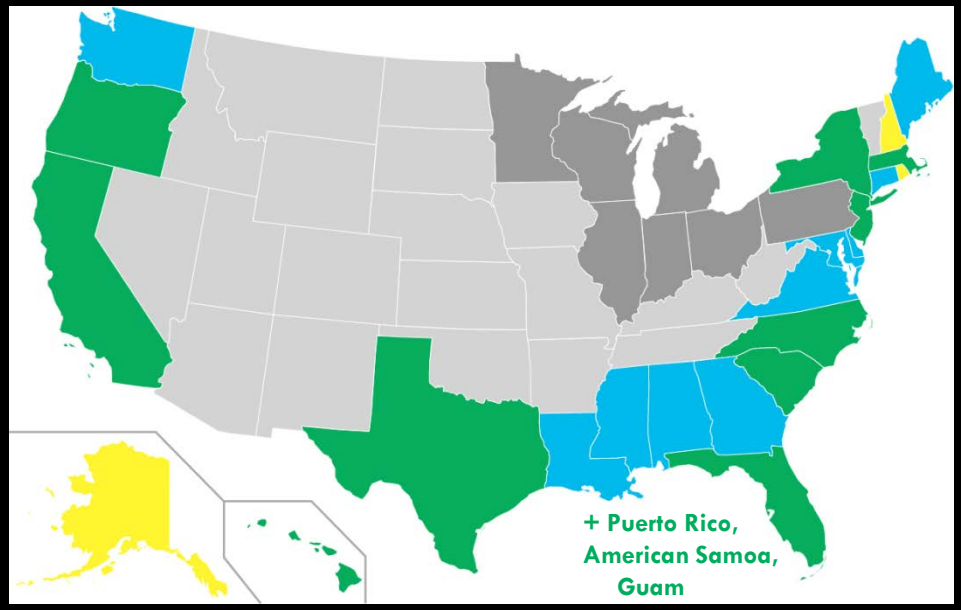


How do you map

COASTAL HAZARDS?

What is the status of coastal hazard mapping in the United States?

Coastal Hazard Map Products by State



- Non-coastal states
- Great Lakes states (many with hazard maps)
- Localized flood, tsunami or shoreline change maps
- Statewide hazard maps w/ additional products
- Composite multi-hazard maps

Mapping Agencies

Federal

FEMA

US Army Corps of Engineers.

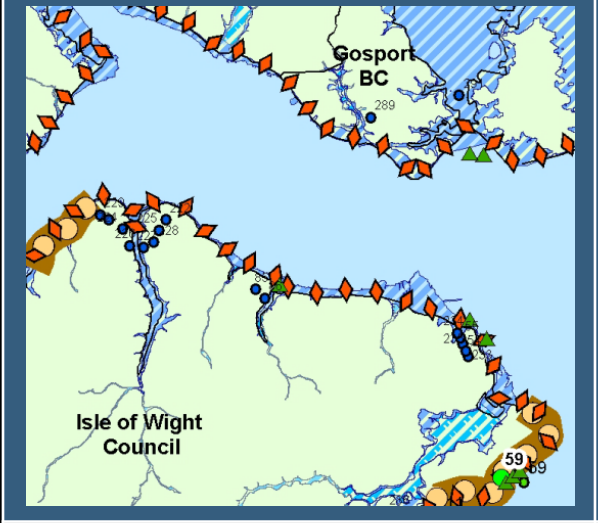
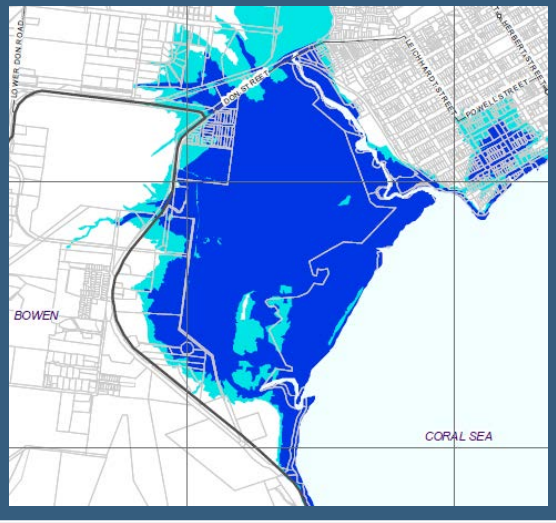
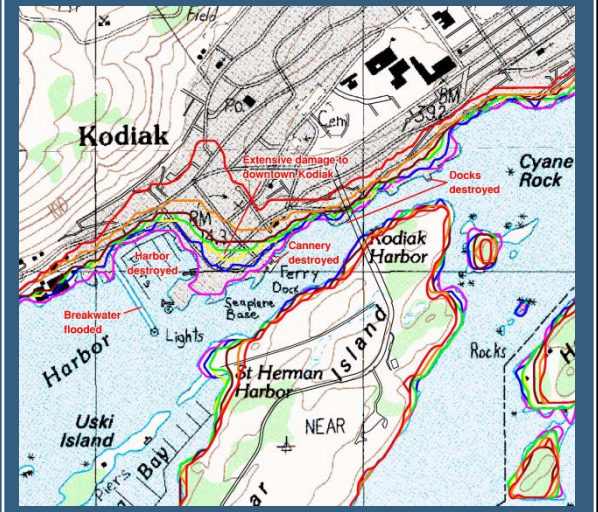
NOAA

USGS science for a changing world

State/Local

- Coastal Management Programs
- Geologic Surveys
- Boating and Waterway Departments
- Zoning Departments
- Fish and Game Departments
- Universities
- Private Consulting Firms

There are three basic categories of coastal hazard mapping:

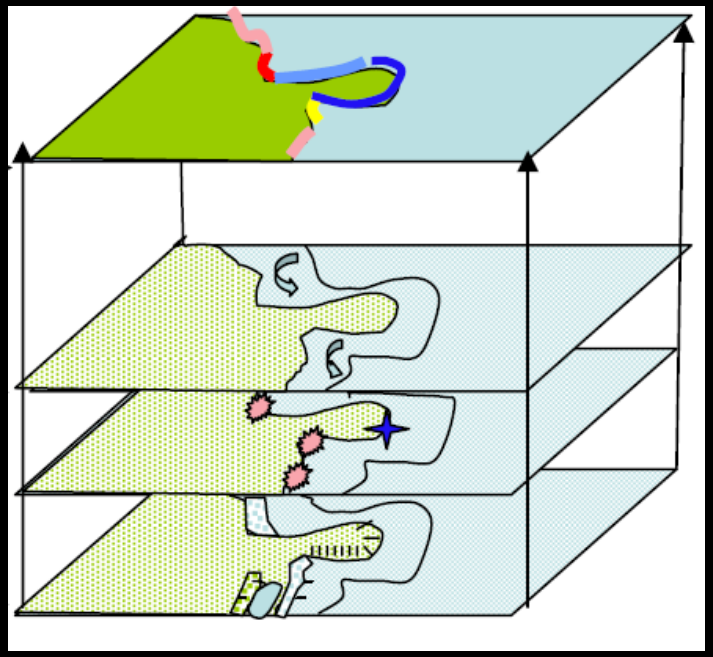
Observed Impacts	Geohazard Potential	Advanced Predictions
• Recent or historic geohazard extents • Drawn from oral, recorded, instrumented or observational record	• Measured geomorphic characteristics combined with known processes • May include calculations such as recurrence intervals	• Require extensive baseline data • Incorporate models and multiple scenarios
Example: SCOPAC, 2005 *Current and Historic Natural Hazards, Isle of Wight, UK*	Example: Queensland CP, 2010 *Storm Tide Inundation Area, Bowen, Australia*	Example: Suleimani et al., 2002 *Tsunami hazard maps of the Kodiak area, Alaska*
		

Composite coastal hazard maps

Coastal Classification and Hazard Bands/Ribbons/Lines/Strips

Stacked Maps

- **Geomorphology and coastal processes**
- **Historically recorded hazards**
- **Existing defenses**



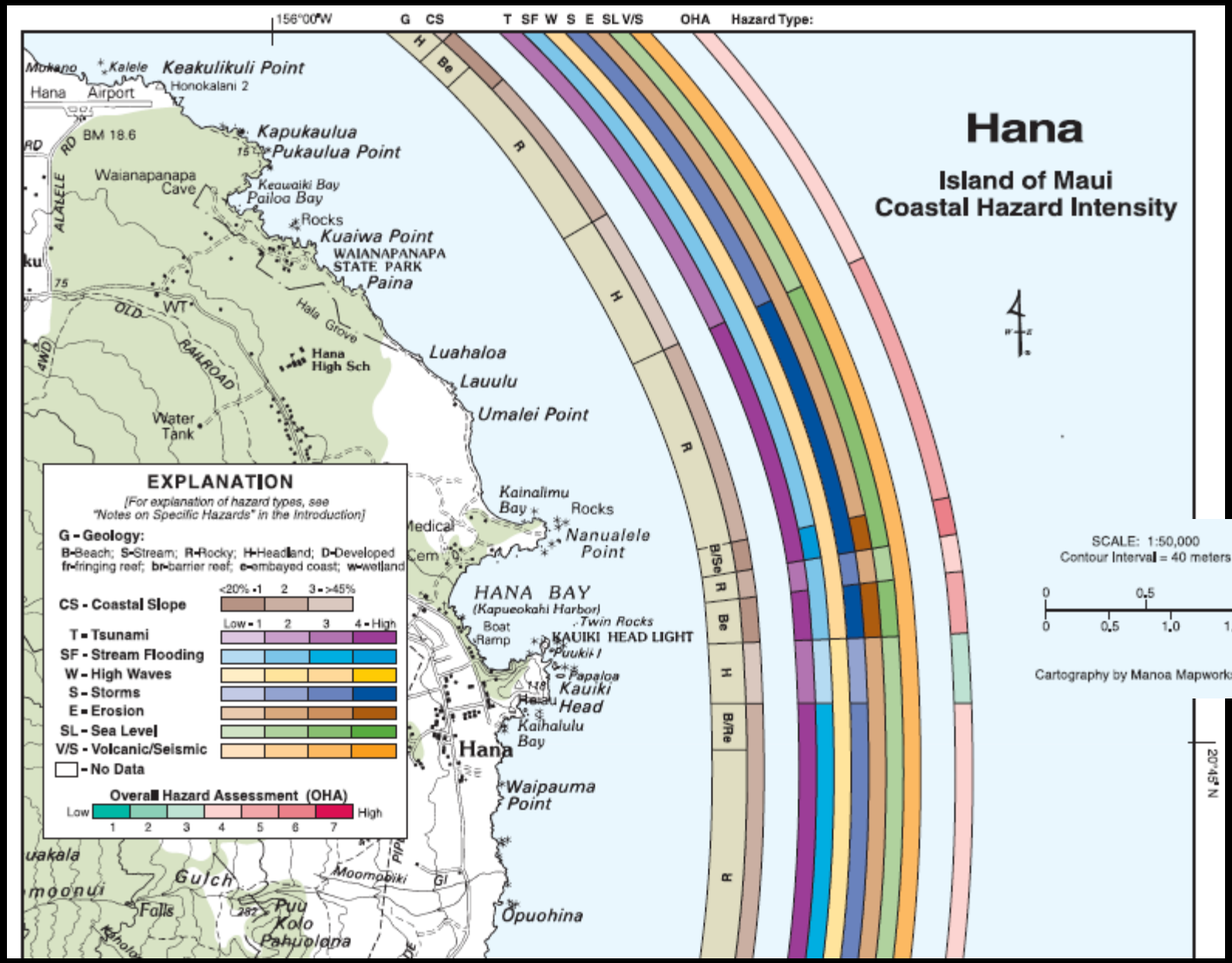
Each band/line has its own attribute field and definition

An example from *Atlas of Natural Hazards in the Hawaiian Coastal Zone* (Fletcher et al., USGS 2002):

Hazard Intensity Rank Definitions

Hazard	Low (1)	Moderately Low (2)	Moderately High (3)	High (4)
Erosion	long-term accretion (>10 yr) with no history of erosion, or dynamic cycles with consistent annual accretion	long-term stable or minor erosion/accretion cycles with erosion fully recovered by accretion; low rocky coasts; perched beaches	long-term erosion rate <1 ft/yr or highly dynamic erosion/ accretion cycles with significant lateral shifts in the shoreline	chronic long-term erosion >1 ft/yr, or beach is lost, or seawall at water-line for portions of the tidal cycle

Example continued…



Challenges Associated with Coastal Hazard Mapping Specific to Alaska

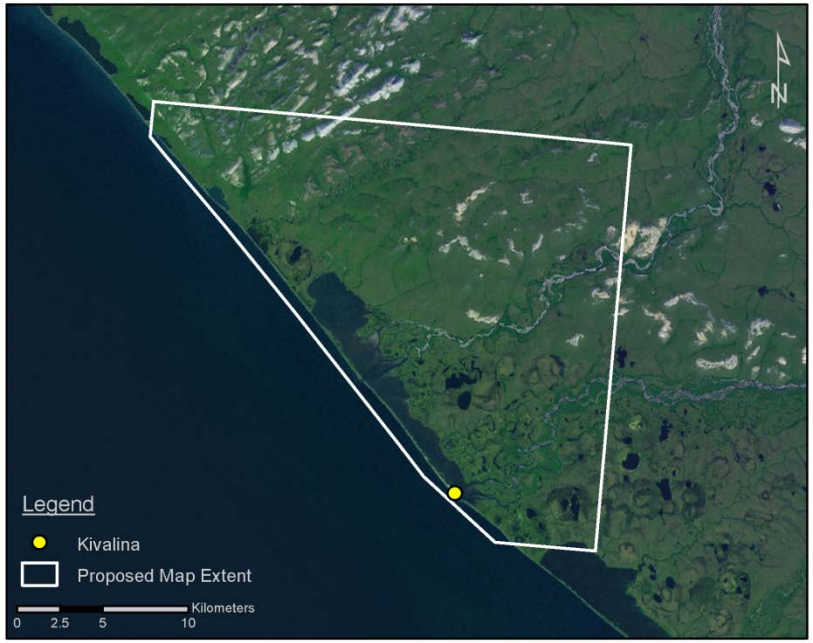
Shaktoolik, AK *(Kinsman 2011)*

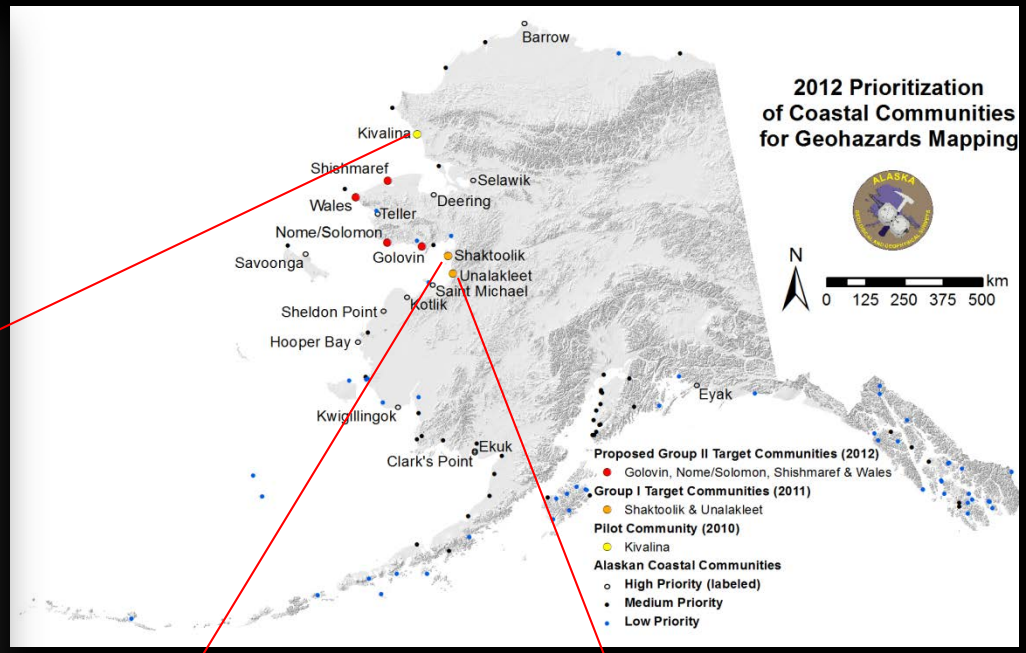
vs.

San Diego, CA *(www.oceanlight.com)*

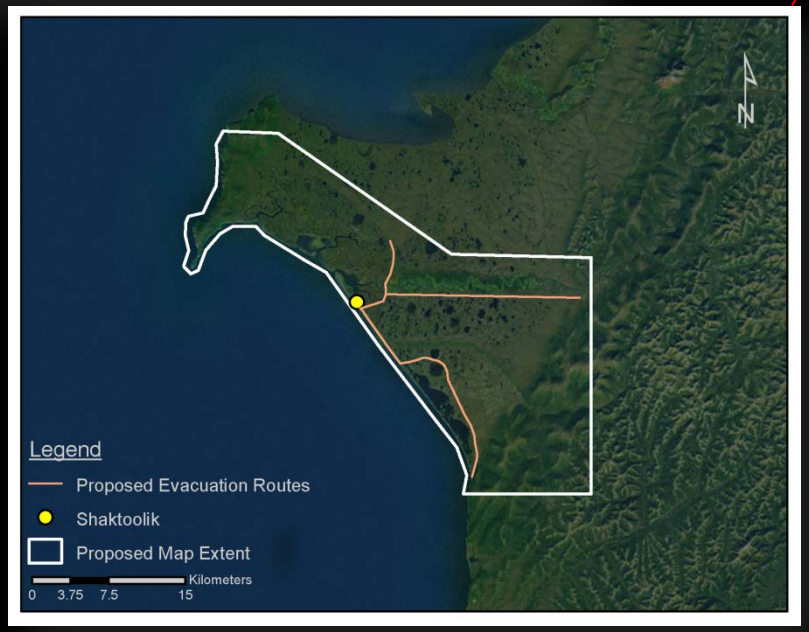
- Existing methodologies designed for densely populated coastlines
- Longest coastline in the United States - very diverse coastal environments
- Extremely limited baseline data
  - Water levels, historic event record, aerial imagery, topography & bathymetry
- Few detailed hazard-specific studies
- Coastal economics are fundamentally different
- Unique hazards & different emphasis

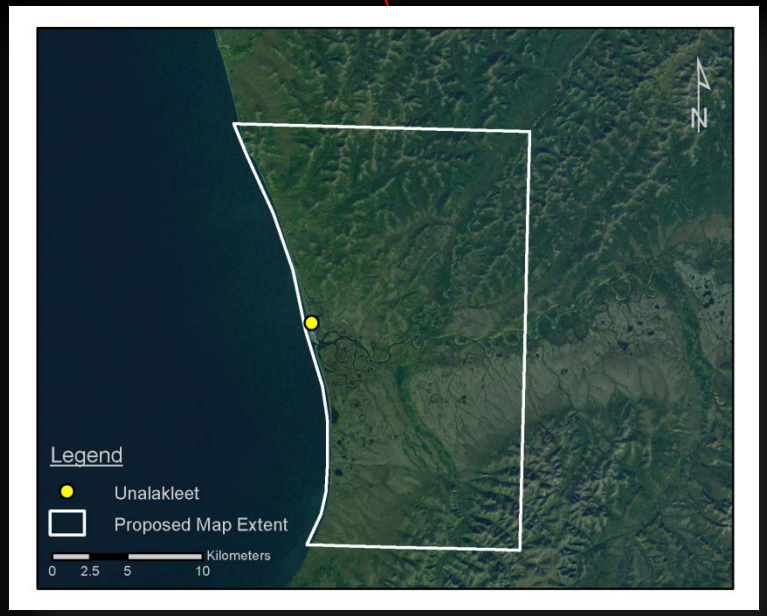
Current DGGS Project Locations





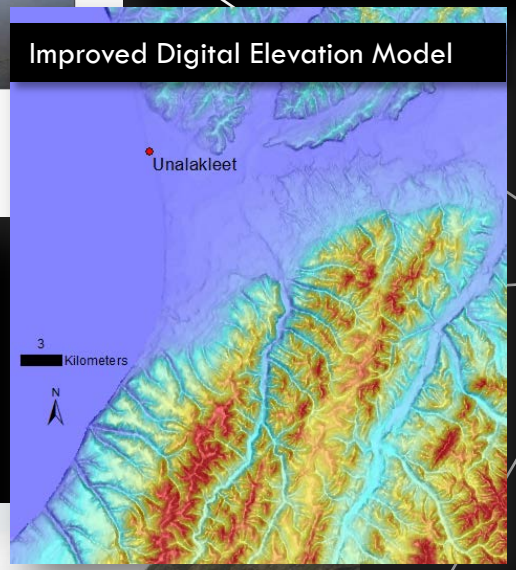
~30 miles of coastline per community





DGGS Approach to Coastal Hazard Mapping

Outside reports, maps, model results, expert and resident knowledge



Field investigations including baseline data collection & ground truthing

Synthesis

Coastal Classification Bands

- Beach slope
- Sediment size
- Shoreline type
- Tidal Range
- Dominant processes
- Engineered structures

Coastal Hazard Bands

- Erosion/Accretion of sediments
- Irreversible coastal retreat
- Coastal flooding
- Wave exposure (+debris)
- Overwash & inlet features
- Ivu

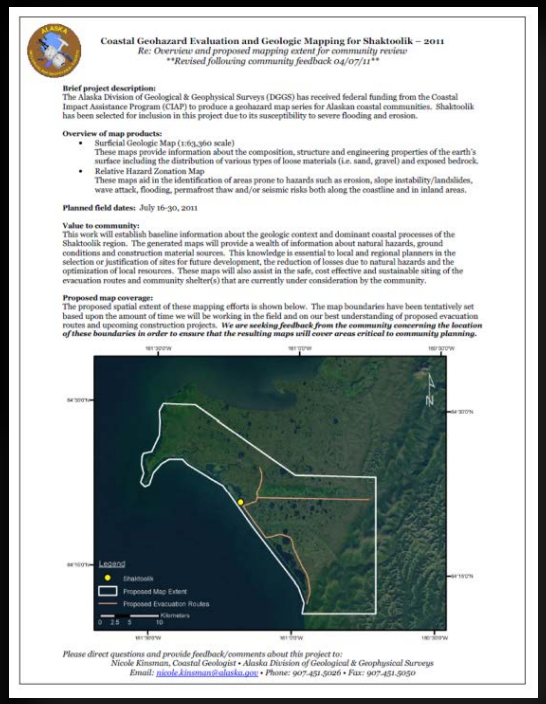
Composite Coastal Hazard Maps for Alaskan Communities

Inland Hazard Zones

- Landslides/slope failure
- Seismic hazards (liquefaction)
- Flooding (stream & river)

Community Involvement

- Project information sheets
  - Seeking input about mapping extent
  - Request information about local concerns



Coastal Geohazard Evaluation and Geologic Mapping for Shaktoolik – 2011
Re: Overview and proposed mapping extent for community review
Revised following community feedback 04/07/11

Brief project description:
The Alaska Division of Geological & Geophysical Surveys (DGGS) has received federal funding from the Coastal Impact Assistance Program (CIAP) to produce a geohazard map series for Alaskan coastal communities. Shaktoolik has been selected for inclusion in this project due to its susceptibility to severe flooding and erosion.

Overview of map products:
- Surficial Geologic Map (1:63,360 scale)
  These maps provide information about the composition, structure and engineering properties of the earth's surface including the distribution of various types of loose materials (i.e. sand, gravel) and exposed bedrock.
- Relative Hazard Zonation Map
  These maps aid in the identification of areas prone to hazards such as erosion, slope instability/landslides, wave attack, flooding, permafrost thaw and/or seismic risks both along the coastline and in inland areas.

Planned field dates: July 16-30, 2011

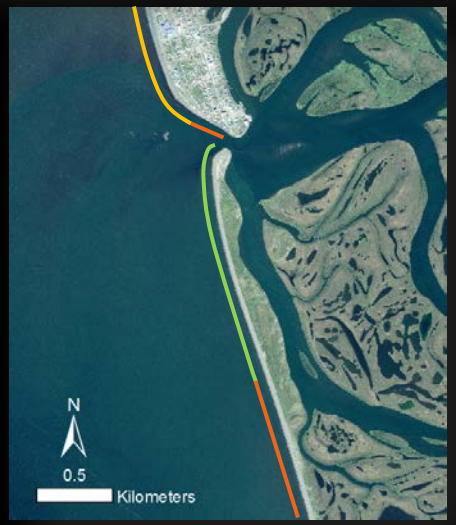
Value to community:
This work will establish baseline information about the geologic context and dominant coastal processes of the Shaktoolik region. The generated maps will provide a wealth of information about natural hazards, ground conditions and construction material sources. This knowledge is essential to local and regional planners in the selection or justification of sites for future development, the reduction of losses due to natural hazards and the optimization of local resources. These maps will also assist in the safe, cost effective and sustainable siting of the evacuation routes and community shelter(s) that are currently under consideration by the community.

Proposed map coverage:
The proposed spatial extent of these mapping efforts is shown below. The map boundaries have been tentatively set based upon the amount of time we will be working in the field and on our best understanding of proposed evacuation routes and upcoming construction projects. ***We are seeking feedback from the community concerning the location of these boundaries in order to ensure that the resulting maps will cover areas critical to community planning.***

Please direct questions and provide feedback/comments about this project to:
Nicole Kinsman, Coastal Geologist • Alaska Division of Geological & Geophysical Surveys
Email: nicole.kinsman@alaska.gov • Phone: 907-451-5026 • Fax: 907-451-5050

- Team stays within the community during multi-week field projects

- Hire local boats & operators
- Use of local Native place names



- Include elders and leaders in review process/mapping
  - Content and usefulness
  - Development of local knowledge category on map
- We take an active role in relocation advisory groups

Obstacles to Mapping

Walrus (dead) on beach - Shaktoolik, AK *(Smith, 2011)*

- Selection and prioritization of communities
- Accuracy of outside maps, reports & investigations
- Preservation of clear links to baseline data & uncertainty
- Statewide hazard category ranking w/ clear explanations
- Cartographic challenges (clutter, basemaps, minimum change/distance)
- Conveying coastal process knowledge
  - Not all coastal erosion is irreversible
  - Role of climate change component
- Protect the autonomy of communities by providing tools for informed decision making

How can

HAZARDS IN THE COASTAL ZONE BE MITIGATED?

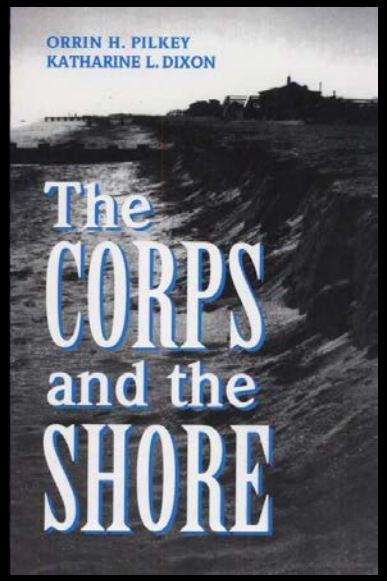
Management Options

Do Nothing / Abandon

Adapt / Accommodate

Managed Retreat

Defend / Fortify



- The European approach = preventative
- United States practice = reactionary
- An Alaskan advantage

DO NOTHING
ABANDON

Stay the course until no longer possible to remain in hazardous area.

Pros:

- Less expensive
- Maximizes usefulness of existing structures
- Natural course of action
- Minimal effects on nearby property

Cons:

- *Dangerous*
- Potentially harmful to environment
- Legal grey area in some states
- ‘Unfair’ to property owners

Pacifica, CA (Gary Griggs)

ADAPT
ACCOMMODATE

Examples:

- Build on raised foundations
- Protect infrastructure from salt corrosion
- Employ movable housing
- Establish emergency procedures and evacuation plans
- Raised gardening beds
- Install and improve warning systems
- Document known hazards & manage future development

Seward, AK (Orson Smith)

MANAGED RETREAT

Phases out imperiled structures on an as-able basis

Complex politics are always involved, concern about loss of community identity

In Alaska this strategy takes the form of “relocation” for many rural coastal communities

Currently 3 AK communities are exploring full relocation and 12 are seeking phased retreat options

Newtok is in the process of relocating to Mertarvik

DEFEND
FORTIFY

Hard solutions:
- Seawalls
- Revetments
- Breakwaters
- Groins

Soft solutions:
- Beach nourishment
- Sediment bypass systems
- Dewatering
- Revegetation
- Dual use structures

Trend outside of Alaska moving towards more soft solutions.

False sense of security issue

Deters long-term management strategies

Local-level vs. State & Federal

Unalakleet Revetment, AK (Kinsman)

(Guide by Stoney J.Wright)

Hooper Bay Tundra Trail(ADN 2011)

Seawalls

Pebble Beach, CA (Kinsman)

Del Mar, CA (CA Coastal records project)

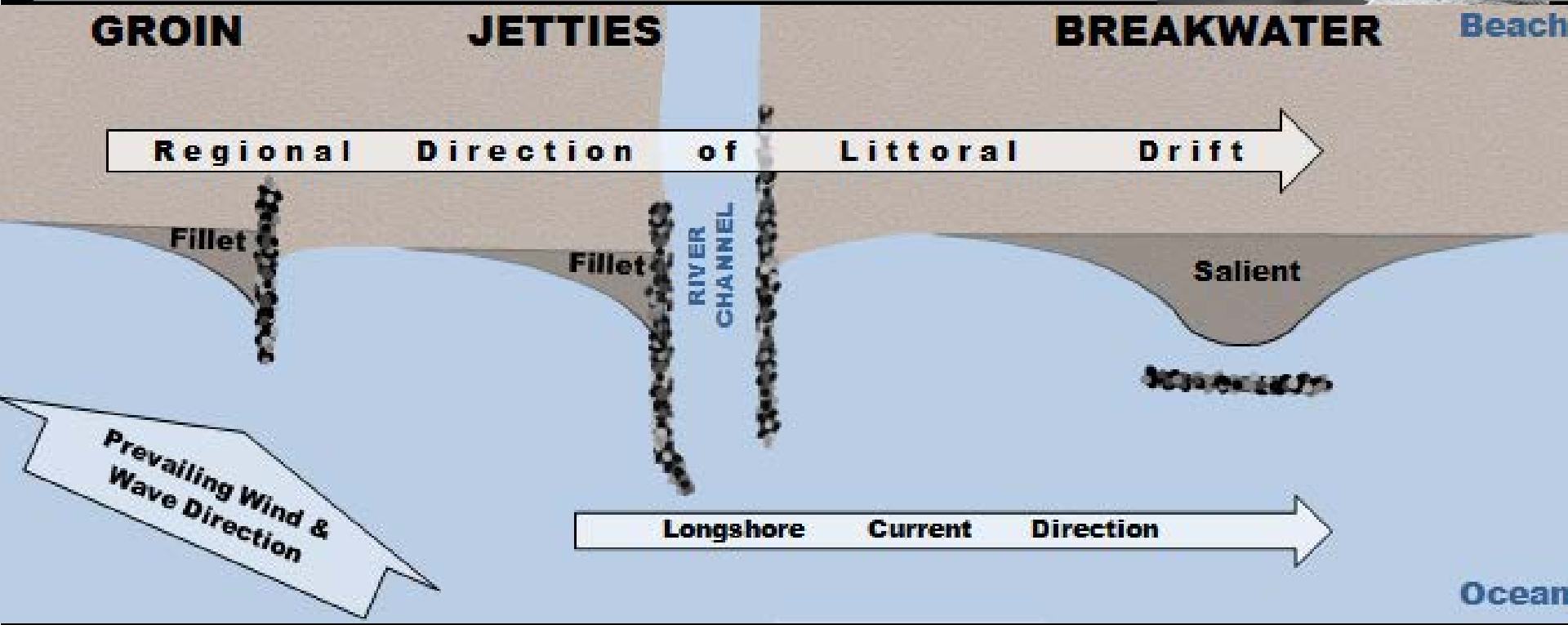
Revetments – Fort Ord

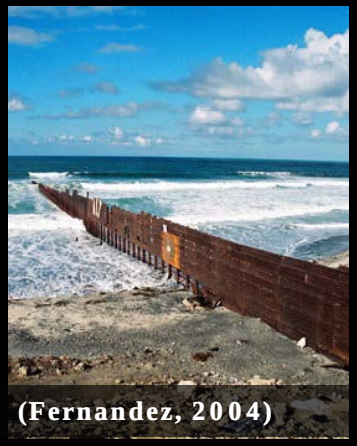
(CA Coastal records project)

Revetments – Fort Ord

(CA Coastal records project)

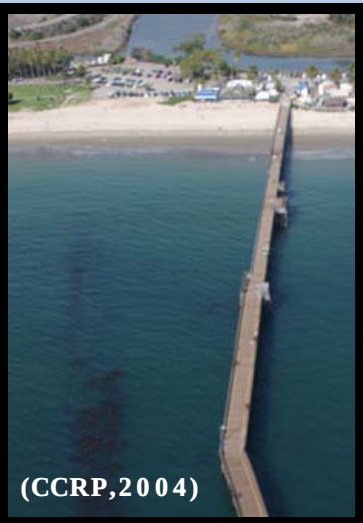
Stabilization/littoral barriers




(Fernandez, 2004)

(HBVB, 2009)

(CCRP,2002)


(CCRP,2004)

Engineered Coastal Structures

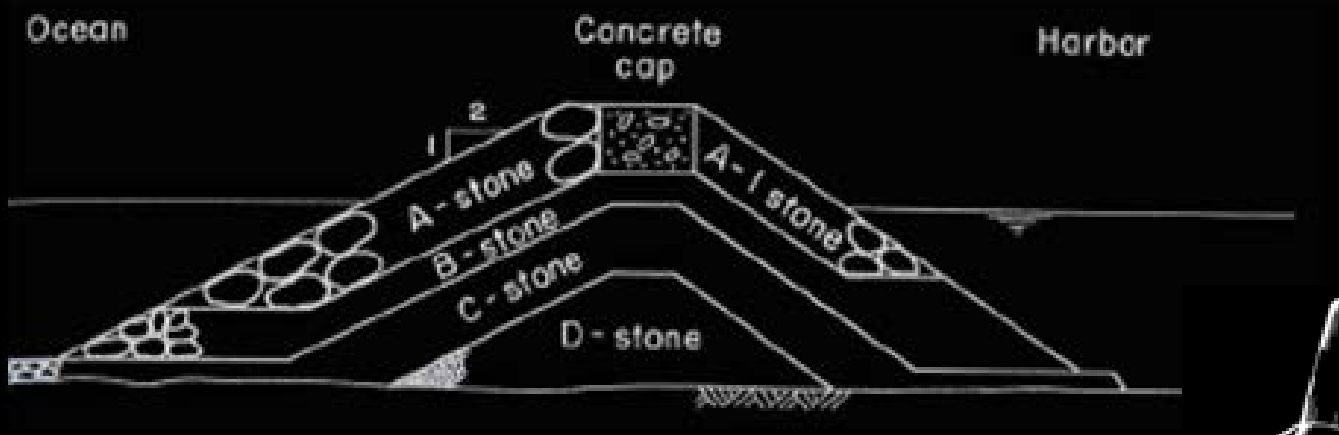
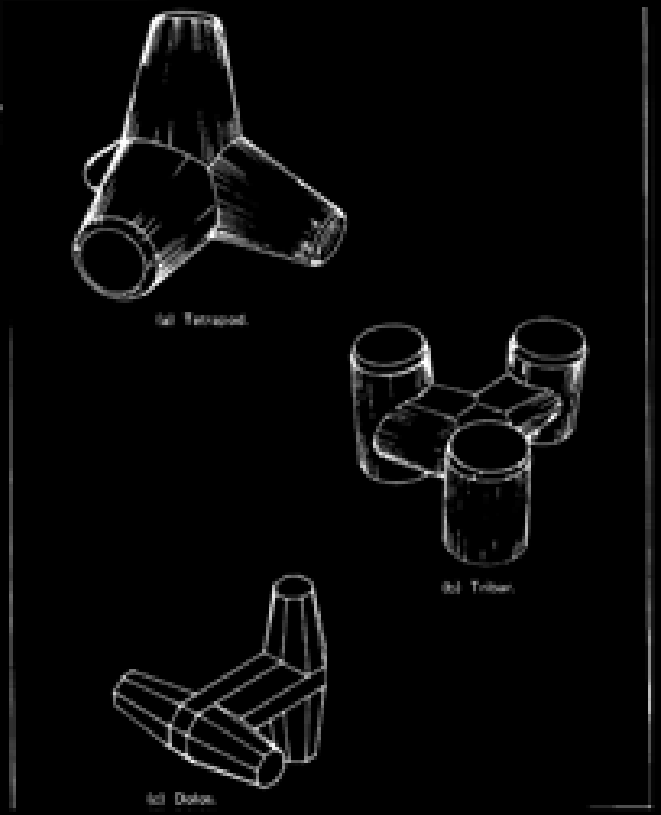


Photo by Susan Winters



Beach Nourishment

"Beach nourishment involves the addition of large quantities of sand or gravel to beaches with the aim of repairing eroded areas or widening existing ones." (Komar, 1998)

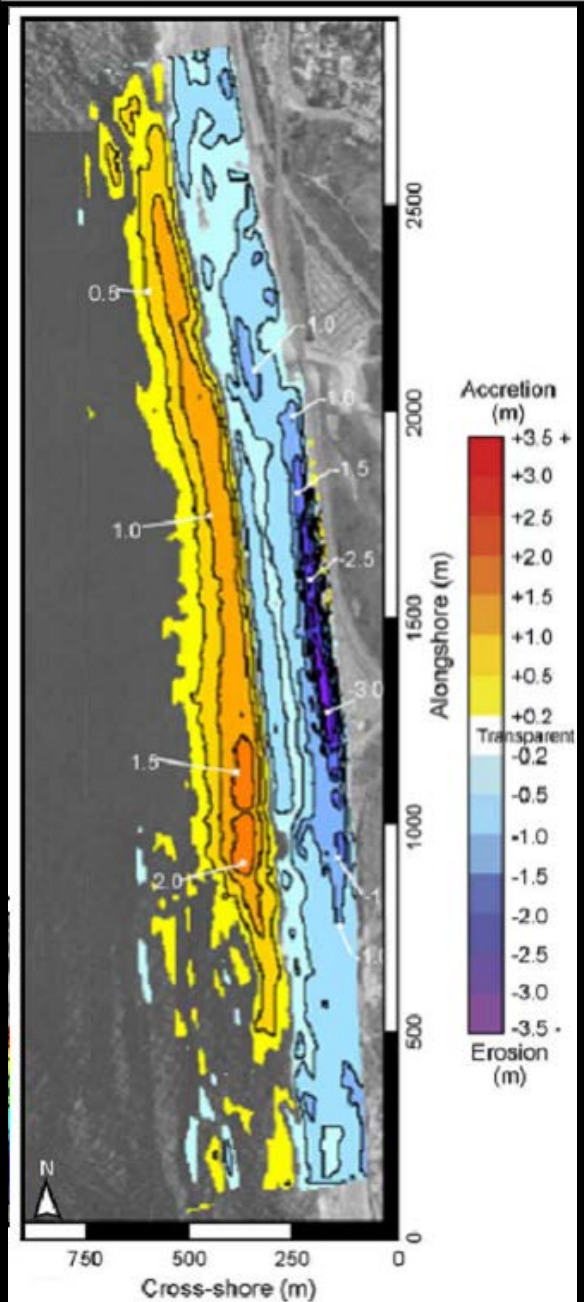
- Problems
  - Locating compatible sediment
  - Transporting adequate quantities
  - Retaining the sand
  - Adverse environmental effects
  - Variable *Lifespans*
  - Expensive

(Griggs, Patsch and Savoy, 2005)

← Dredging and Nourishment at South Carlsbad State Beach, 2001

Image from Scripps Coastal Geomorphology Group, 2003 (http://coastalchange.ucsd.edu/)

Mixed Success…



- 2001
- $17.5 million
- 2 million cubic yards
- Oceanside to Imperial Beach (~6 mi), San Diego County
- 25-100 ft. wider
- Lifespan: Just over 1 year

(Patch and Griggs, 2006)

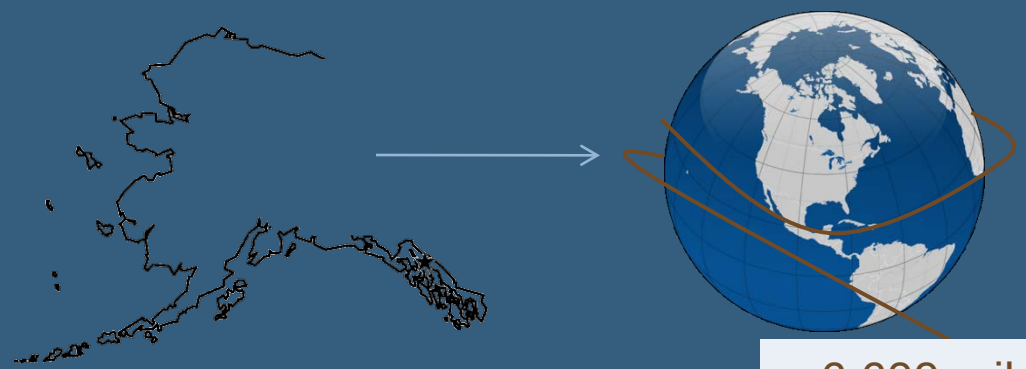
← Changes in nearshore bathymetry over a 23 day period around a nourished area at Torrey Pines State Beach in response to a November, 2001 storm event.

(Seymour, 2005)

What is

HAPPENING ON THE ALASKAN COAST?

Why is the Alaska interested in coastal hazard maps?



~ 6,600 mile coastline
> 40,000 mile tidal shoreline

2010 Census: 64% of AK residents live in coastal communities

12% of AK communities are not participating in the National Flood Program
Including: Unalaska, Stebbins, Kenai, Savoonga, Gambell, Hooper Bay, Unalakleet

2009 Government Accountability Office report identified 20 coastal Alaska Native villages as imminently threatened by flooding and erosion

Many of Alaska's coastal communities are involved in mitigation or adaptation efforts in response to natural hazards

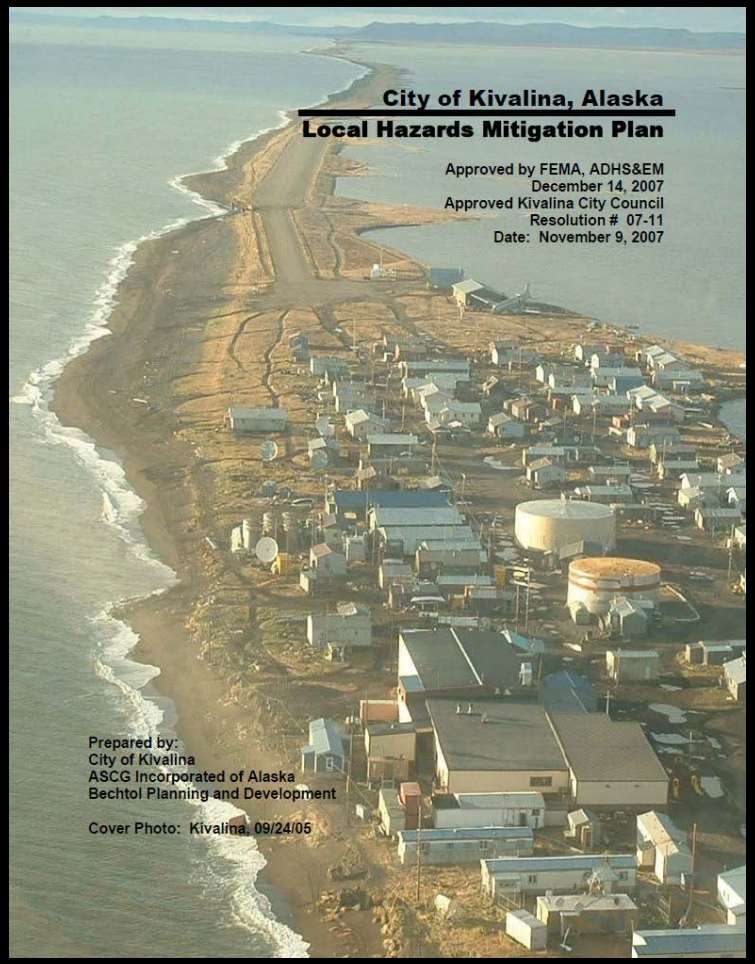
The State and local governments require sound baseline data to fuel informed decision-making

The Coastal Zone Management Act (1972)

- CZMA encourages *integrated* state-level coastal management
- Goal to “protect, restore, and responsibly develop our nation’s diverse coastal communities and resources”
- Participation is voluntary & State management plans vary
- Access to federal funding for enhancement, conservation and pollution control

‘Imperiled’ Community Actions

- Hazard Mitigation plans to qualify for federal disaster aid
- Exploring National Flood Plan involvements
- Local mitigation strategies
- DOT armoring of runways
- Fortified evacuation centers
- COE revetment projects
- Evacuation route design
- Relocation plan development – exploratory committees
- Raising awareness
  - Kivalina lawsuit
  - IAWG or GAO lists



Relocation Steps

- Quantification of need to relocate
- Initial site selection
  - Safe & feasible
  - Subsistence access
  - The 3 factors: Water, Barge & Sewage
- Identification of fiscal resources
- Local, State and Federal review of site
  - The 3 factors: Airstrip, School & Post Office
- Land transfer, permitting and exchanges
- Site preparation & relocation

Local/regional body	Example Shaktoolik, AK 2010 Population: 250
City Offices	City of Shaktoolik
Native Village Corp.	Shaktoolik Native Corp.
Local Tribal Council	Native Village of Saqtuliq
Regional Native Corp. (IRA Council)	Bering Straits Native Corp.
Regional Native Nonprofit	Kawerak, Inc.
Borough/ Census Area	Nome Census Area
Coastal Management District (now defunct)	Bering Straits Coastal Resource Service Area

This is a *LONG* process

<u>Obstacles include:</u>
- Frustration
- Role of local knowledge
- Local politics
- Large number of players
- Time constraints
- High expense
- Deferred maintenance of current infrastructure
- Building material sources
- Improved sense of security with engineered measures
- Conflicting studies with limited data

NEWTOK

MERTARVIK

Nunaullemteggun ikayuqulluta tamamta, assirluta aknirtenritellerkamtenun, nuggtarliemtenun ciunerkamteni

a community that builds together for the safe and healthy future of Newtok

Relocation efforts began in 1994

- demonstrated need (ASCG)
- geotechnical report (USACE)
- transportation plan (ASCG, DOT)

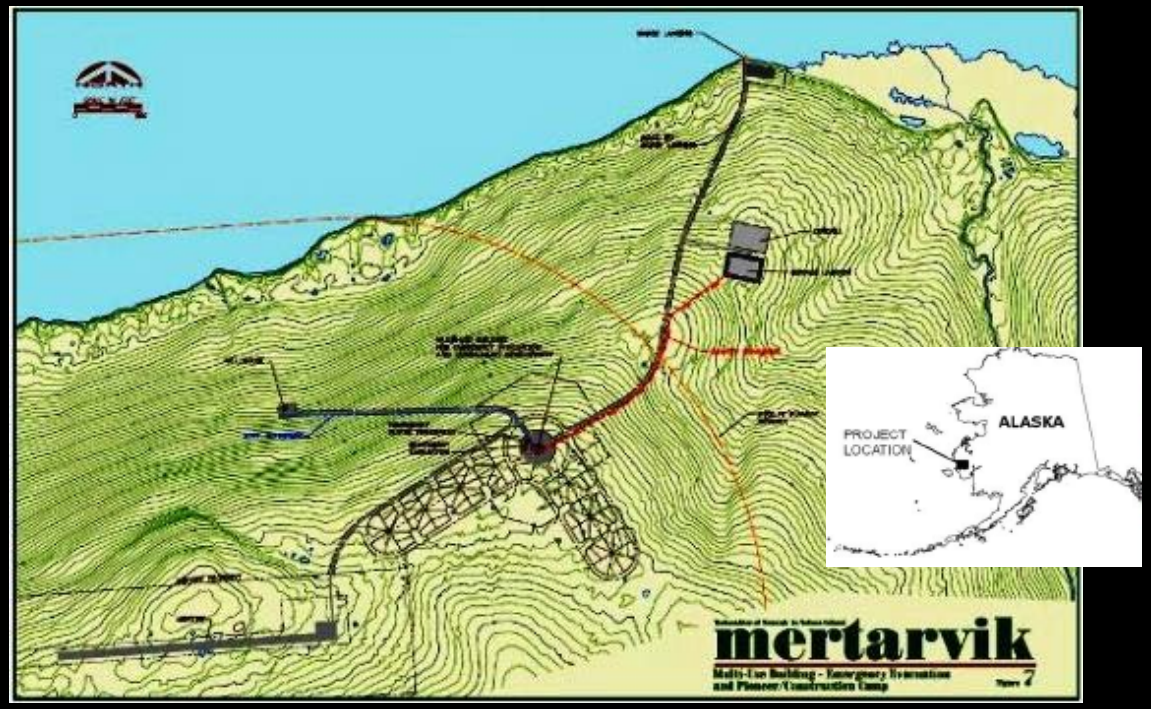
BIA Funding for planning

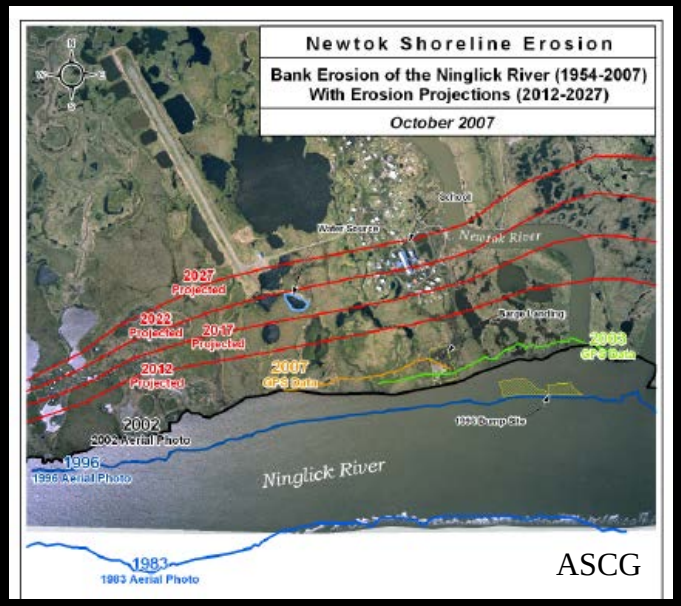
Newtok Planning Group

New site is ~9 miles inland

Located within Nat'l Wildlife Refuge

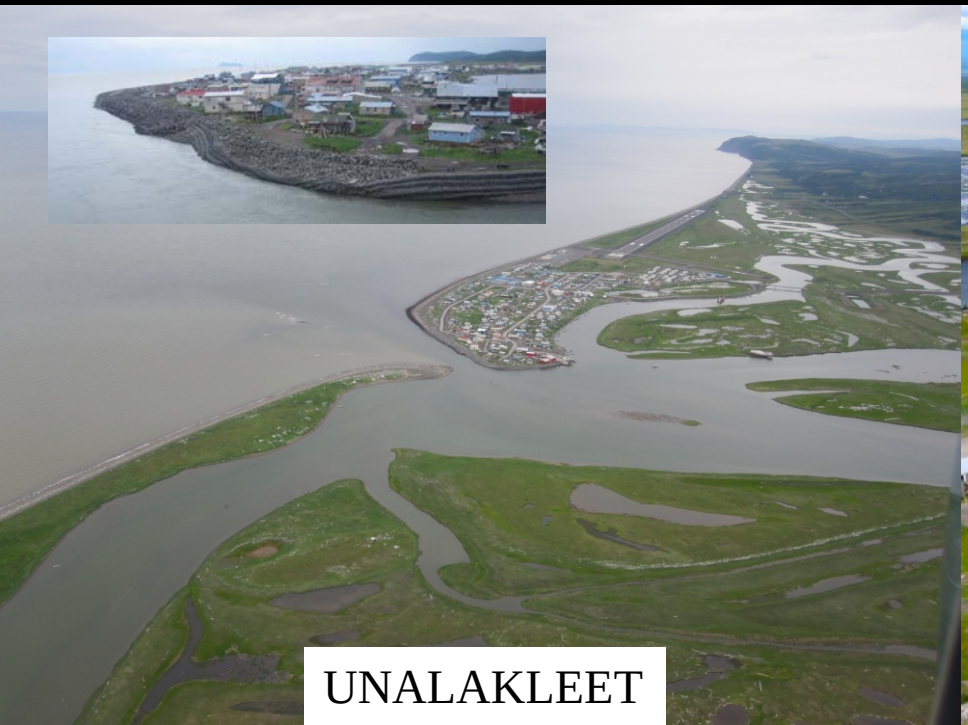
Construction primarily funded with short-term annual $





ASCG

KIVALINA



UNALAKLEET

SHAKTOOLIK

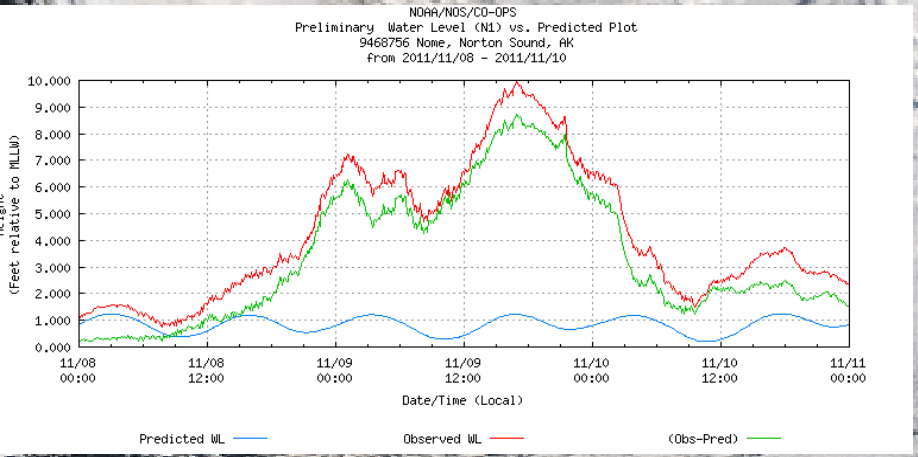
November 2011 Bering Sea Storm DGGS Rapid Response

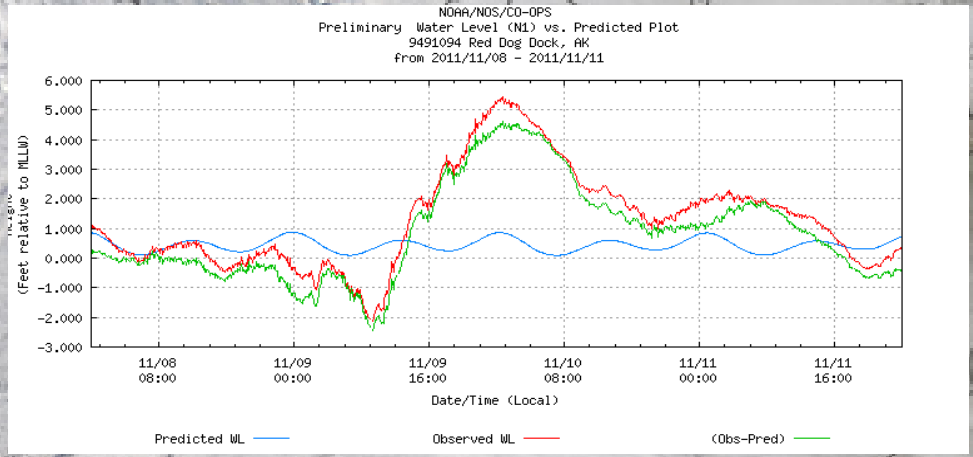
Quick Storm Facts

- November 8, 2011
- Non-tropical cyclone with a low of 945 millibars
- High winds (gusts of up to 85 mph)
- Surge of ~10 feet to parts of Norton Sound

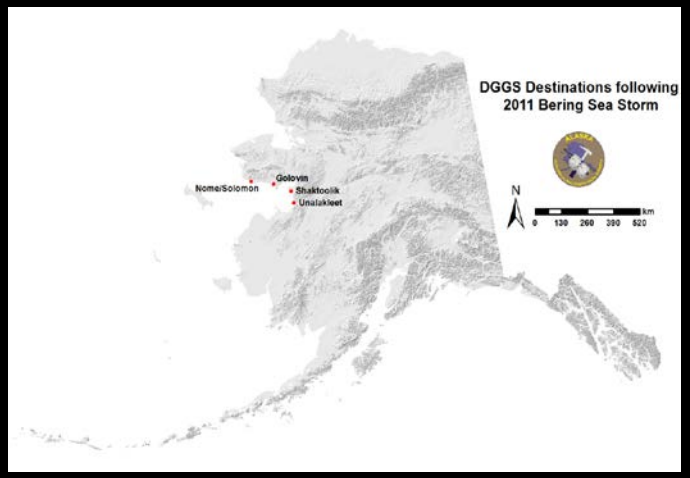
DGGS Rapid Response

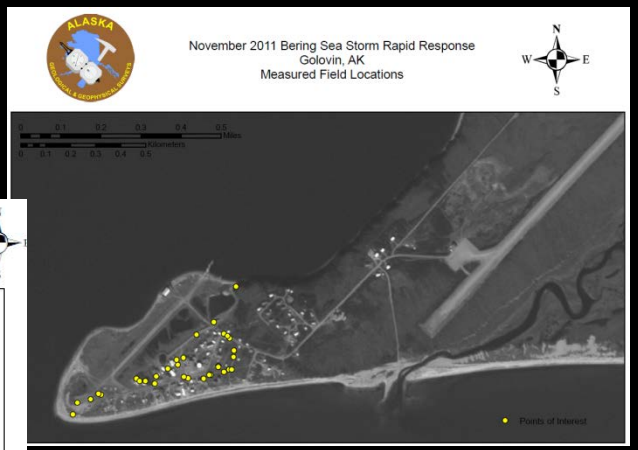
- 4 communities
- w/in 24 hours of storm departure
- Liaison between State & Federal agencies and communities we have worked in





Response Locations



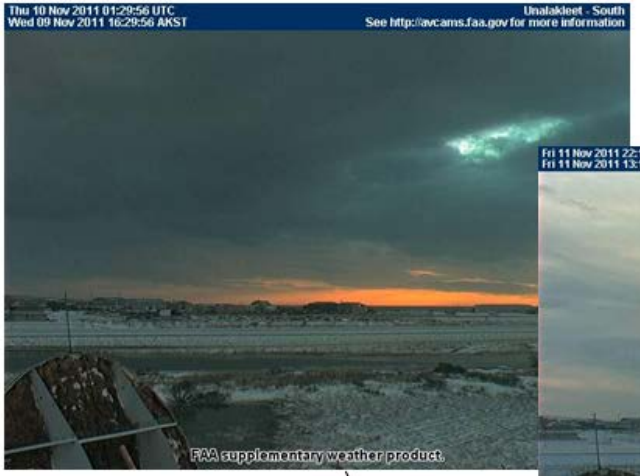


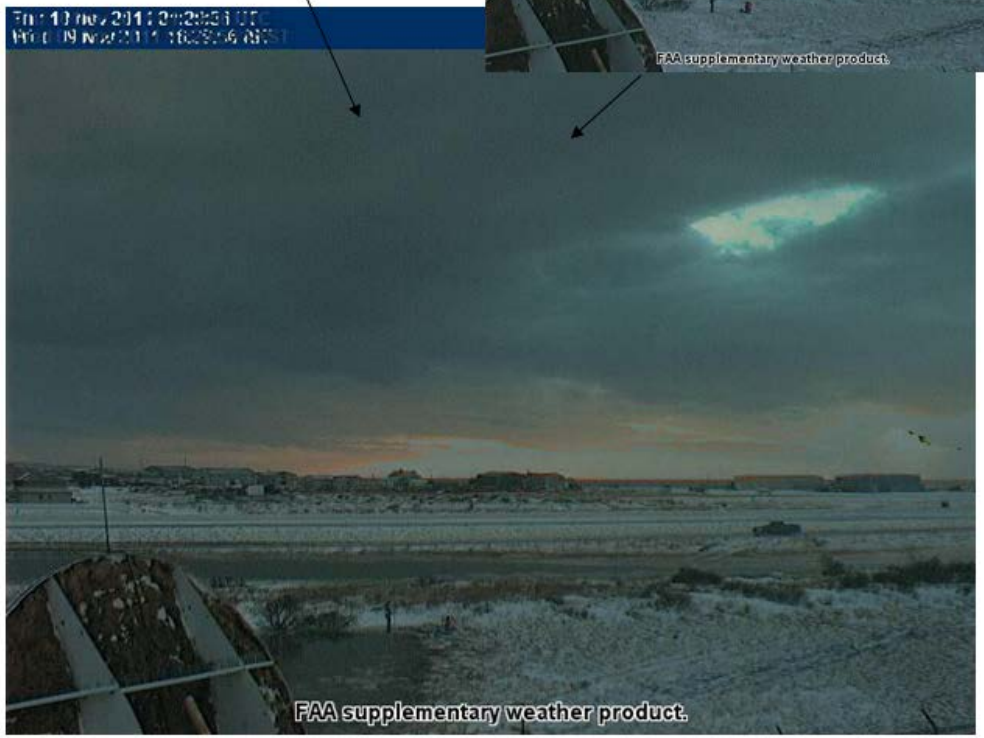
UNALAKLEET

In two days:

- Reoccupied 9 coastal profiles
- Measured 20 inundation extents
- Collected photos & video from residents

Limited flooding up to raised road along front of community, not perceived by all residents to be worse that previous 2000-era storms. Blow-out occurred of gabion revetment at inlet mouth.





SHAKTOOLIK

In two days:

- Reoccupied 5 coastal profiles
- Measured 13 inundation extents
- Collected photos & video from residents

Overwash into Tagoomanick River bend S. of old community site

Overtopping of old woody storm deposit at Native Corp. building

Limited flooding, with more concern on the Tagoomanick River side of the community than on the sea-side due to an ice jam that caused water to back up in the river. Some overtopping of old storm deposits on sea-side and one area of overwash near old community. Significant notching of coastal bluffs at old community site. Perceived by most residents to be worst event at new site (moved there post ’74 storm).

Ice pile-up at old fish processing plant, on Tagoomanick side of the community

NOME/SOLOMON

In one day:

- Established 3 coastal profiles
- Measured ~12 inundation extents

Lots of damage to engineered revetments with large armor rock carried from the ocean side of the road in places into the inland lagoon. Impressive coastal bluff overtopping ~10 miles east of Nome.

GOLOVIN

In one day:

- Measured ~32 inundation extents
- Visited site of ivu at fishcamp
- Collected photos & video from residents

Extensive flooding throughout the lower community and a large ivu (ice push) that carried some cabins kms and piled others up/reduced them to rubble at a fishcamp further up in the bay. Loss of telephone service.

Thank You