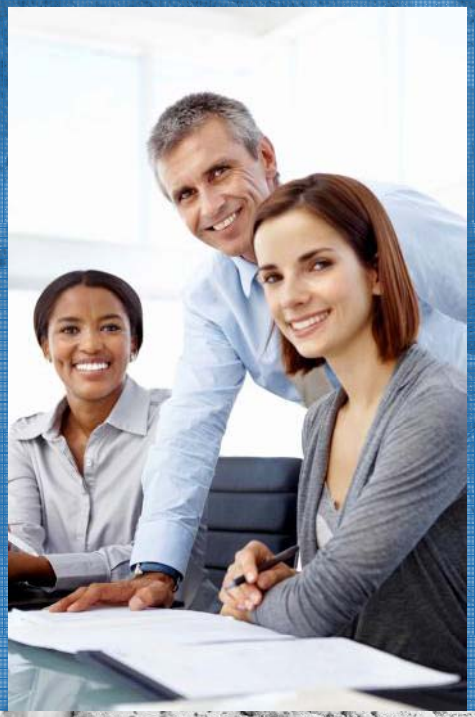

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Expected Sea Level Rise – Implications and Options for Adaptation

John S. Readshaw, P. Eng.
Manager, Coastal Engineering and Dredging
SNC-Lavalin Inc

Contents

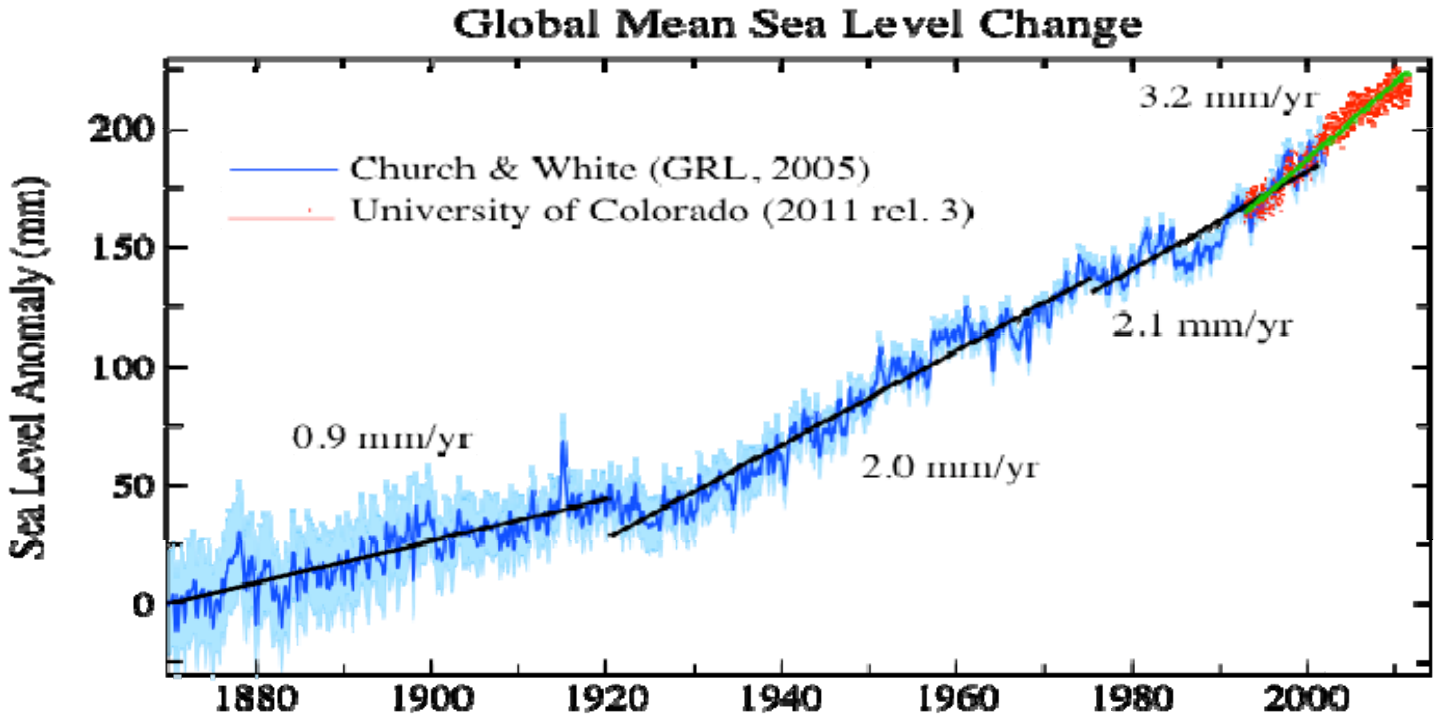
SLR and Expectations

Implications and Consequences

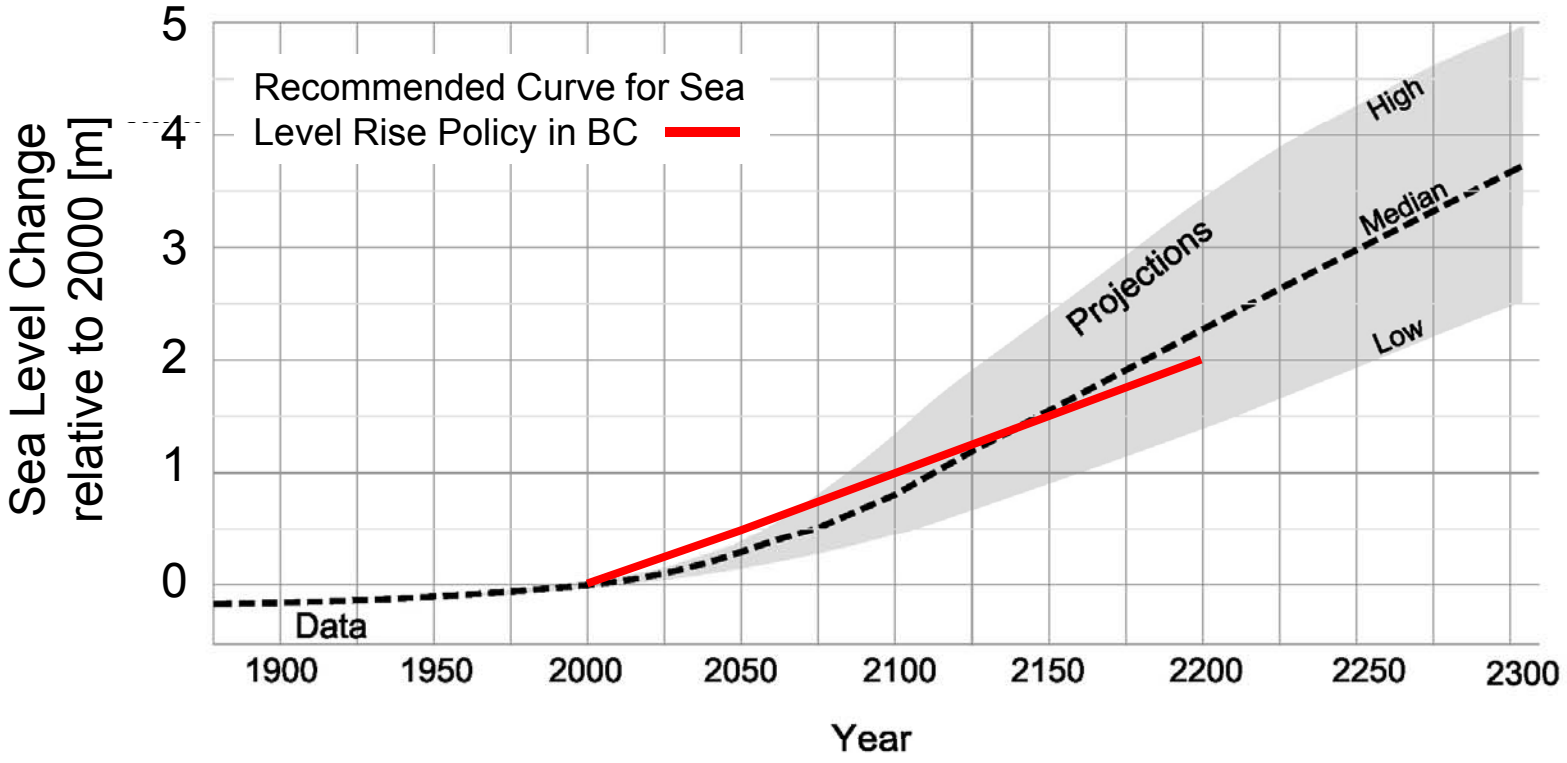
Guidelines for Solutions

Example Situations

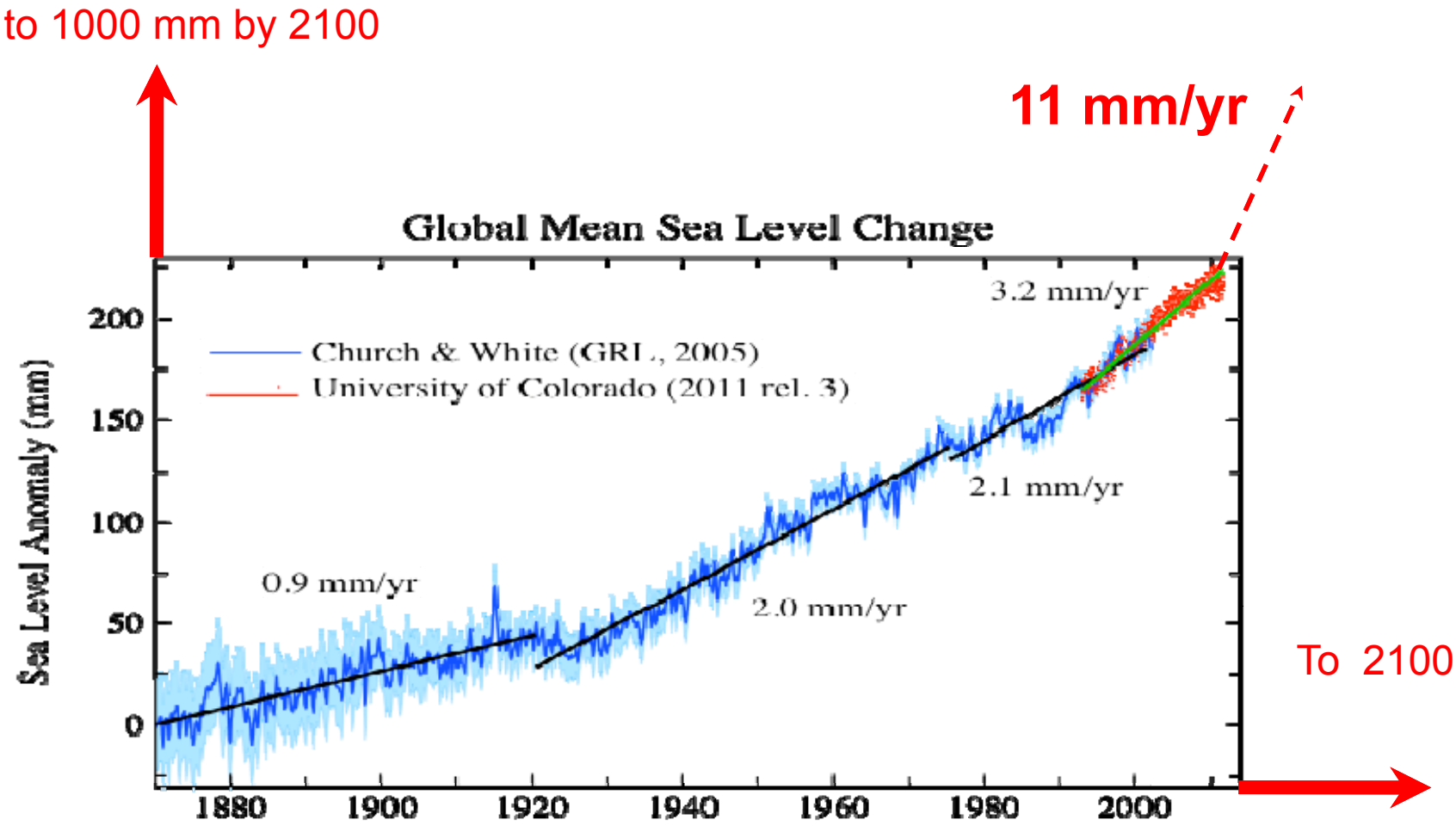
Recent Sea Level Rise Rate



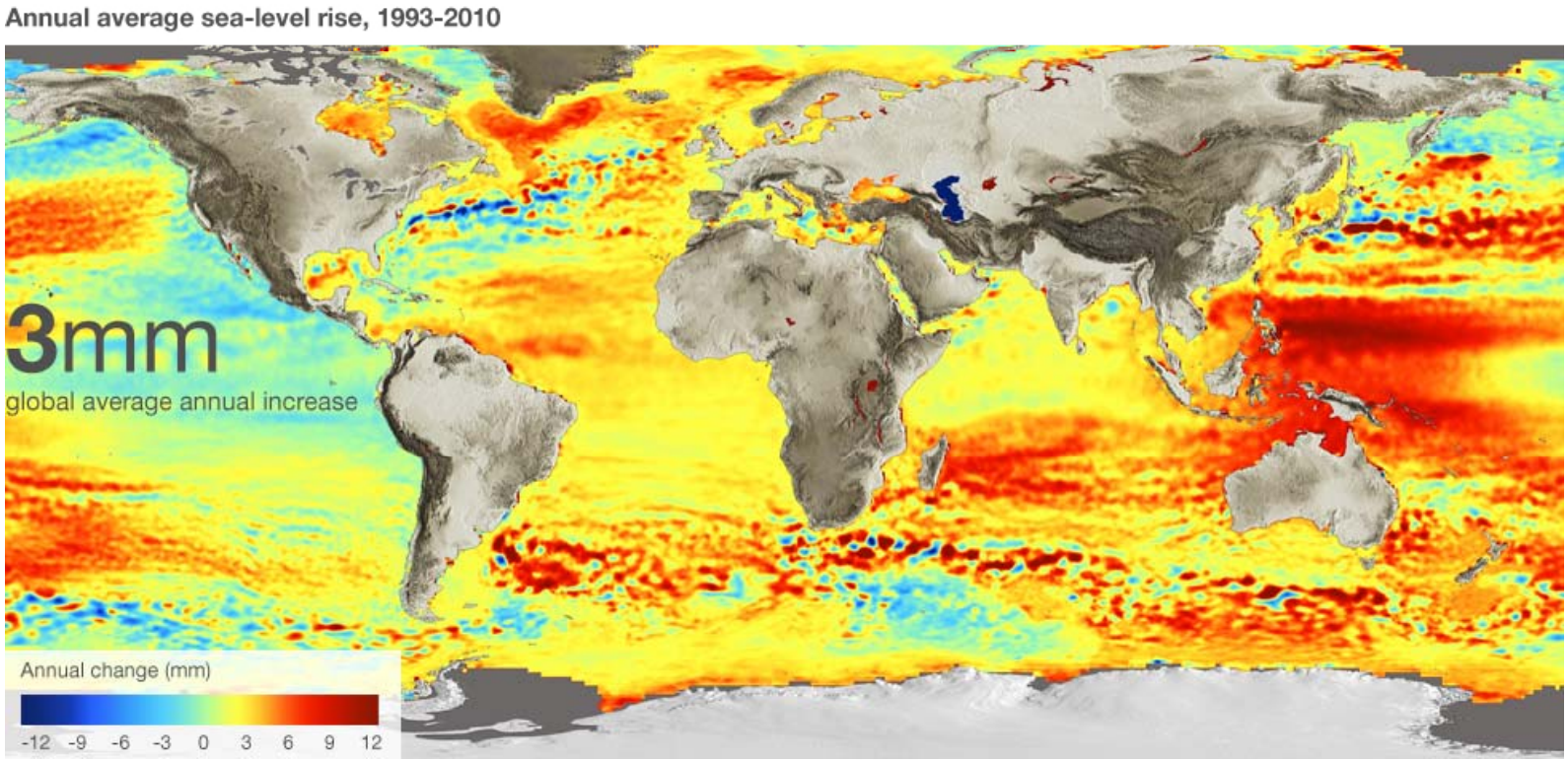
BC Guideline (2011)
Recommendations for SLR Planning



Required Sea Level Rise Rate to Meet Guideline

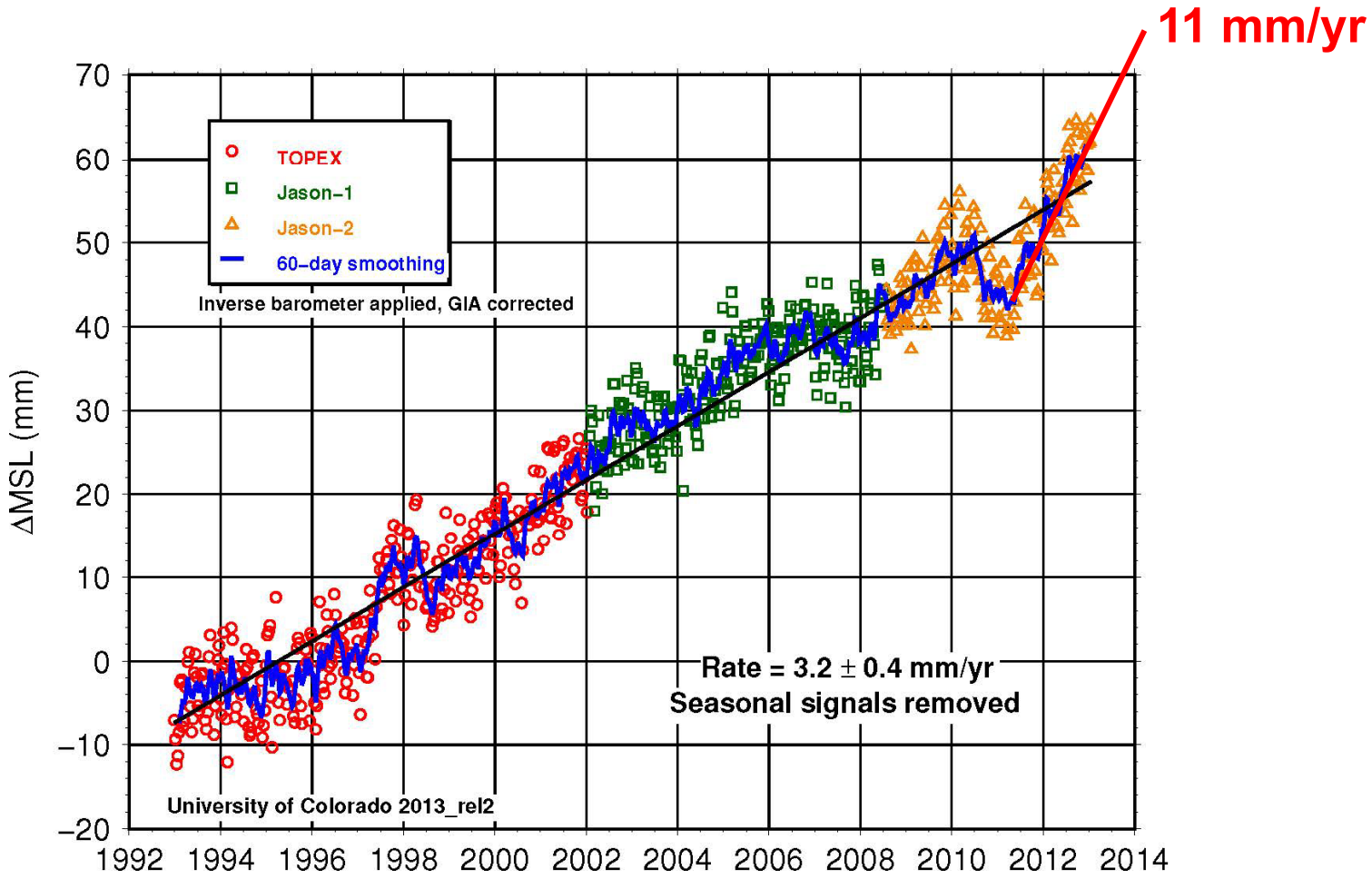


Measured Global Sea Level Pattern
1993 - 2010



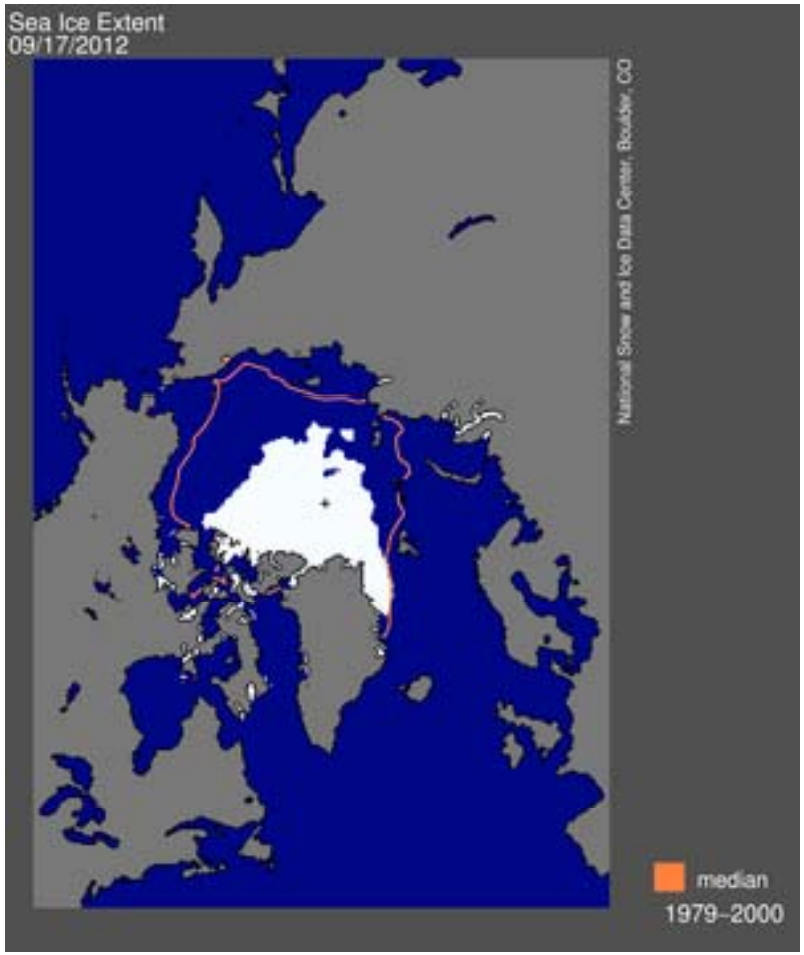
University of Colorado – Sept 2012

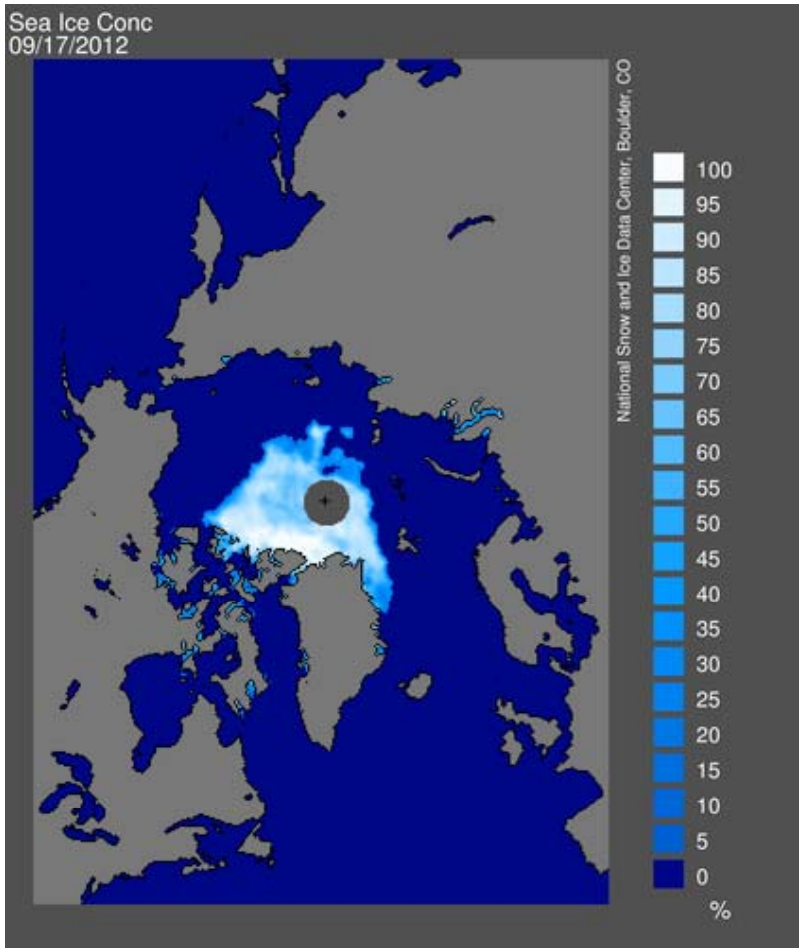
Updated (2013 Global Mean) Sea Level Rise Rate



Adapted from: Nerem, R. S., D. Chambers, C. Choe, and G. T. Mitchum. "Estimating Mean Sea Level Change from the TOPEX and Jason Altimeter Missions." Marine Geodesy 33, no. 1 supp 1 (2010): 435

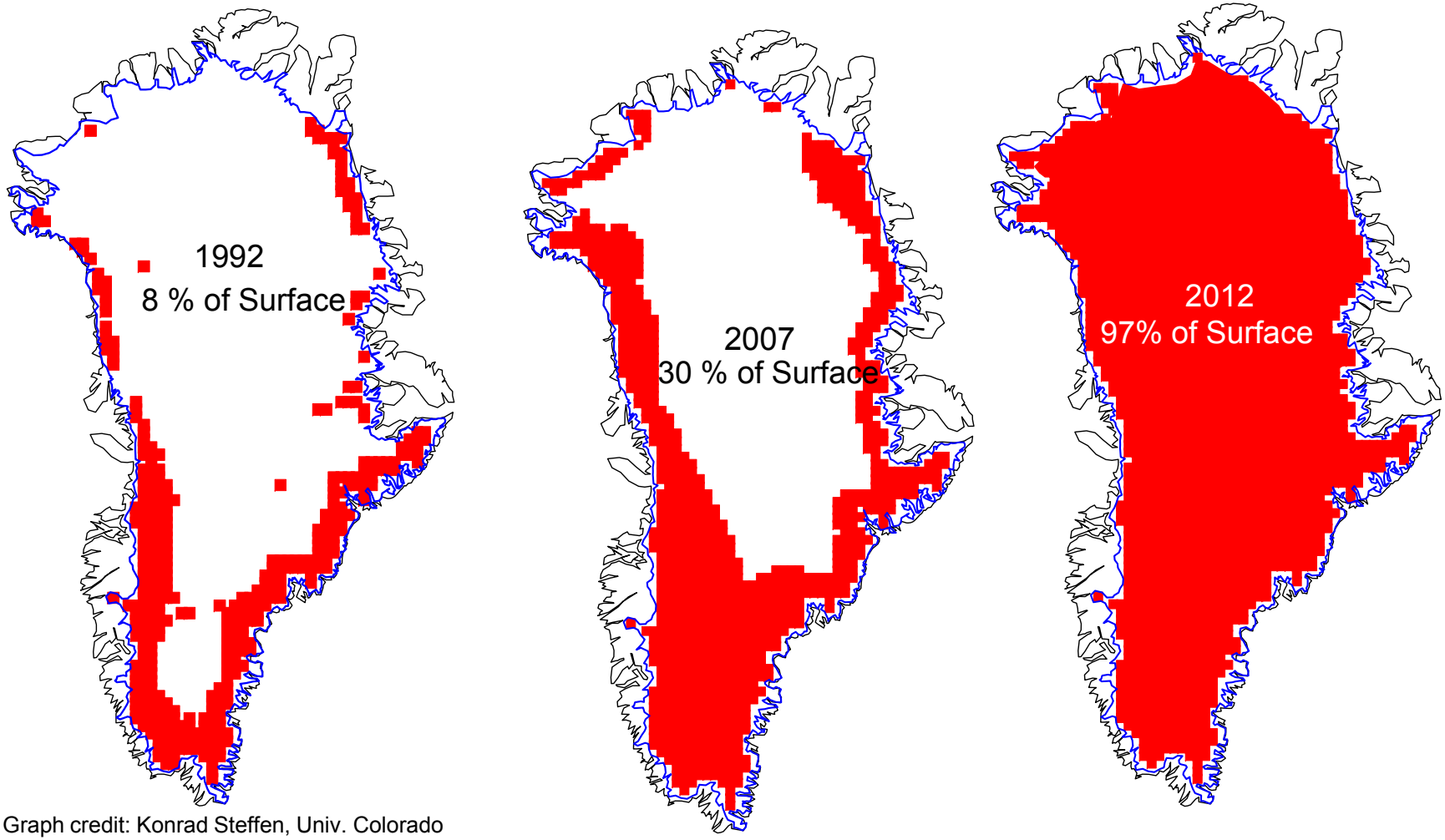
Summer Melting of Arctic Sea Ice





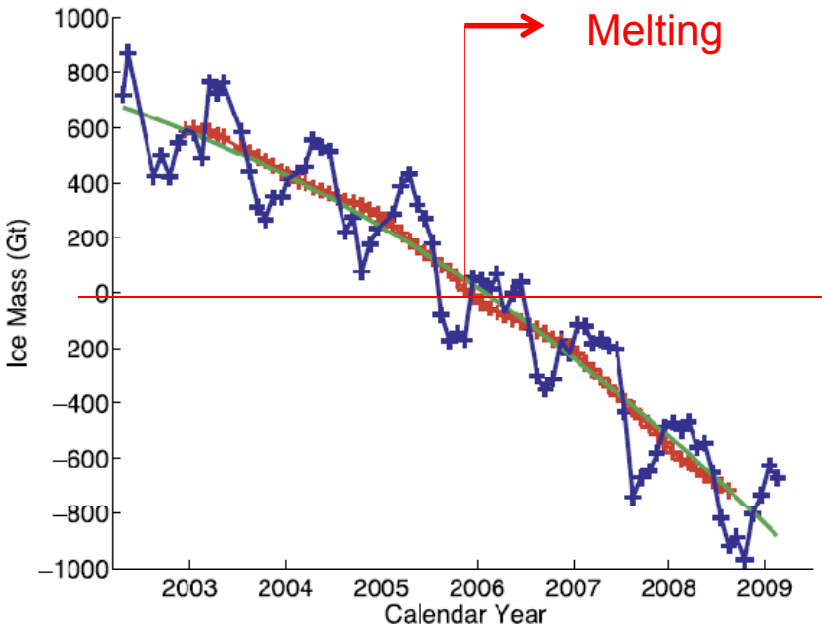
Data: 17 September 2012.
Source: Hansen 2012 and National Snow and Ice Data Center, Boulder, Colorado

Greenland Melt Area Trend

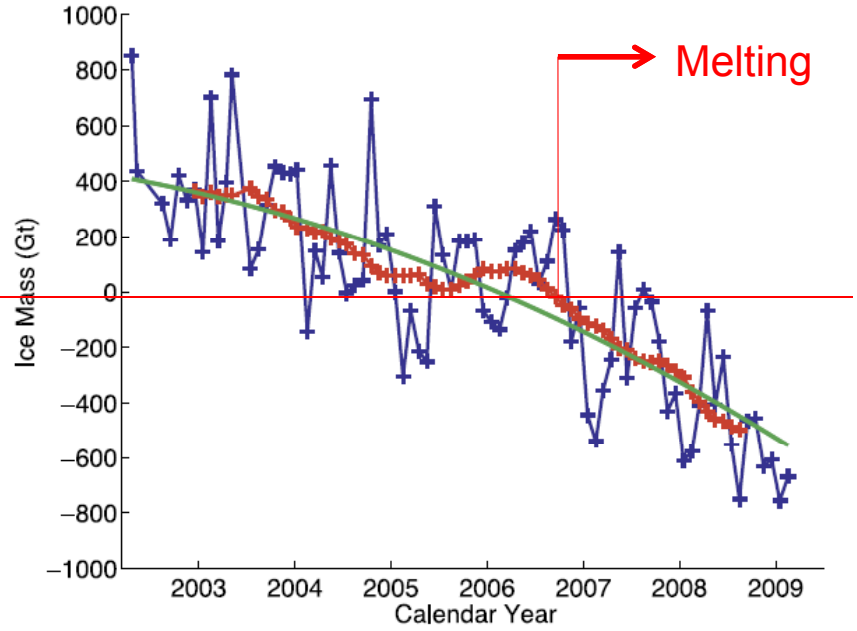


Graph credit: Konrad Steffen, Univ. Colorado

Melting of Large Ice Sheets



Greenland Ice Sheet



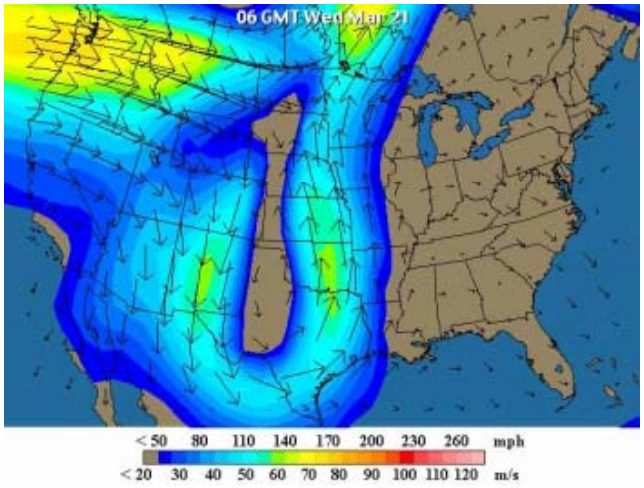
Antarctic Ice Sheet

Source: Velicogna, I. *Geophys. Res. Lett.*, **36**, L19503, doi:10.1029/2009GL040222, 2009.

Arctic Warming

- Arctic warming is altering and slowing the jet stream
- Upper atmosphere weather systems are progressing more slowly
- Increasing occurrence of persistent (stalled) weather
- In future, may increase the chance of a storm at high tide

Path of the jet stream on March 21, ‘12.
Credit: weatherunderground.



Jennifer Francis,Rutgers and Stephen Vavrus University of Wisconsin Madison, GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L06801, 6 PP., 2012
Also:Vladimir Petoukhov, lead author, Potsdam Institute for Climate Impact Research, Germany. Proceedings of the National Academy of Sciences, 2013.

Implications to Coastal BC Waters

Intertidal Water Depths

- More wave energy moving closer to shore
- Stronger wave induced currents
- More and faster erosion of seabed and feeder bluffs, banks or cliffs

- could be offset by sediment transport, but only;
  if sources (cliffs, eroding banks) not armoured.

Implications to Coastal BC Waters

Shallow water near shoreline:

- Increased depth of water near high tide shoreline
- Larger breaking waves
- More wave runup on the shoreline
- Larger wave forces on beach and shoreline materials
- More overtopping (spray) on shorelines and coastal structures

Breaking wave crests close to shoreline during SE storm of 12 March 2012

Waves at edge of highway during storm in November 2011

Peninsula Areas at Risk - 2100

http://www.env.gov.bc.ca/wsd/public_safety/flood/pdf_drawings/index.html

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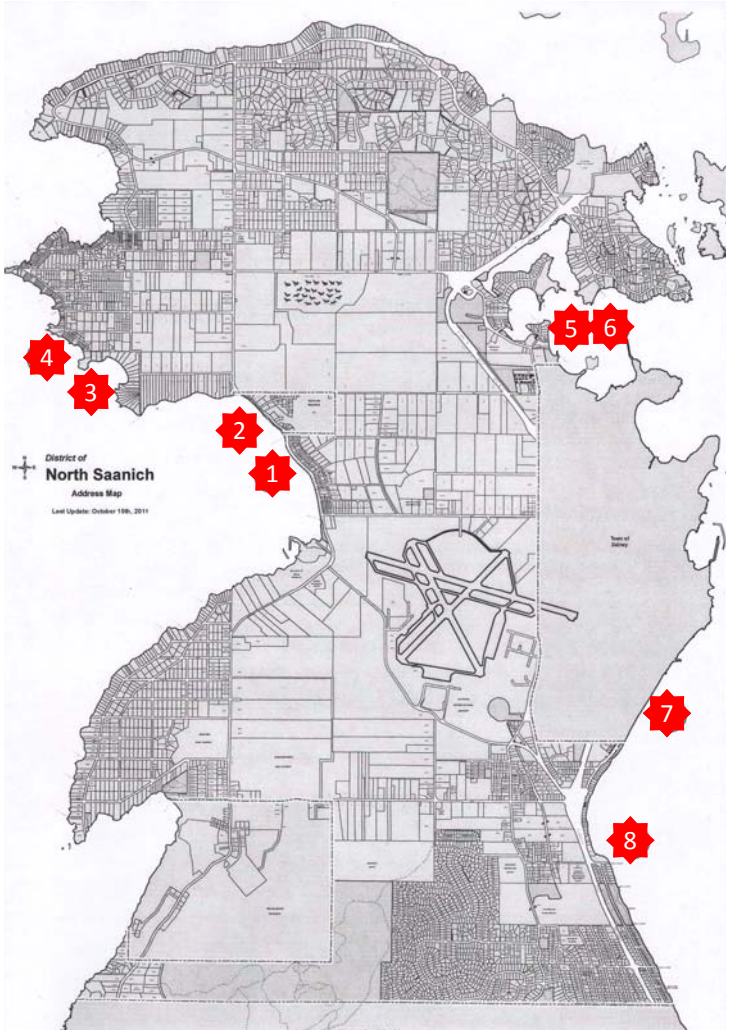
Example Areas



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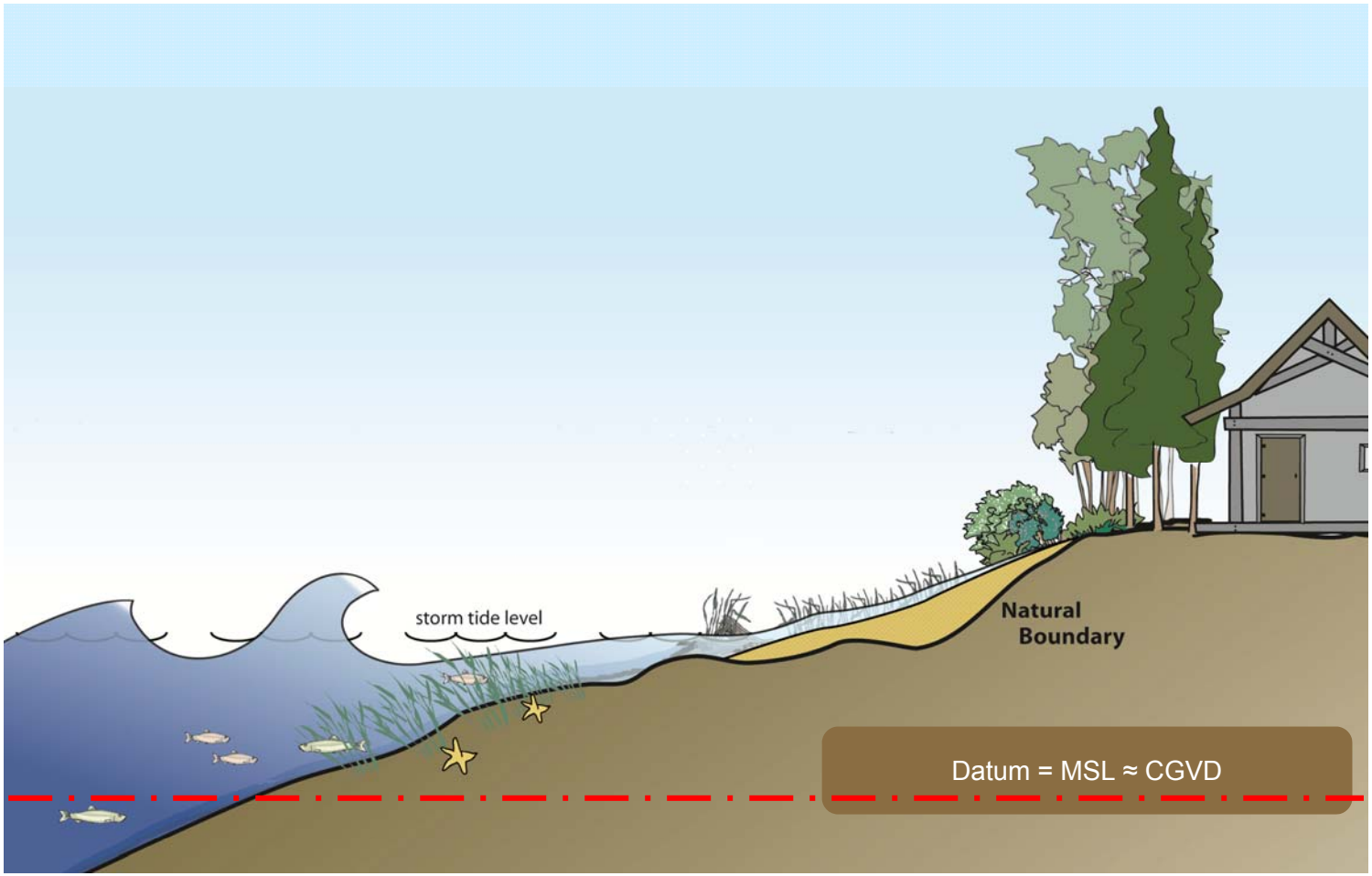
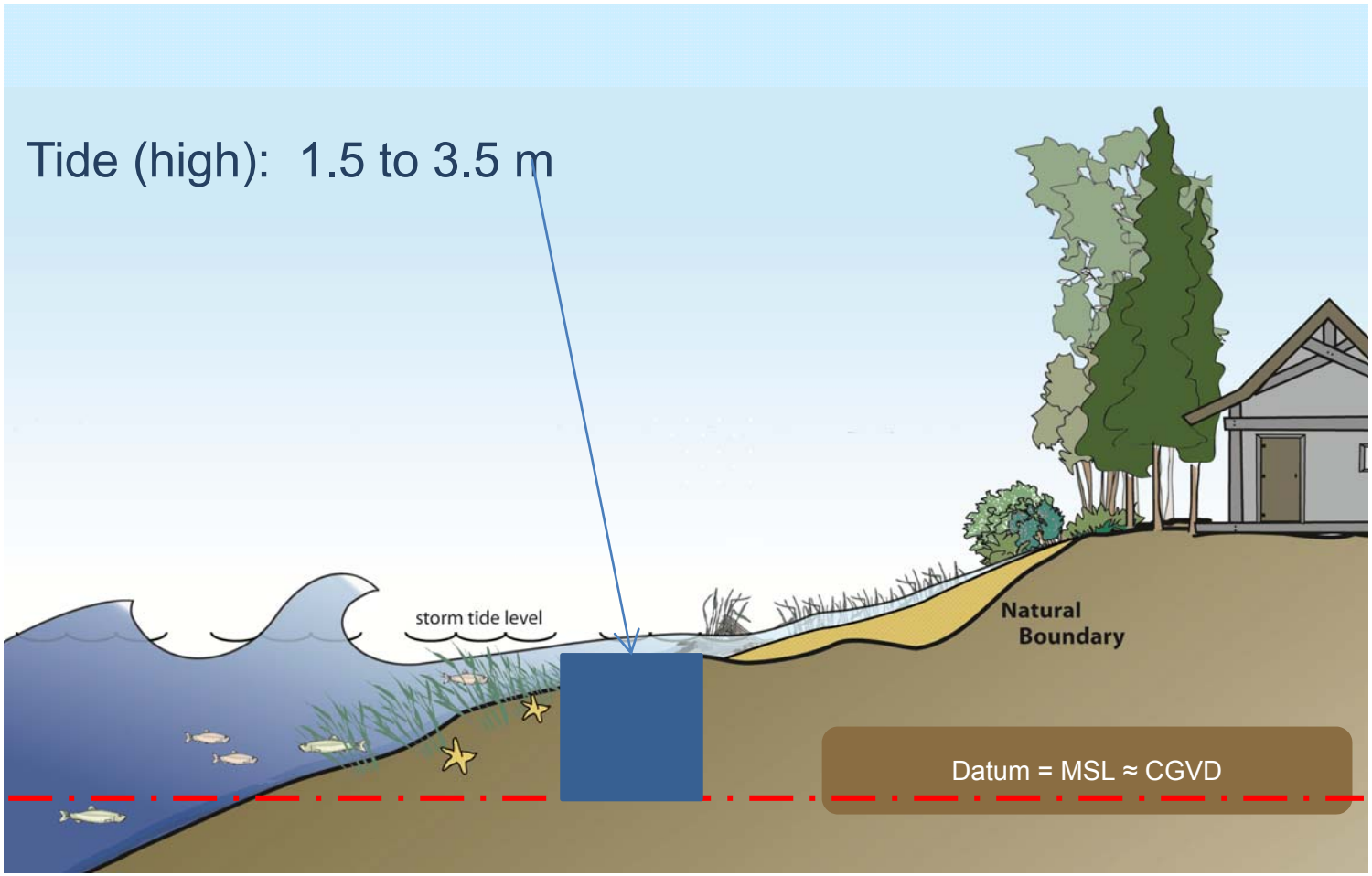
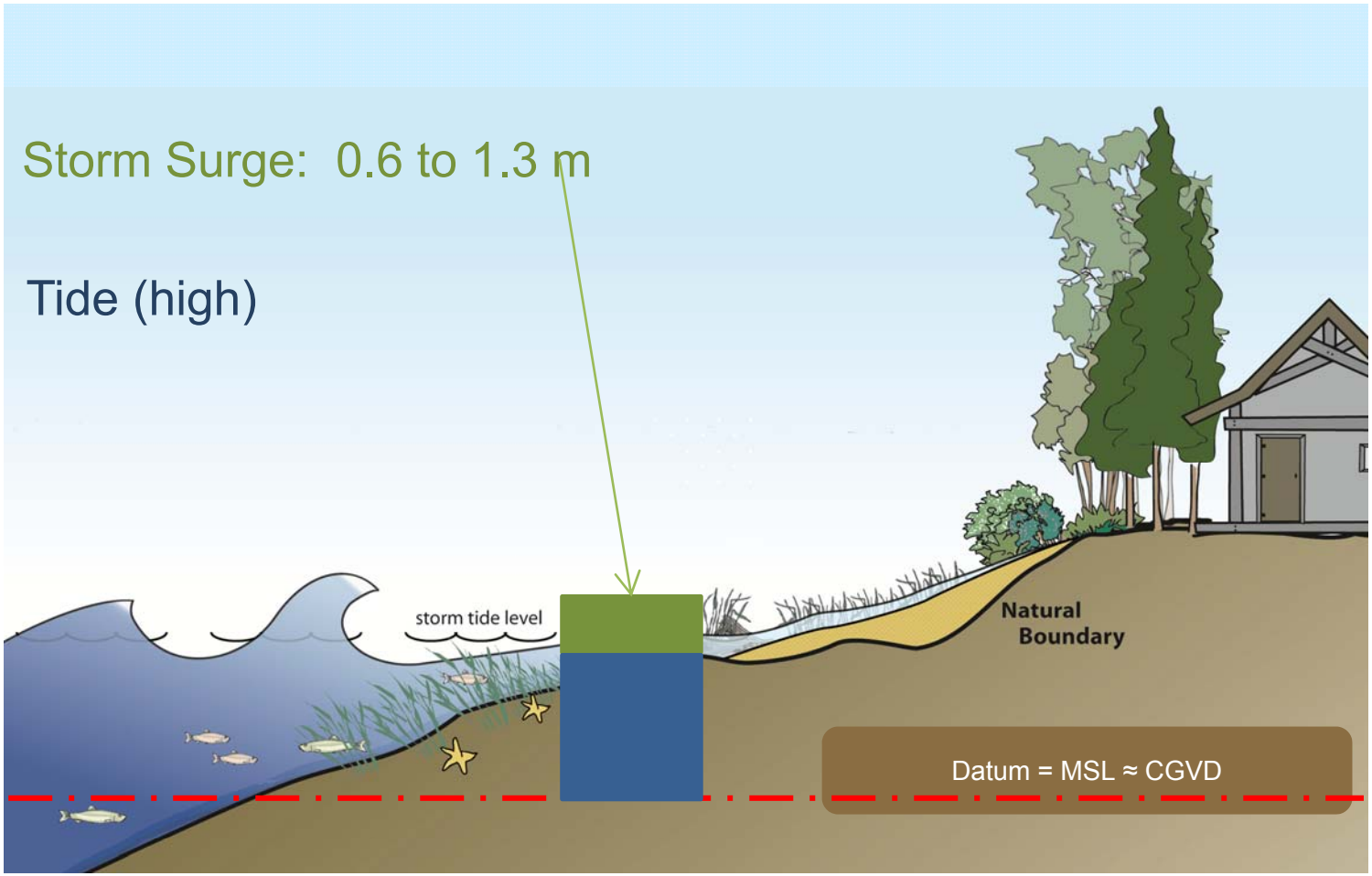
Implications to Shorelines: Components



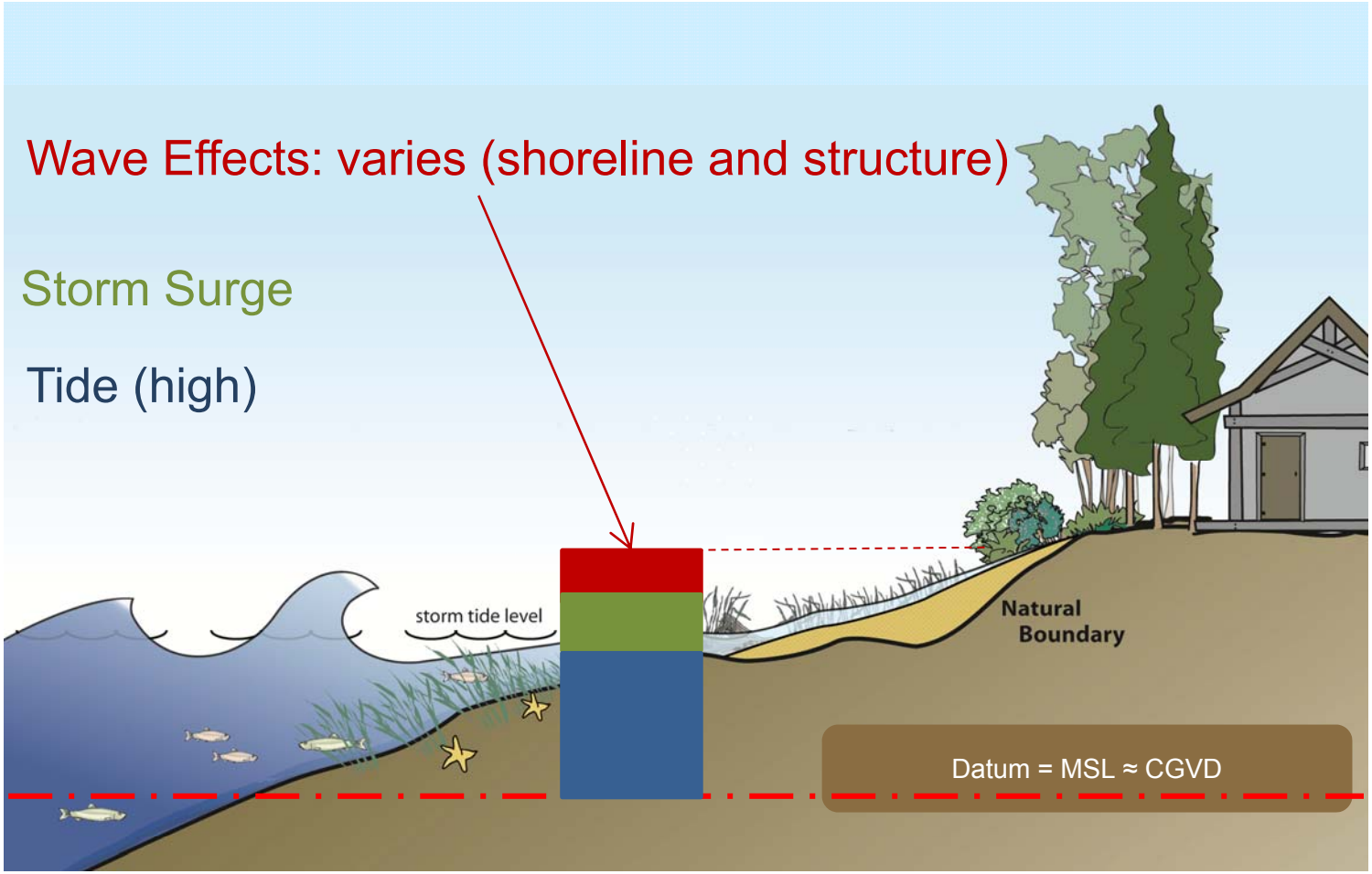
Implications to Shorelines: Components



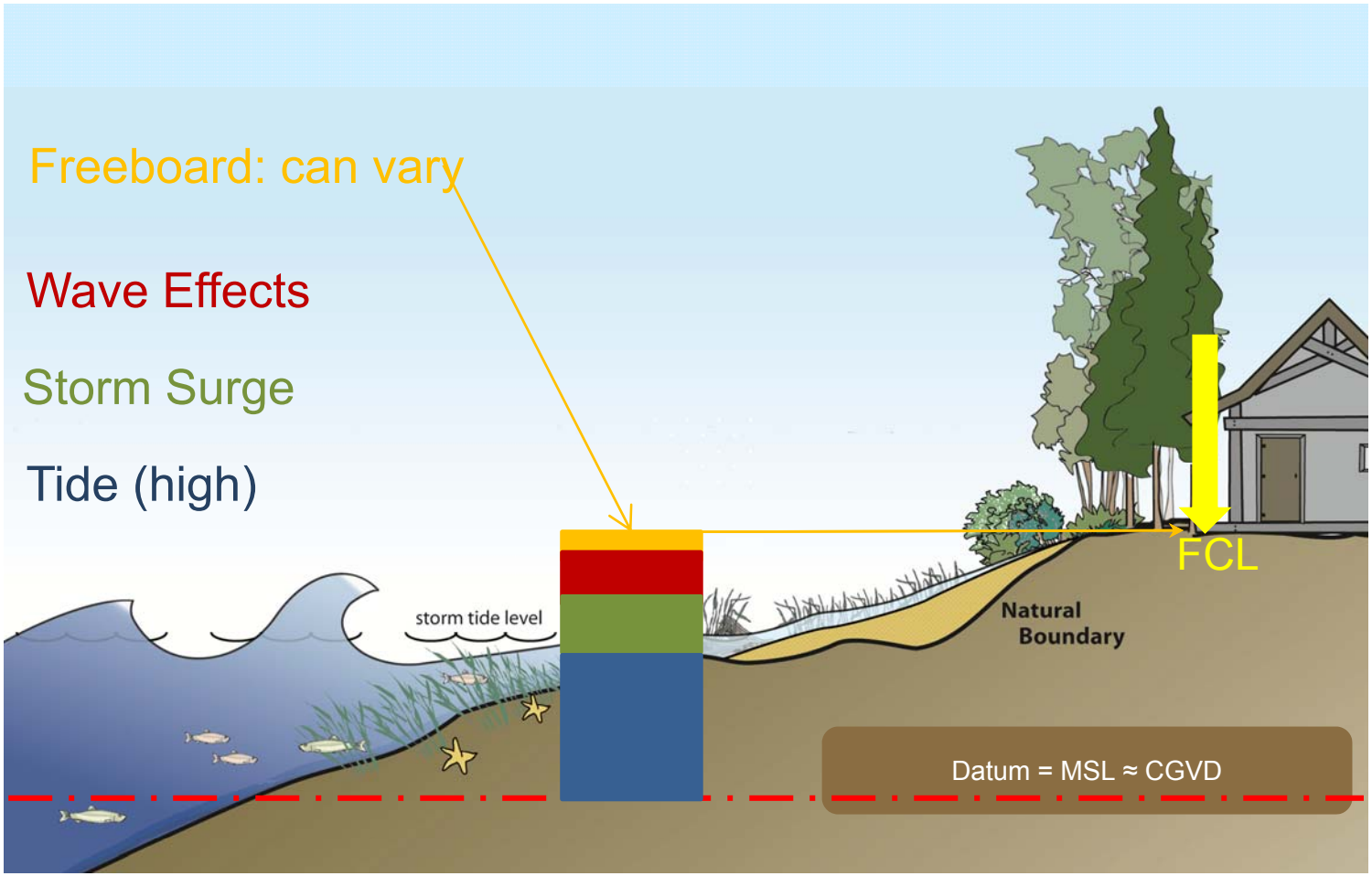
Implications to Shorelines: Components



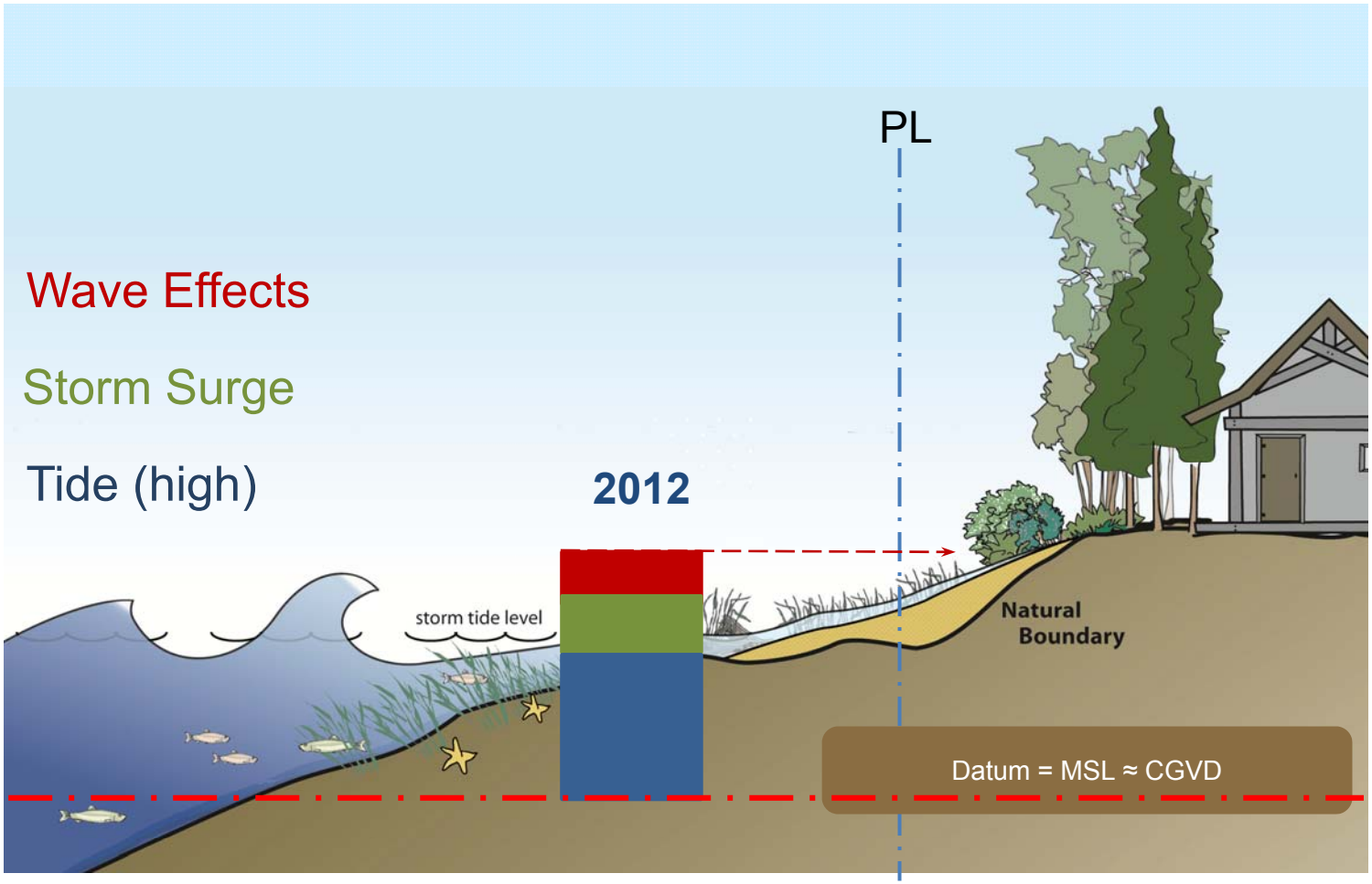
Implications to Shorelines: Components



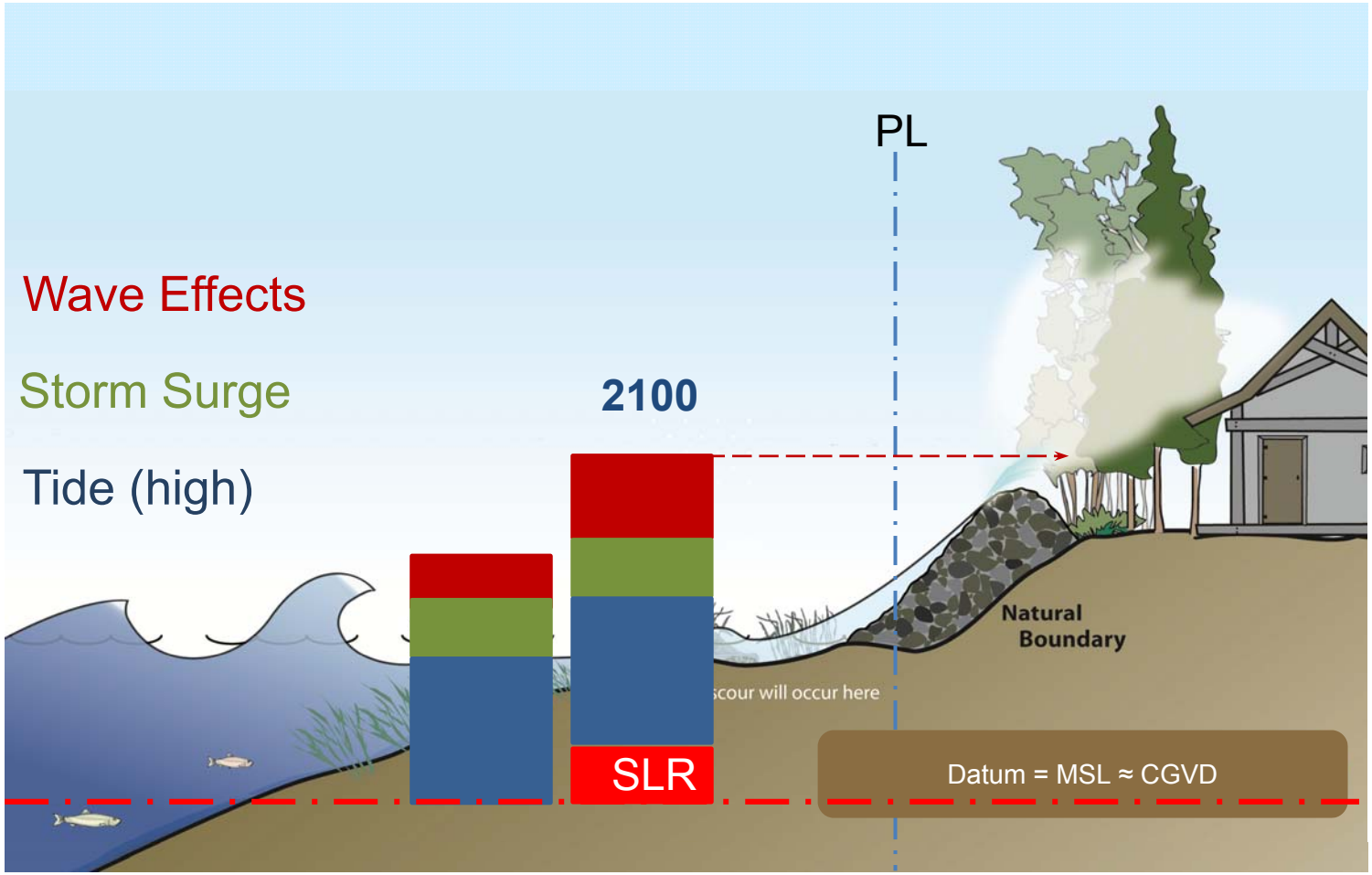
Implications to Shorelines: Components



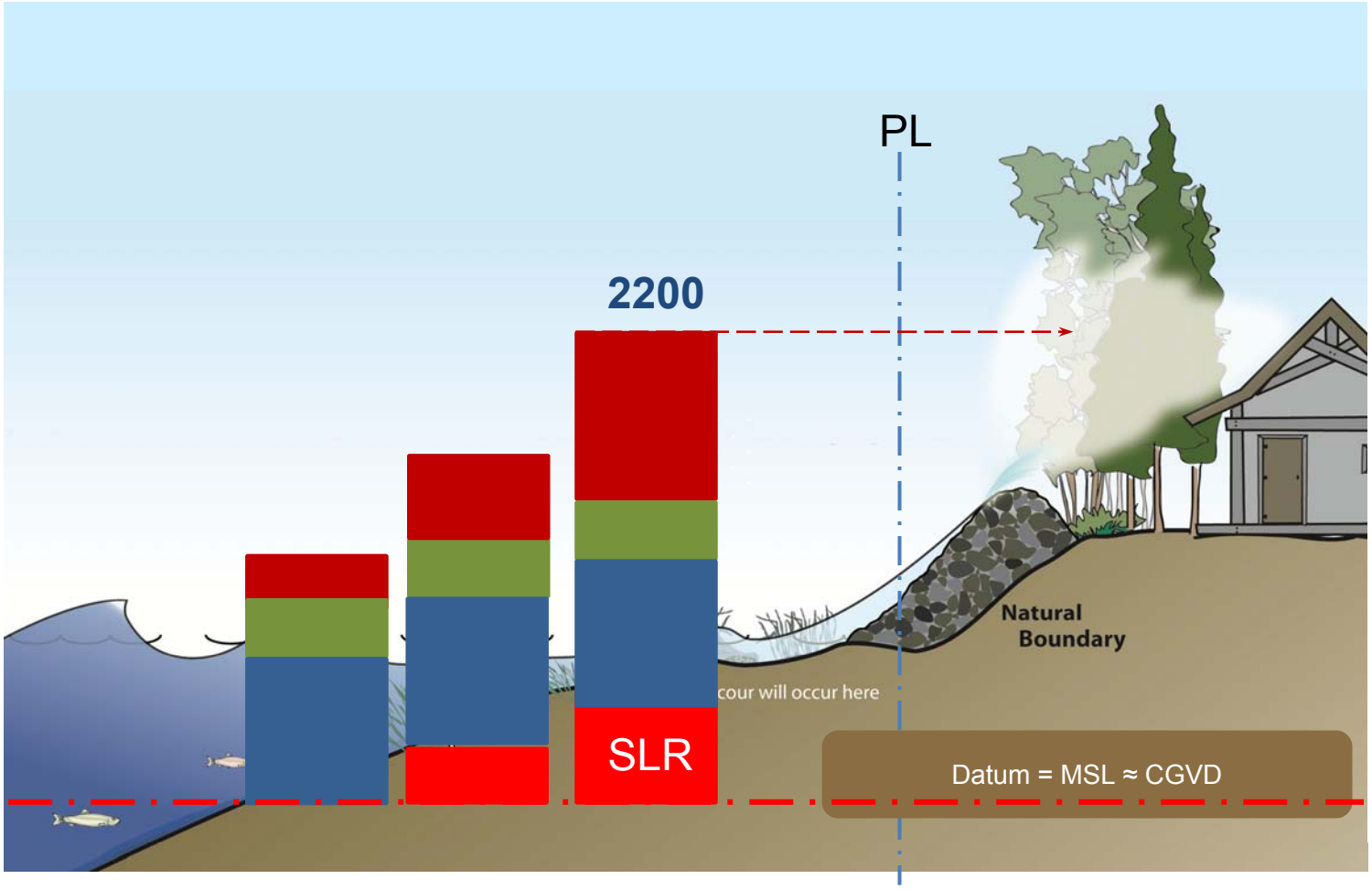
Implications to Shorelines



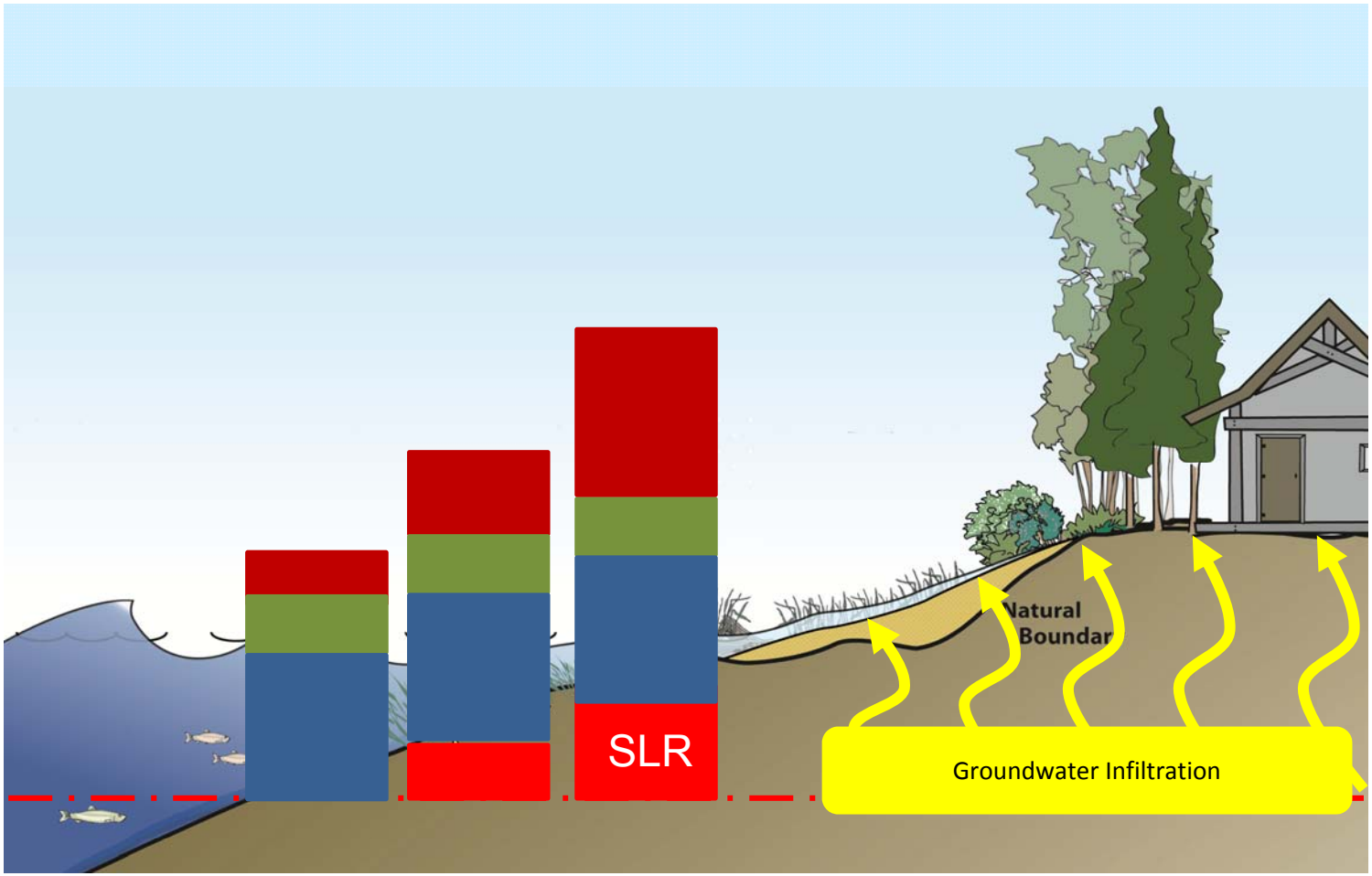
Implications to Shorelines



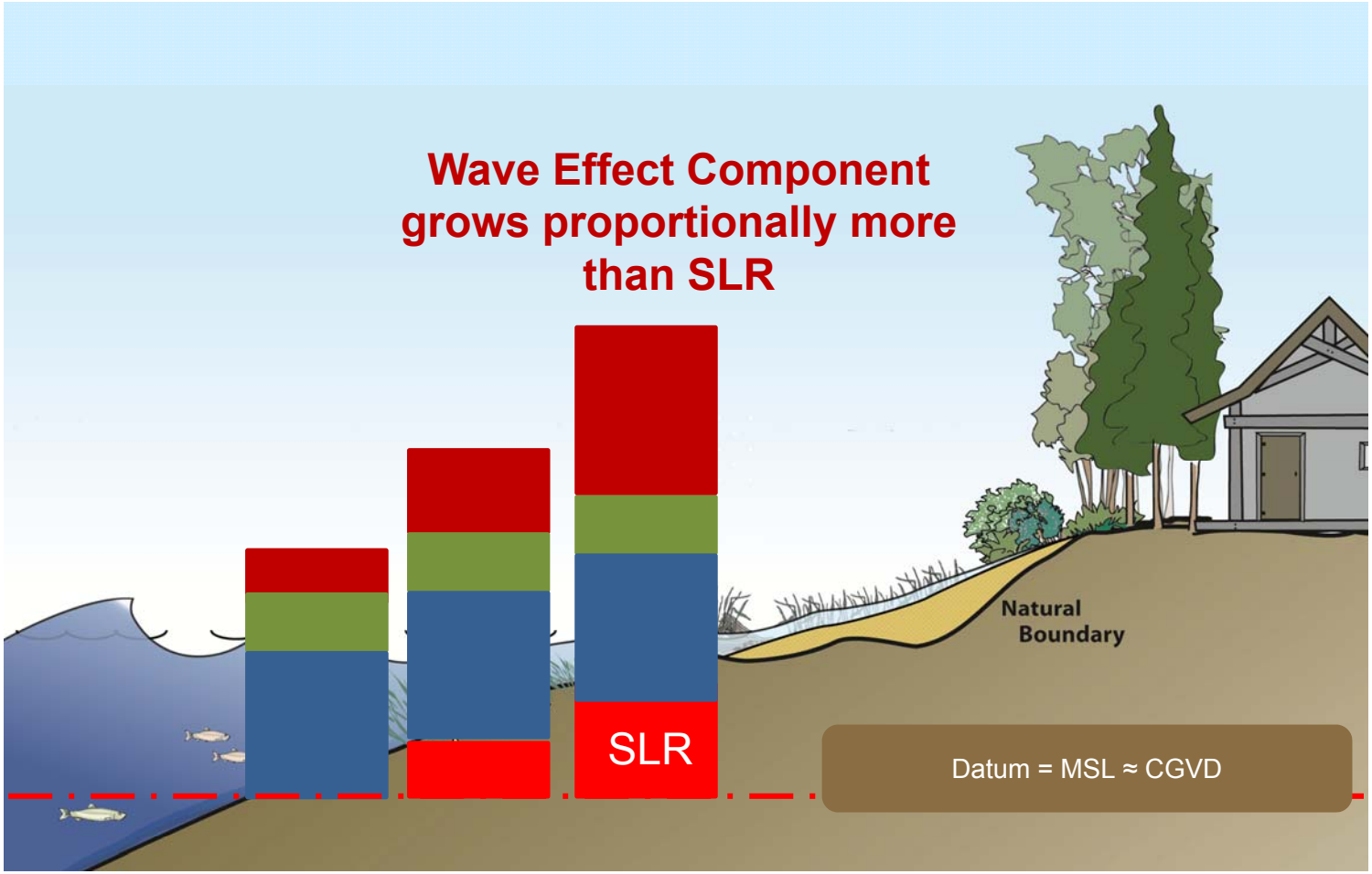
Implications to Shorelines



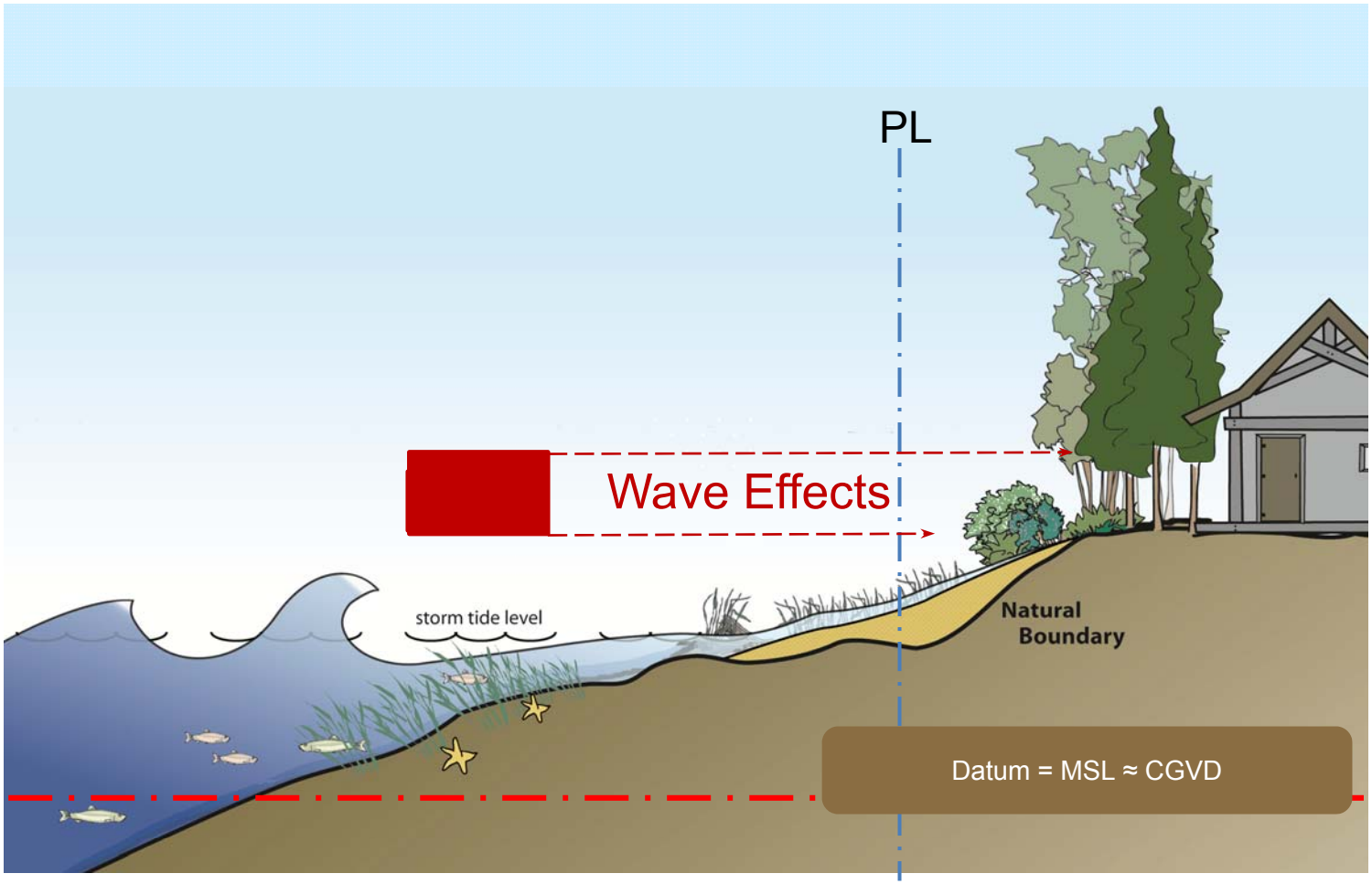
Implications to Shorelines



Implications to Shorelines



Wave Effects – What are they?



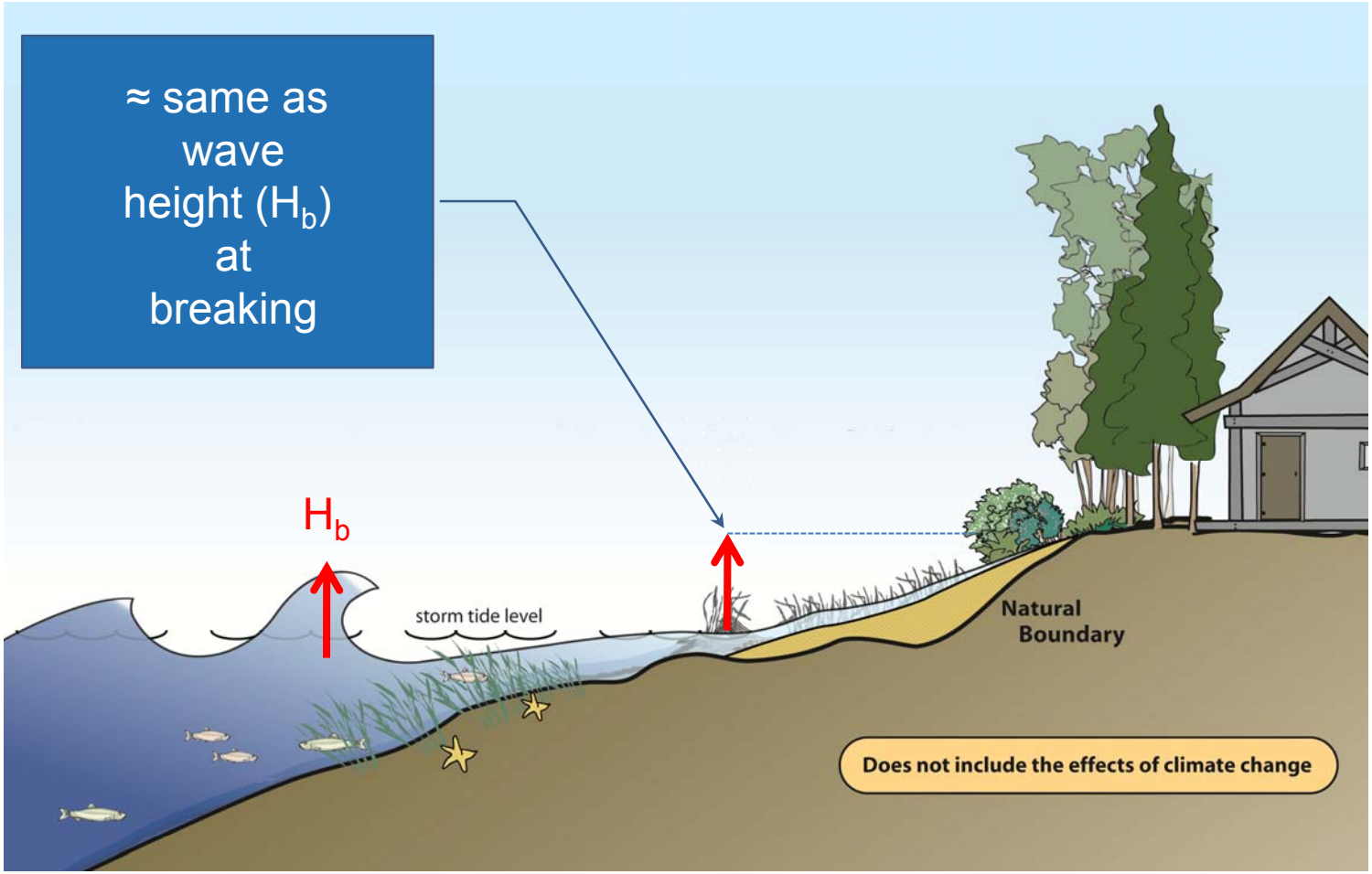
Wave Effects

Wave Effects

Wave Effects

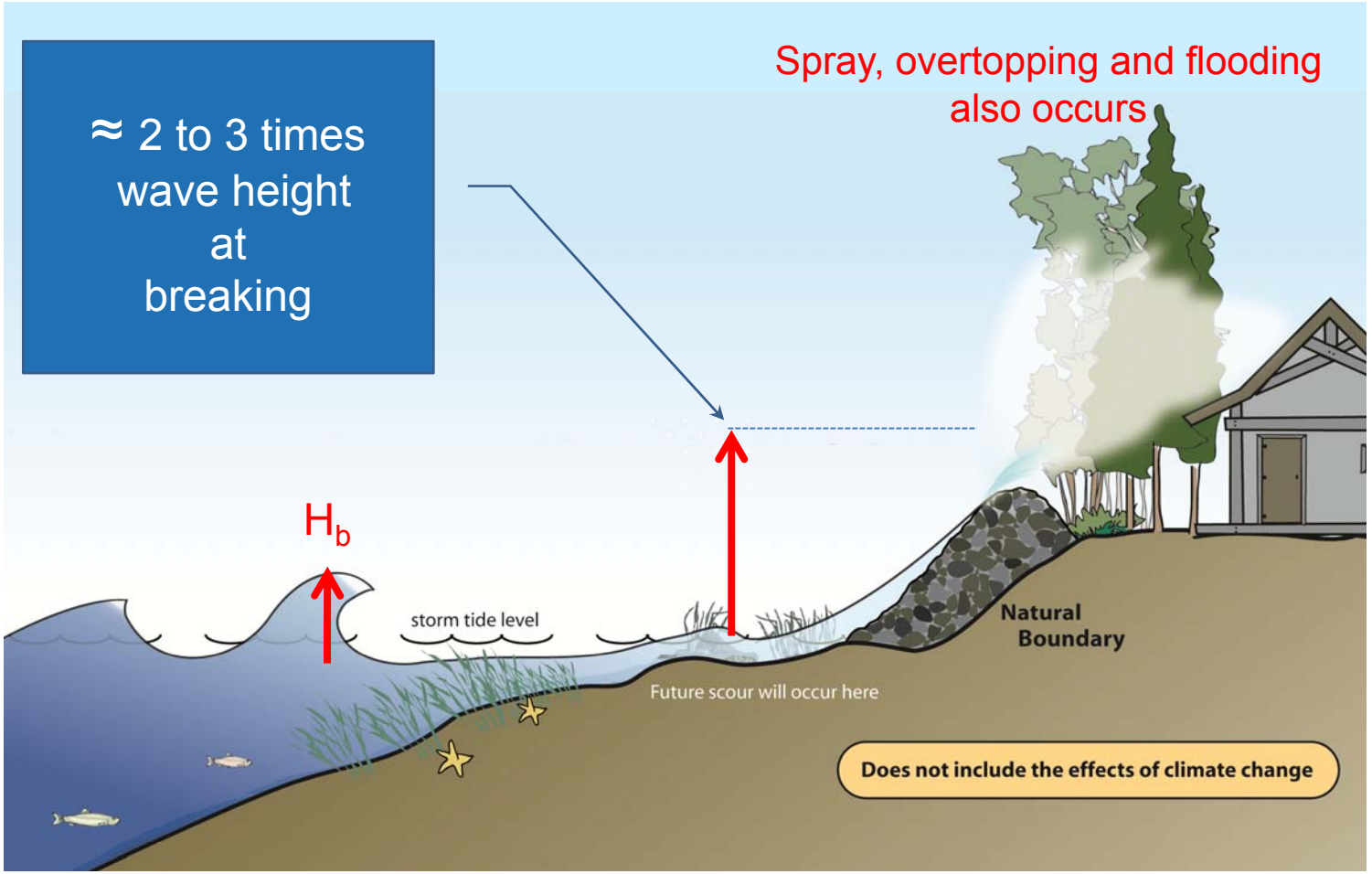
Wave Effect and Structures

Gentle Slopes - Beaches



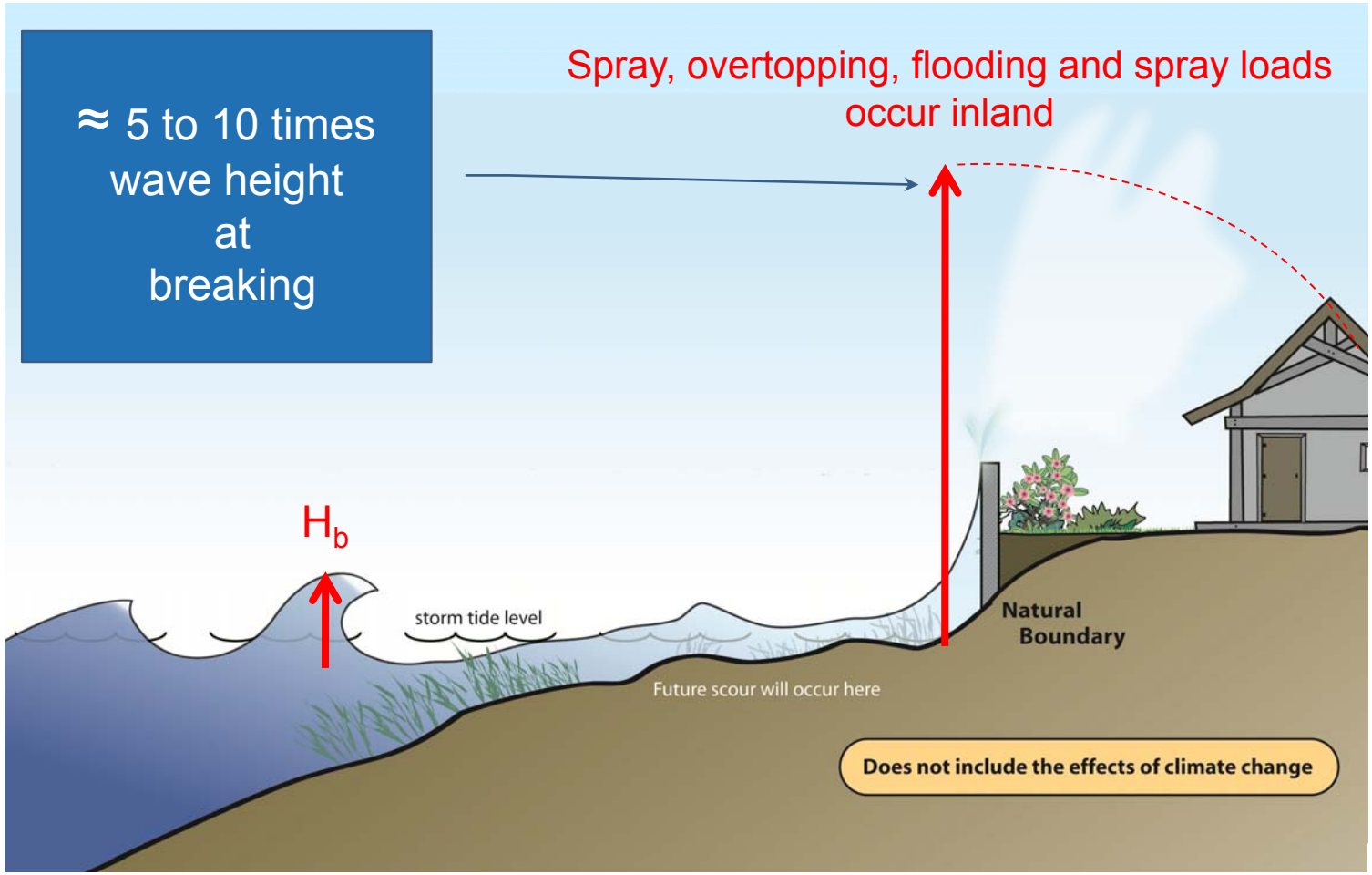
Wave Effect and Structures

Steep Slopes - Revetments



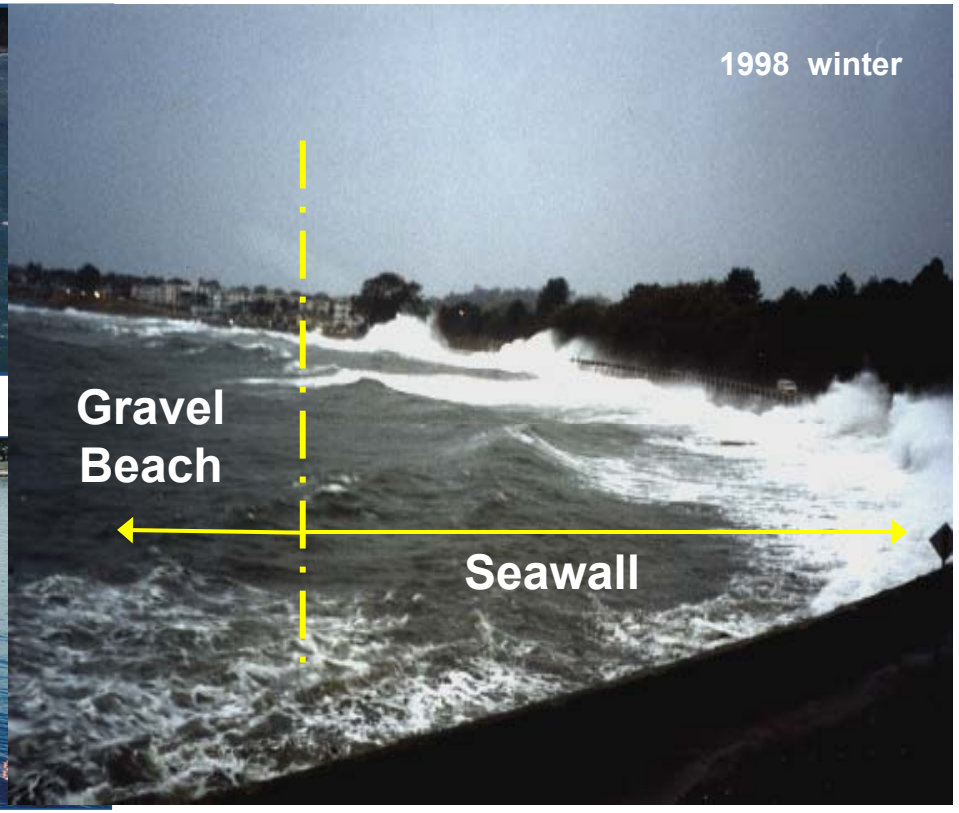
Wave Effect and Structures

Vertical Walls



Beaches Compared to Seawalls

Ross Bay
1994 – stepped seawall overlay installed
1998 – gravel beach in 2 phases



Seawalls and Wave Effects

"Seawall" in approximately 4 m water depth

Overtopping Criteria

Criteria exist for acceptable amounts of wave overtopping.

Hazard and Reason	Mean Discharge liters/m/sec	source
No damage if sea dike crest or rear slope is well protected	50-200	EA, ENW, KFKI, 2007
No damage if sea dike crest or rear slope is a grass covered clay embankment	1-10	EA, ENW, KFKI, 2007
No damage if sea dike crest or rear slope is not protected	0.1	EA, ENW, KFKI, 2007
Note: The mean discharge (q) is defined at the crest of the sea dike.		

If personnel or vehicles will be on seawall (for inspection) allowable discharges reduce by 1 to 2 orders of magnitude.

Flooding at a Rock Seawall

125 L/m/s

Sustained winds in Strait of Georgia:
40 – 45 knots
(approx "annual" expected storm peak windspeed)

Sea state (Hs) at Halibut Bank:
3.1 m
(approx "1/5 year" storm)

High tide + 0.6 to 0.8 m surge
approx "annual expected surge water level"

CONSEQUENCES:

- **Revetment was damaged in many places**
- **Flooding occurred in properties on other side of the road**
- **Roadway unsafe for pedestrians**

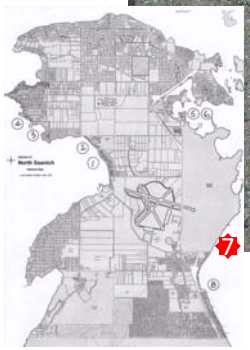
Runup on a Beach

Ross Bay Beach

- 12 March 2012 storm 09:00 AM
- Views show maximum wave run up on beach near high tide
- Sidewalk = +3.5 m CGVD
- Approximately 1.1 m above Tide plus Surge

1- Scoter Trail

7 - Lochside Drive



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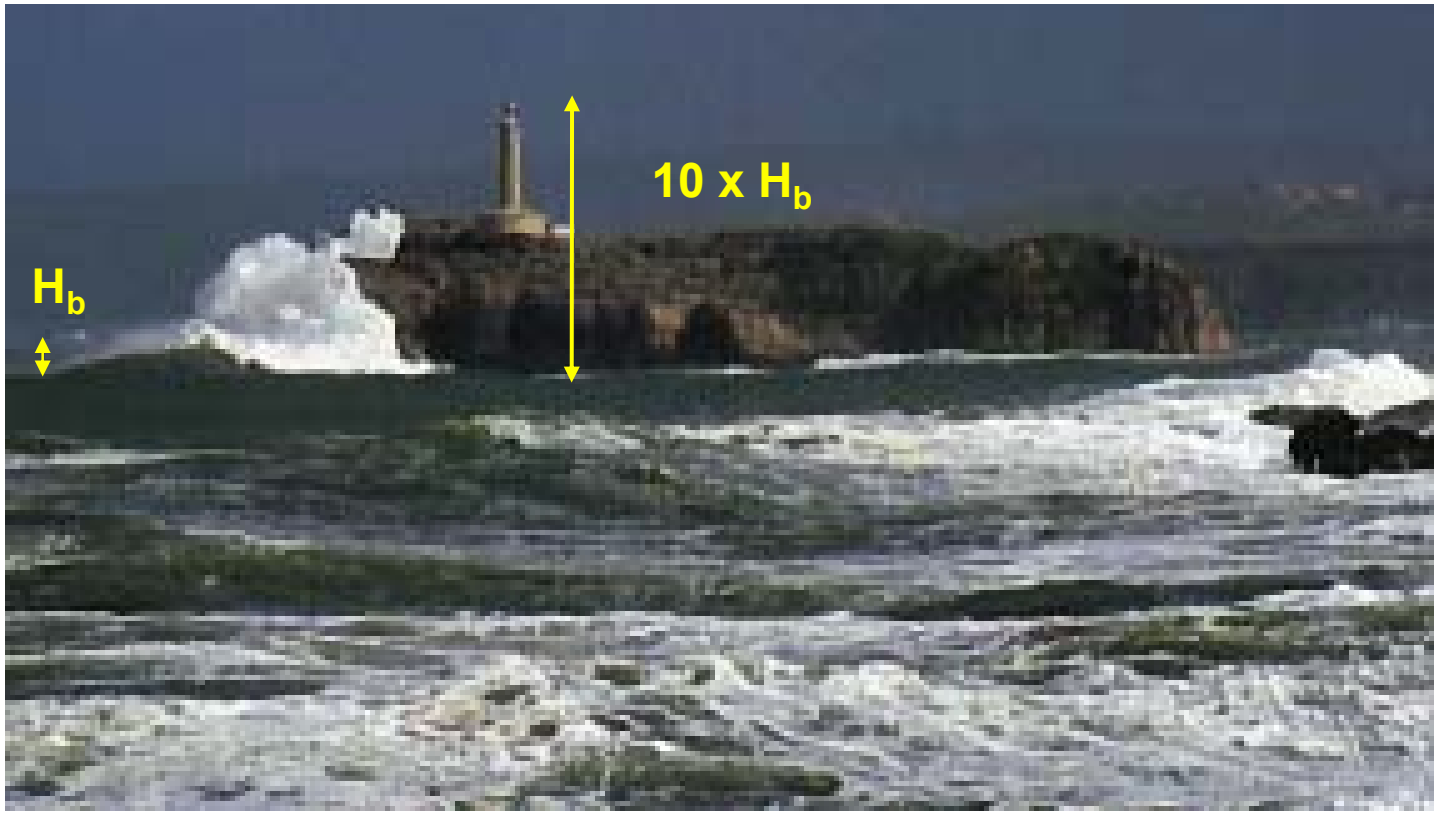
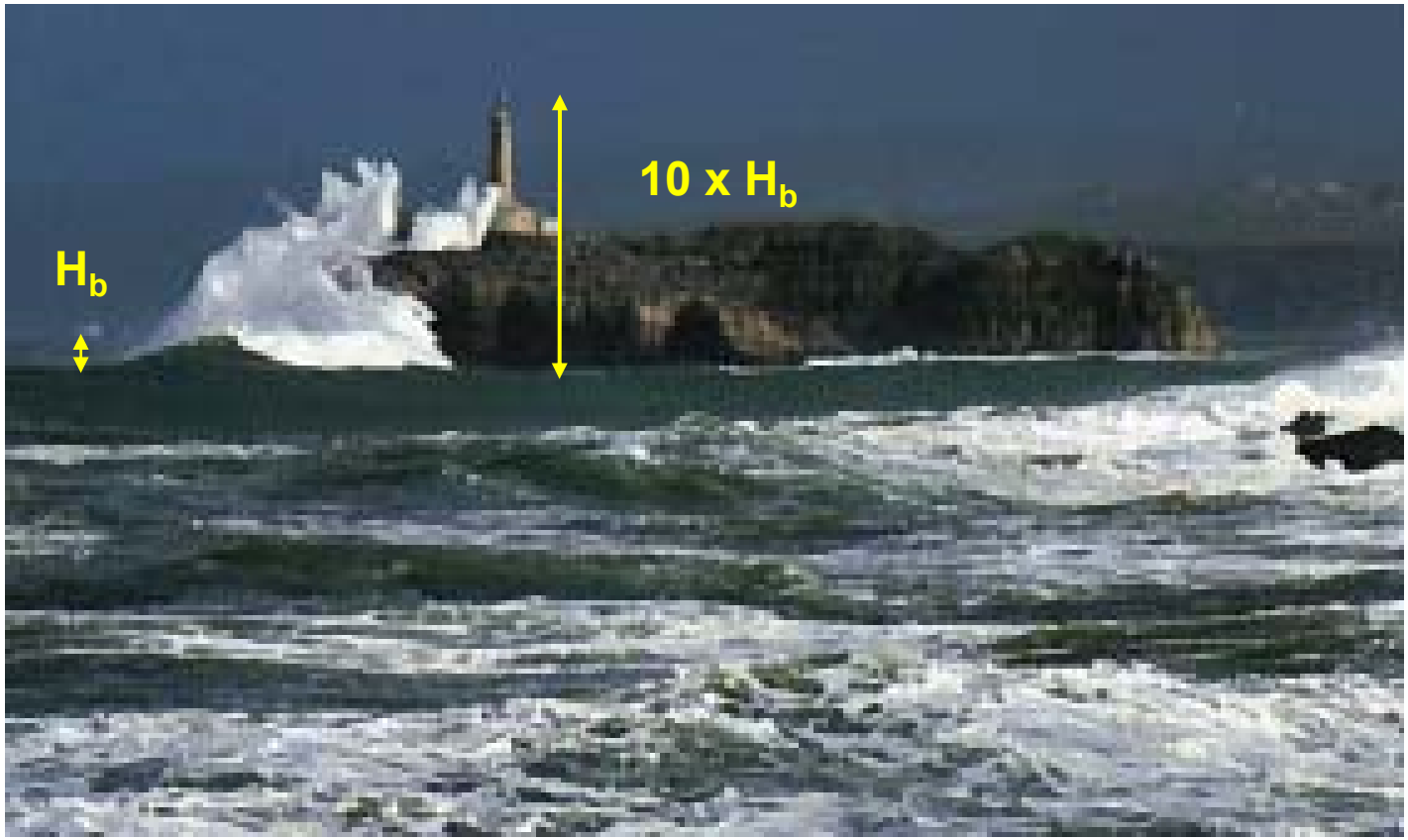
Spray Loads

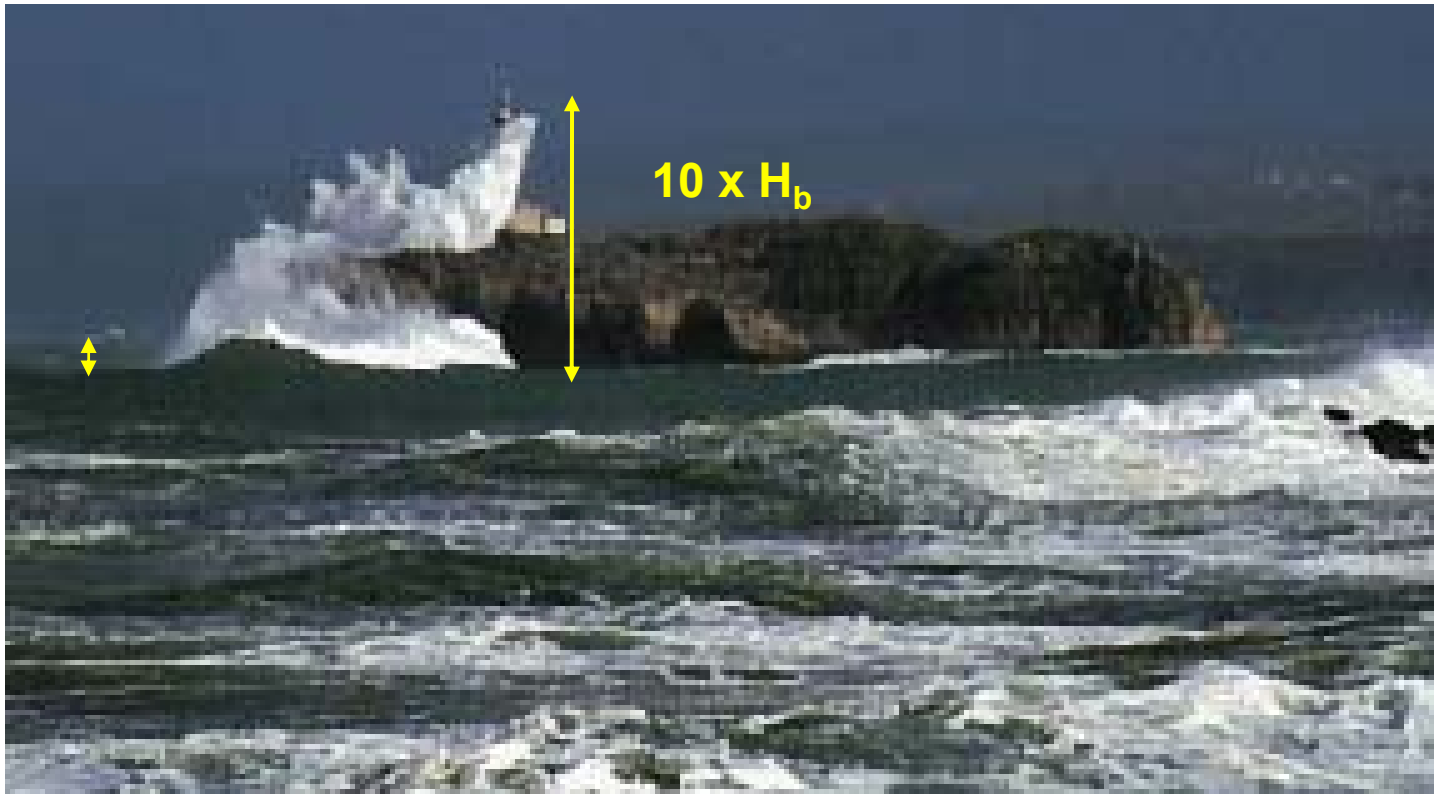
Spray Loads



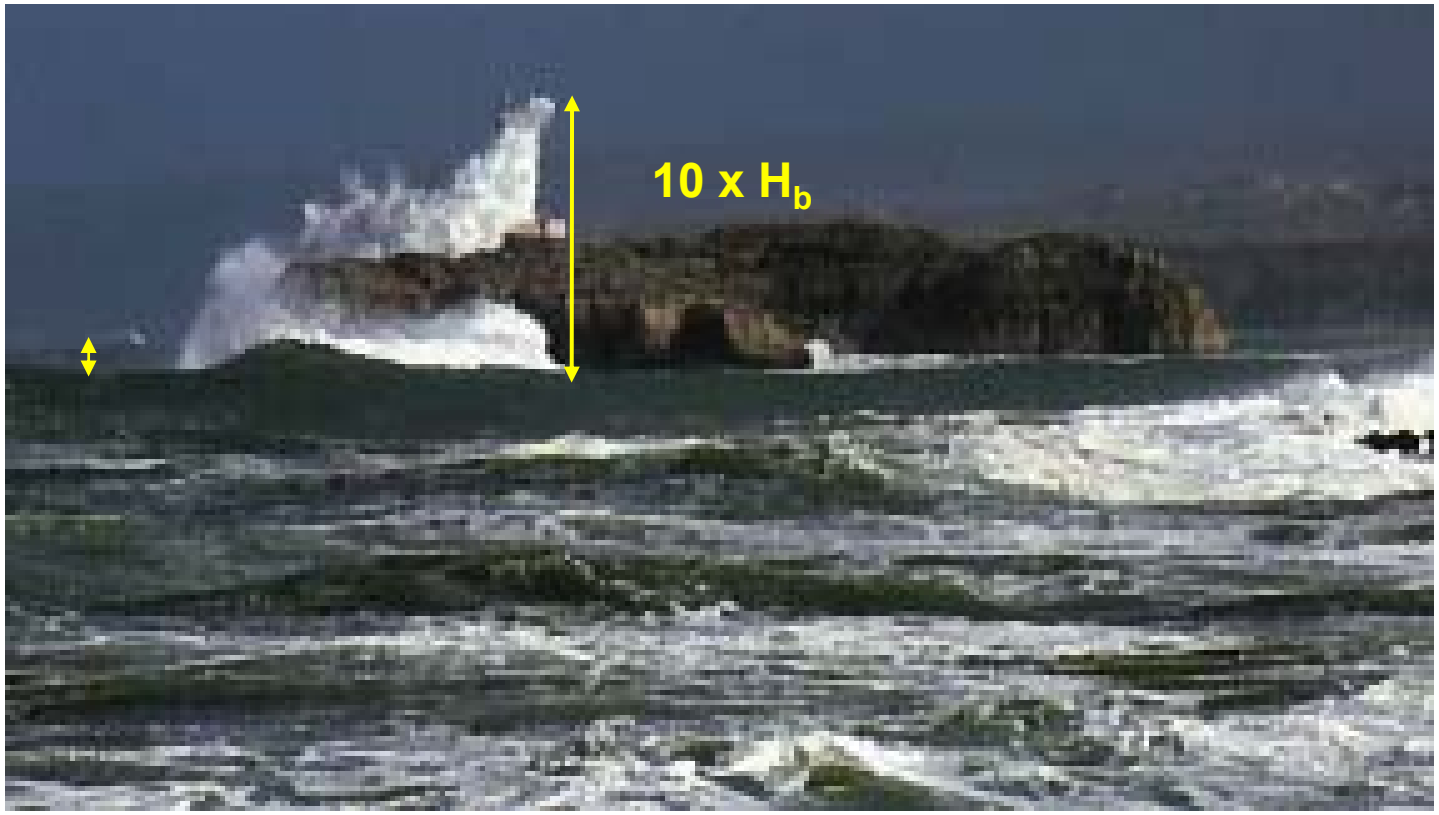
Spray Loads



Spray Loads



Spray Loads



Criteria for Structural Damage

Guideline Criteria exist to keep loadings within acceptable limits

Hazard and Reason	Mean Discharge liters/m/sec	source
No damage expected to Building structural elements on a building located behind the seawall. (q is defined at the building)	1	EA, ENW, KFKI, 2007
No damage to Equipment set back 5 – 10 m from edge of seawall crest. (q is defined at the sea dike)	0.4	EA, ENW, KFKI, 2007

- Spray loads can be greater than usual design pressures (NBC Wind Loading Pressures)
- Very aggressive seawall returns are required to reduce loads.

Loads That Can Be Expected

NBC Wind Load on typical residential building:

0.8 KPa

Spray loads measured up to 50 m or more from seawall:

5 to 50 KPa

Loads used for design of weather deck structures on a ship:

20 to 35 KPa

depending on Code

Loads on upper decks of ships:

5 to 10 KPa

depending on deck and Code

3 - Towner Estates

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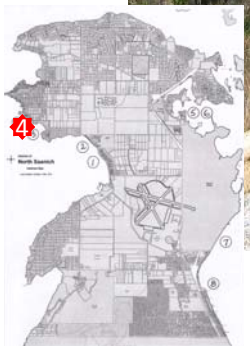
4 - Madrona Drive



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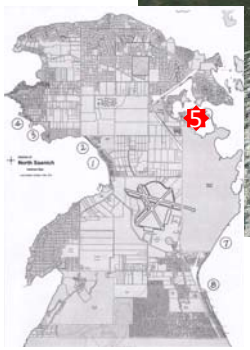
5 - Marina Drive



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6 - Capital City Yacht Club – Tsehum Harbour

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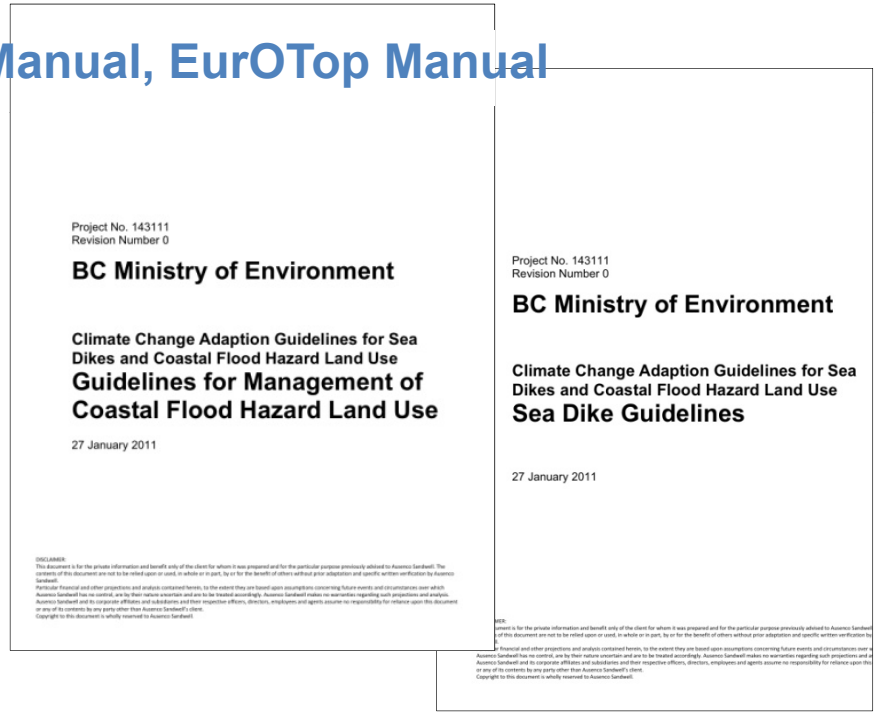
Guidelines and Standards

Engineering Standards

- ISO 21650: Actions from Waves and Currents on Coastal Structures
- British Standard (BSA 6349)
- CEM (USACE)
- EU (Codes and Guidelines), Rock Manual, EurOTop Manual

Stewardship Guidelines

- BCSC Coastal Stewardship Manual
- Green Shores ™
- Sea Grant Program USA: Wisconsin and Alaska
- WA State Department of Ecology
- Green Shores for Homes
- Friends of San Juan County



Project No. 143111
Revision Number 0

BC Ministry of Environment

Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use

Guidelines for Management of Coastal Flood Hazard Land Use

27 January 2011

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Project No. 143111
Revision Number 0

BC Ministry of Environment

Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use

Sea Dike Guidelines

27 January 2011

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What to do?

Options to Deal with SLR

Avoid

Where
How high

Protect

Seawalls
Revetments – Dikes
Beaches

Retreat

How far
How high

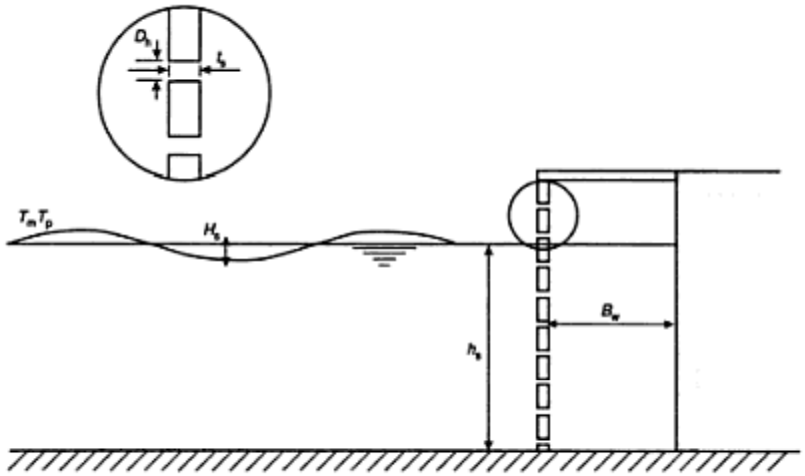
Accommodate

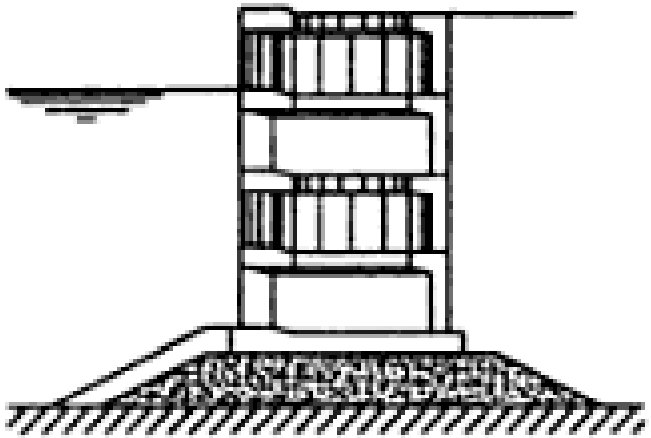
Interim protection
Raise grades
Flood Proof

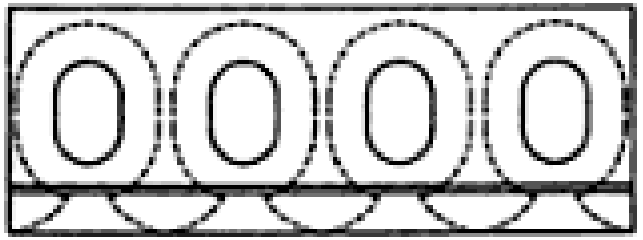
Design Selection Issues

- **Location, Location Location**
  - SLR – no option
  - Storm Surge – no option
  - Wave Effects – exposure (direction and fetch)
- **Open coast:**
  - Small Sediments → Alongshore Stability → Need Control
- **Embayment:**
  - Cross Shore Sorting → Volume of Material → Recharge Cycle

Absorbing Seawalls







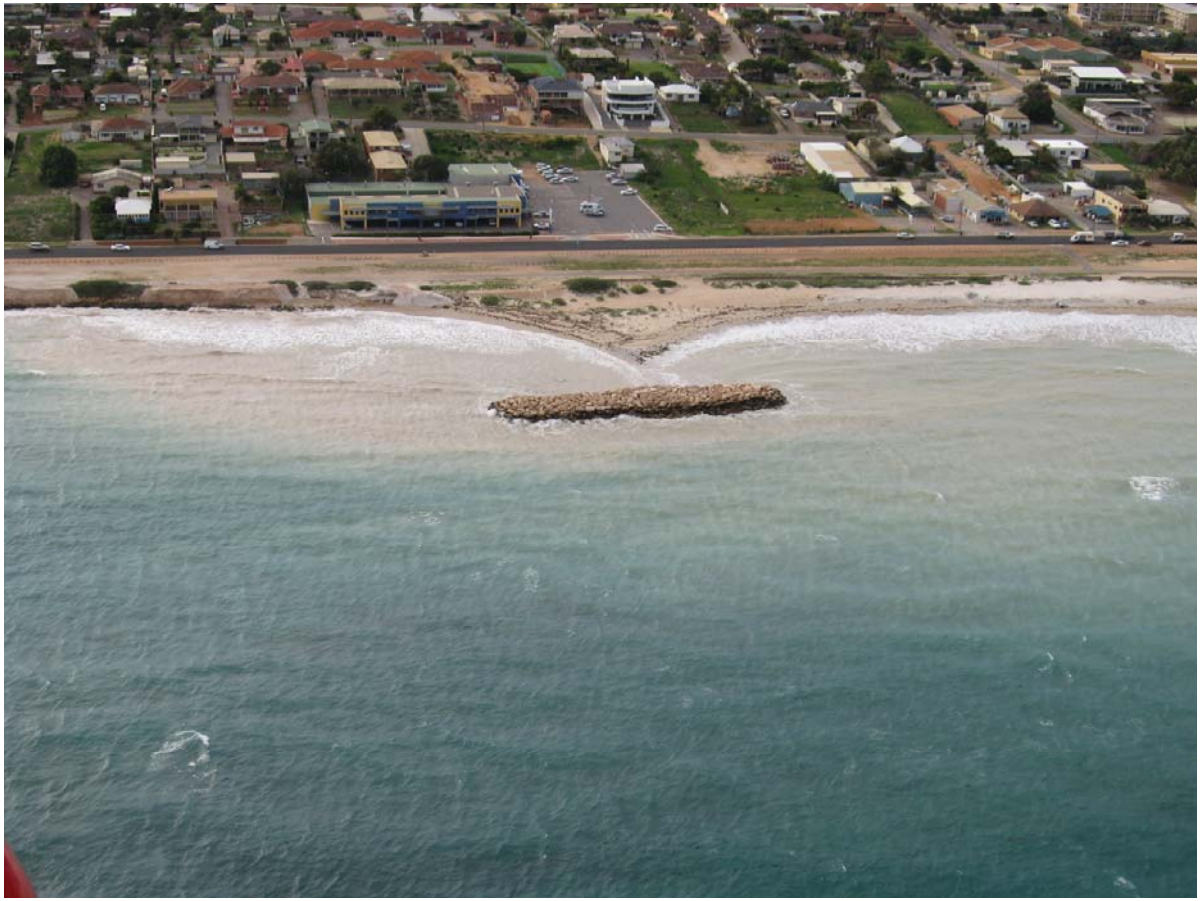
Absorbing Seawalls

Control Options for Intertidal Sediments

- **Groynes – shore perpendicular - generally inefficient**
- **Sills – usually lower to improve bypassing**
- **Headlands**
  - L and T shaped headlands
  - Reefs
- **Offshore Breakwaters**
- **Offshore reefs**

L - Headland

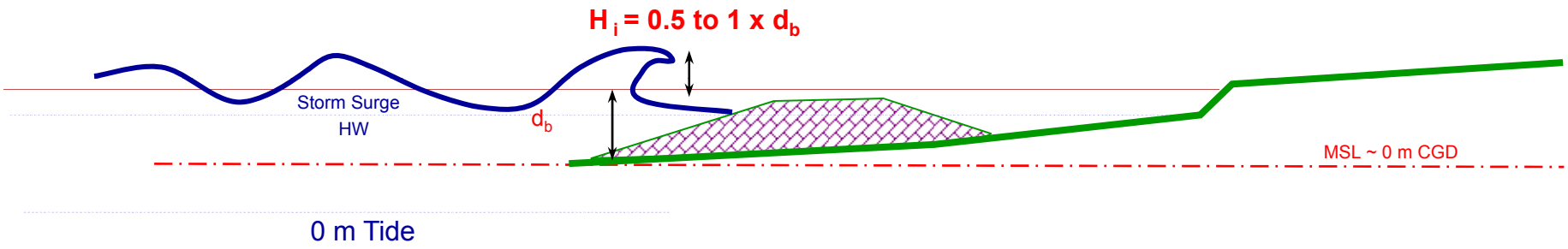
T headland - Offshore Breakwater



Headland System – Qualicum Beach

constructed 2006

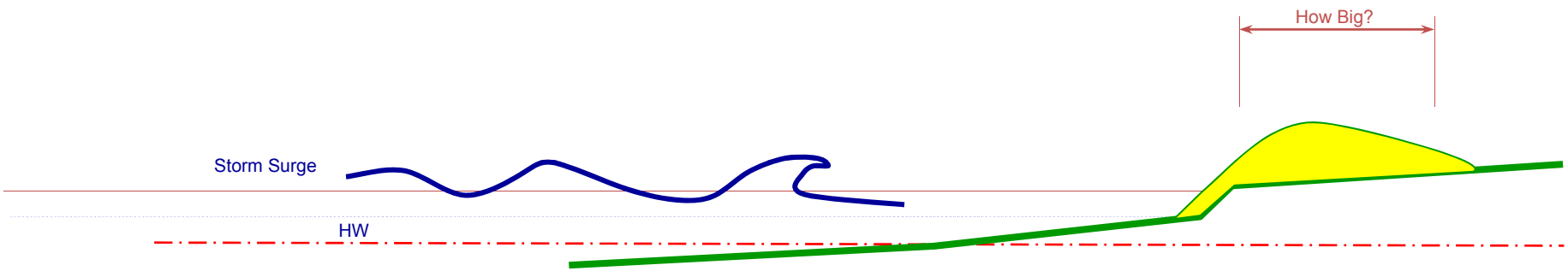
Alternatives – Offshore Reef



Offshore Reefs

Offshore Reefs

Alternative – Storm Berm (Dune)



Storm Berm (fine sand dune)

Storm Berm (fine sand)

Storm Berm

Storm Berm – Parksville

coarse (quarry run) material on upper intertidal portion of original beach

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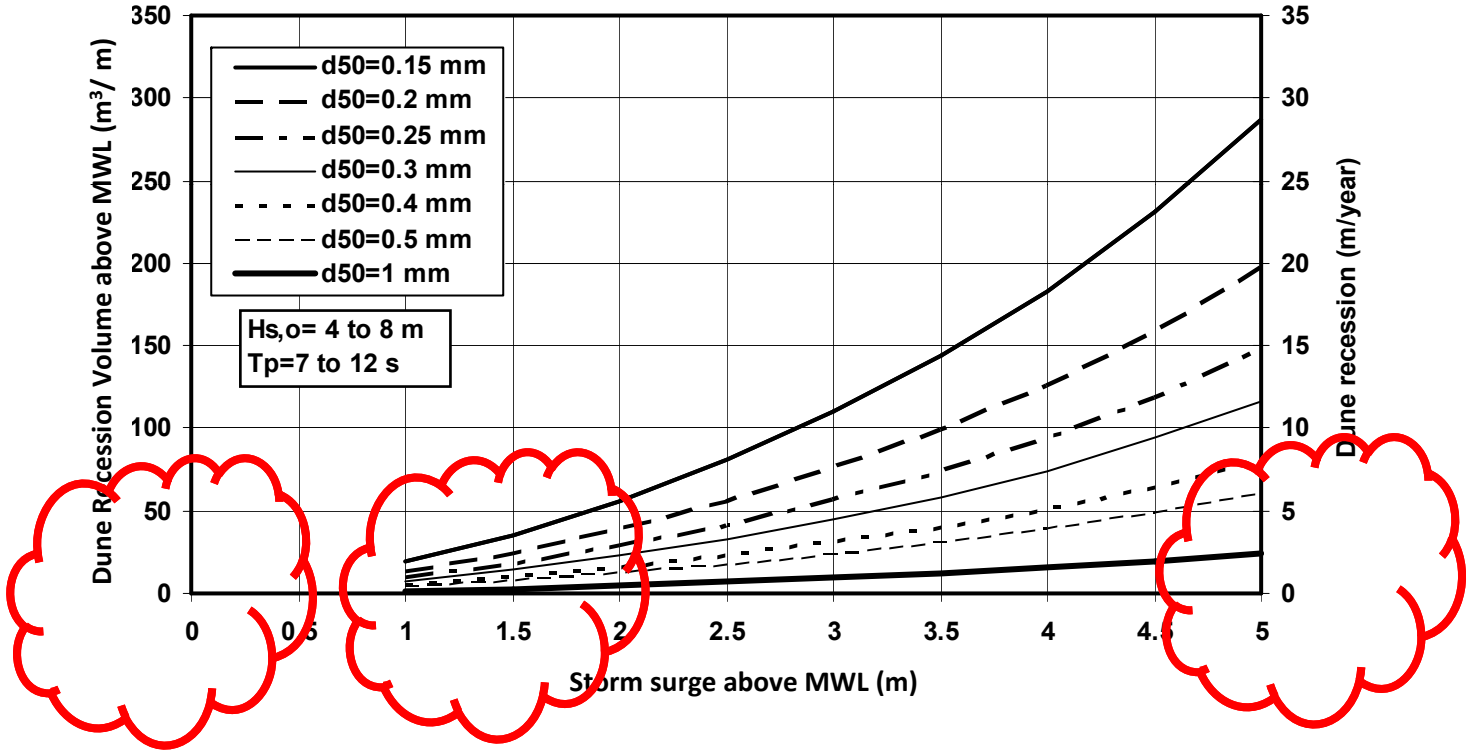
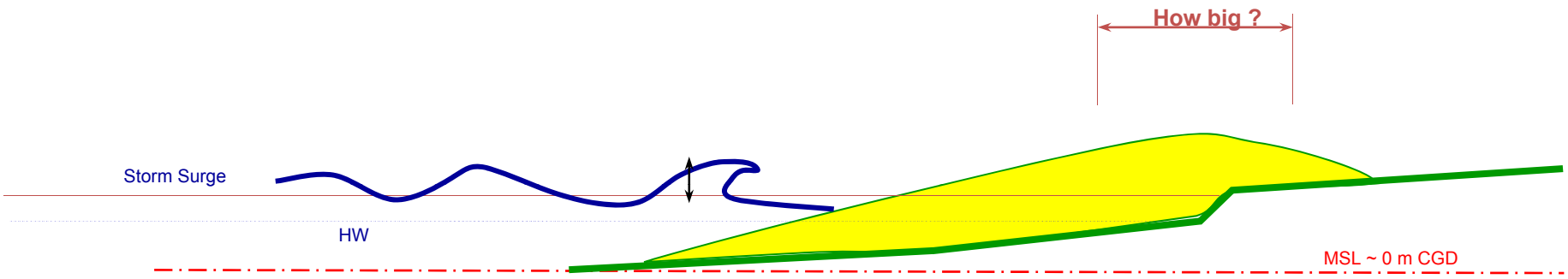
Storm Berm Design Guideline – Fine Sand



van Rijn, Coastal Engineering, 2009

Alternatives – Restored Foreshore:

combines Storm Berm with intertidal profile replenishment



8 - Bazan Bay

2 - Tseycum Reserve

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What Can the Property Owner Do Now?

Observation, Observation, Documentation

- **Establish a known elevation reference on your property**
- **Make it visible – identify areas and features vulnerable to SLR**
- **Take repetitive photographs and video of wave interaction and beach changes**
  - Seasonal
  - High tides
  - Storm conditions – try to capture the angle of approach of waves, in particular, under many conditions
- **Document changes to the character (type of sediment, extent of coverage, changes in both) of beaches and toe of cliffs**
- **Define your functional requirements for future measures (adaptation):**
  - How long should it last
  - What are the site vulnerabilities?
  - What are the tolerable consequences?
- **Review and consider upland alternatives:**
  - Divert or control surface water runoff
  - Maintain vegetative cover over shoreline area
  - Can access to shoreline for small equipment be improved?
  - Are there options to move back or up?
  - Talk with neighbours – can joint alternatives be mutally beneficial?

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Thank you.

John Readshaw
Manager, Coastal Engineering
Ports & Marine Group
SNC-Lavalin Inc.
1800 – 1075 West Georgia Street
Vancouver, BC
V6E 3C9

WE CARE
NOUS VEILLONS

WE CARE embodies SNC-Lavalin's key corporate values and beliefs. It is the cornerstone of everything we do as a company. **Health and safety, employees,** the **environment, communities and quality:** these values all influence the decisions we make every day. And importantly, they guide us in how we serve our clients and therefore affect how we are perceived by our external partners. **WE CARE** is integral to the way we perform on a daily basis. It is both a responsibility and a source of satisfaction and pride by providing such important standards to all we do.

WE CARE about the health and safety of our employees, of those who work under our care, and of the people our projects serve.

WE CARE about our employees, their personal growth, career development and general well-being.

WE CARE about the communities where we live and work and their sustainable development, and we commit to fulfilling our responsibilities as a global citizen.

WE CARE about the environment and about conducting our business in an environmentally responsible manner.

WE CARE about the quality of our work.