# Sea Level Rise in Oregon: Projections, Impacts, and Adaptation


*Photo: Armand Thibault, Neskowin, 2008*

**Peter Ruggiero**

**College of Earth, Ocean, and Atmospheric Sciences**

College of Earth, Ocean, and Atmospheric Sciences

Oregon State University

The New York Times | SUNDAY REVIEW

# Can You Guess What America Will Look Like in 10,000 Years? A Quiz

By BENJAMIN STRAUSS, SCOTT KULP and PETER CLARK

Produced by JASMINE C. LEE, ANJALI SINGHVI and BILL MARSH

APRIL 20, 2018

## Can you guess which states these are?

The New York Times | SUNDAY REVIEW

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APRIL 20, 2018

## Can you guess which states these are?

# 3.

| | |
|---|---|
| Alabama | Mississippi |
| Alaska | New Hampshire |
| Arkansas | New Jersey |
| California | New York |
| Connecticut | North Carolina |
| Delaware | Oregon |
| Florida | Pennsylvania |
| Georgia | Rhode Island |
| Hawaii | South Carolina |
| Louisiana | Texas |
| Maine | Vermont |
| Maryland | Virginia |
| Massachusetts | Washington |

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## Can you guess which states these are?

# 3.

**97.3 percent flooded**

- Alabama
- Alaska
- Arkansas
- California
- Connecticut
- Delaware
- **Florida**
- Georgia
- ~~**Hawaii**~~
- Louisiana
- Maine
- Maryland
- Massachusetts
- Mississippi
- New Hampshire
- New Jersey
- New York
- North Carolina
- Oregon
- Pennsylvania
- Rhode Island
- South Carolina
- Texas
- Vermont
- Virginia
- Washington

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## Can you guess which states these are?

## 6.

| | |
|---|---|
| Alabama | Mississippi |
| Alaska | New Hampshire |
| Arkansas | New Jersey |
| California | New York |
| Connecticut | North Carolina |
| Delaware | Oregon |
| Florida | Pennsylvania |
| Georgia | Rhode Island |
| Hawaii | South Carolina |
| Louisiana | Texas |
| Maine | Vermont |
| Maryland | Virginia |
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## Can you guess which states these are?

# 6.

**40.9 percent flooded**

| | |
|---|---|
| Alabama | Mississippi |
| Alaska | New Hampshire |
| Arkansas | New Jersey |
| California | New York |
| Connecticut | ✓ **North Carolina** |
| Delaware | ✗ ~~**Oregon**~~ |
| Florida | Pennsylvania |
| Georgia | Rhode Island |
| Hawaii | South Carolina |
| Louisiana | Texas |
| Maine | Vermont |
| Maryland | Virginia |
| Massachusetts | Washington |

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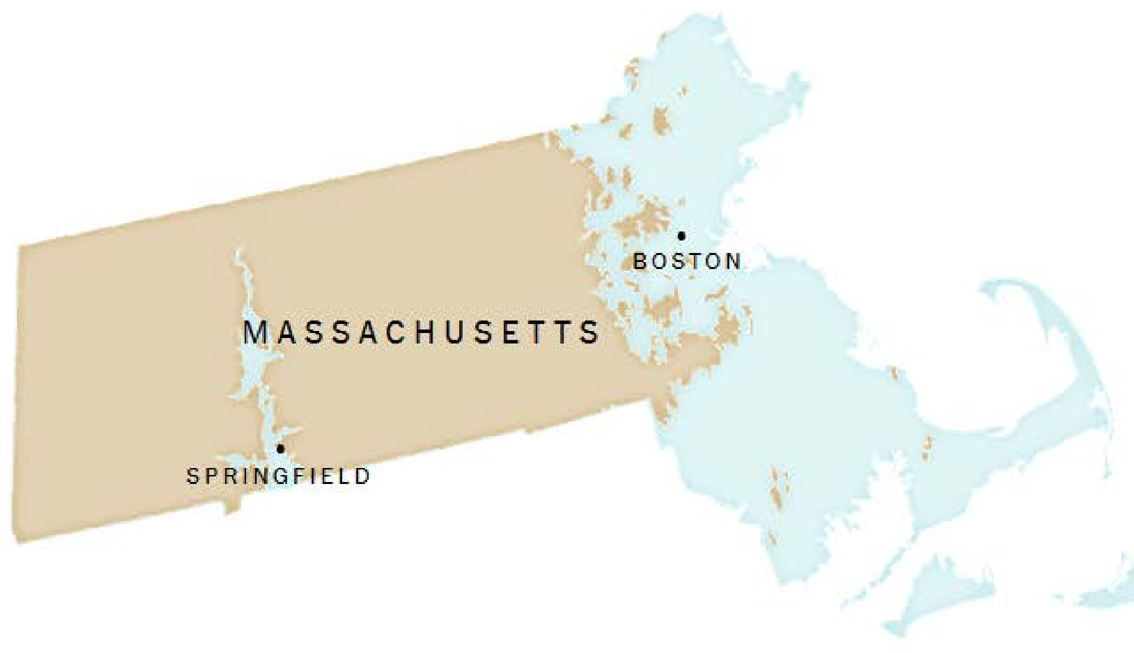
APRIL 20, 2018

## Can you guess which states these are?

# 8.

**36 percent flooded**

| | |
|---|---|
| Alabama | Mississippi |
| Alaska | New Hampshire |
| Arkansas | New Jersey |
| California | New York |
| Connecticut | North Carolina |
| Delaware | ~~Oregon~~ |
| Florida | Pennsylvania |
| Georgia | Rhode Island |
| Hawaii | South Carolina |
| Louisiana | Texas |
| Maine | Vermont |
| Maryland | Virginia |
| **Massachusetts** | Washington |



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APRIL 20, 2018

## Can you guess which states these are?

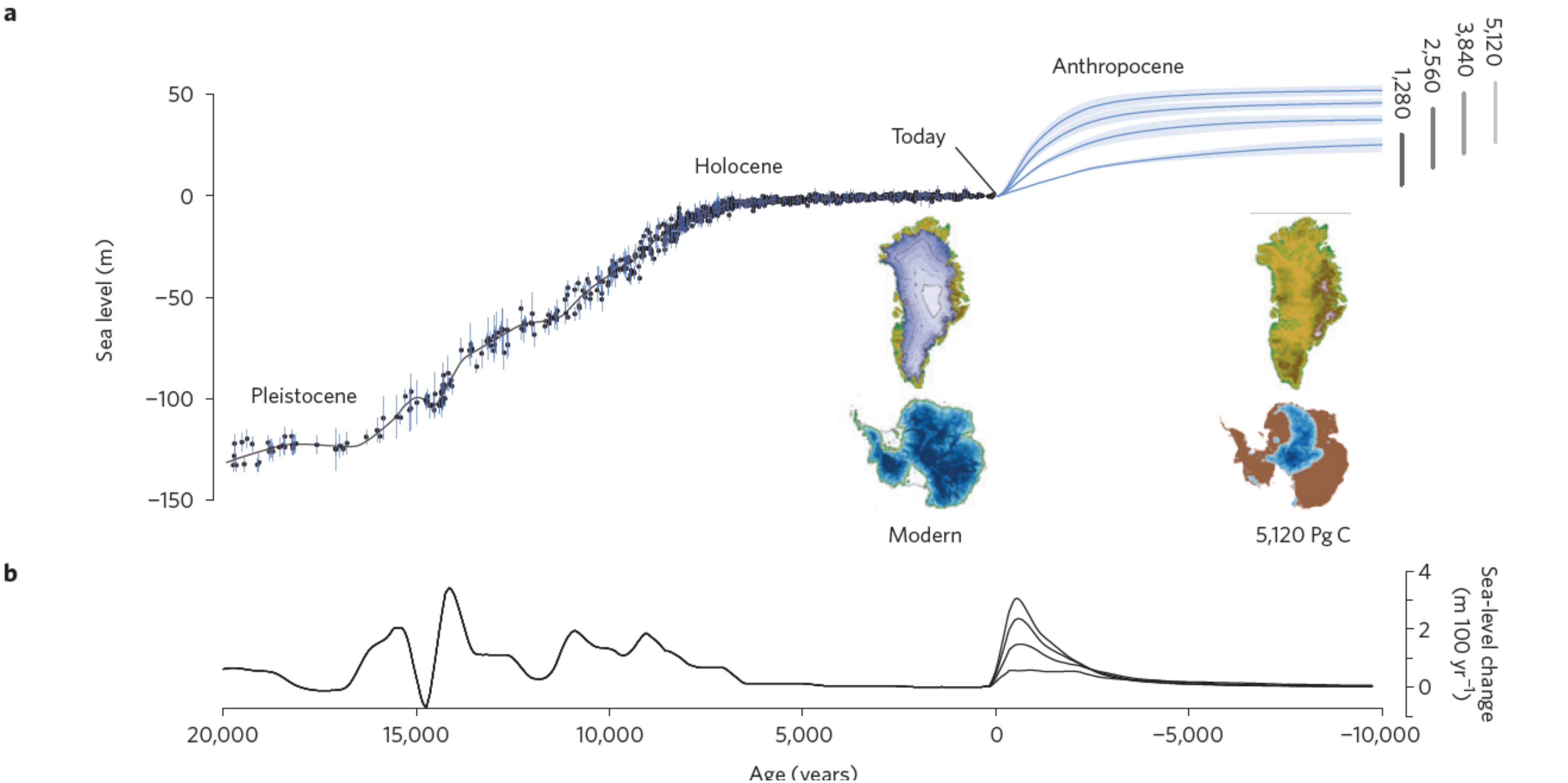

**Oregon**
2.7 percent

PERSPECTIVE
PUBLISHED ONLINE: 8 FEBRUARY 2016 | DOI: 10.1038/NCLIMATE2923
nature climate change

# Consequences of twenty-first-century policy for multi-millennial climate and sea-level change

Peter U. Clark[1*], Jeremy D. Shakun[2], Shaun A. Marcott[3], Alan C. Mix[1], Michael Eby[4,5], Scott Kulp[6], Anders Levermann[7,8,9], Glenn A. Milne[10], Patrik L. Pfister[11], Benjamin D. Santer[12], Daniel P. Schrag[13], Susan Solomon[14], Thomas F. Stocker[11,15], Benjamin H. Strauss[6], Andrew J. Weaver[4], Ricarda Winkelmann[7], David Archer[16], Edouard Bard[17], Aaron Goldner[18], Kurt Lambeck[19,20], Raymond T. Pierrehumbert[21] and Gian-Kasper Plattner[11]

… long-term perspective illustrates that policy decisions made in the next few years to decades will have profound impacts on global climate, ecosystems and human societies — not just for this century, but for the next ten millennia and beyond.



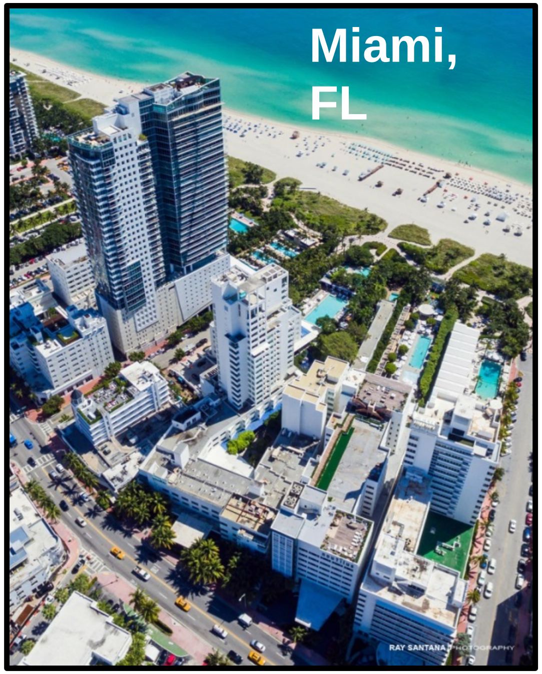
## Scenes from king tides on the Oregon and Washington Coasts

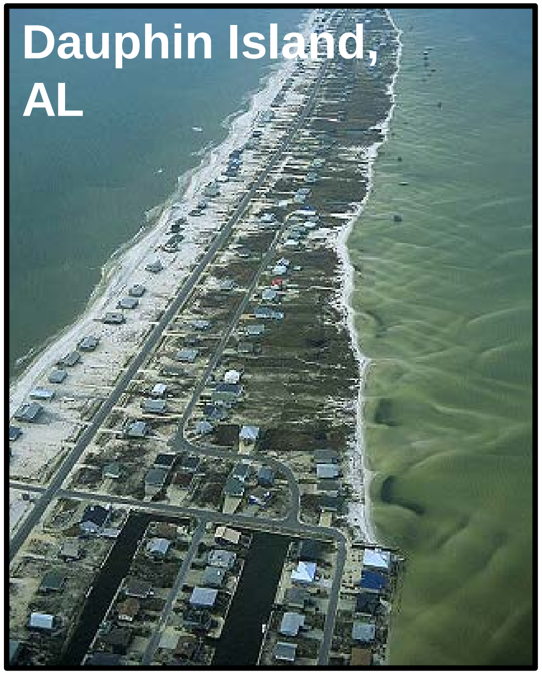
Giant king tides and foul weather produced tumultuous waves dozens of feet high that smashed the Oregon and southwest Washington Coast Saturday, Jan. ...

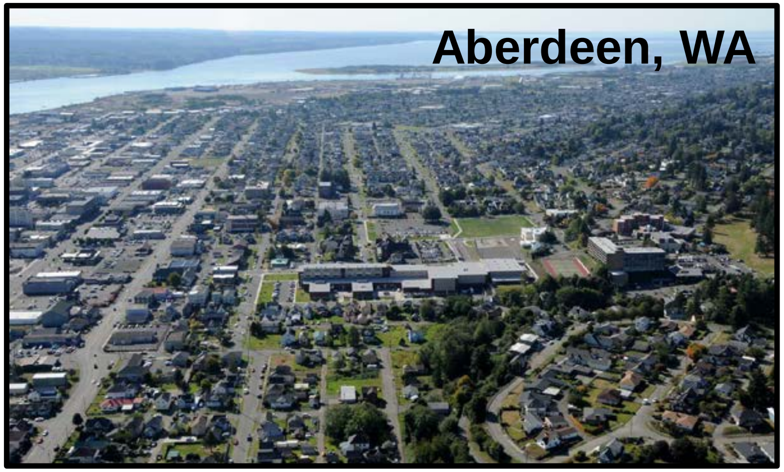
Saturday, 11 January 2020

Photo/video credit: Patrick Corcoran

# Why does understanding extreme coastal water levels matter?




# Why does understanding extreme coastal water levels matter?




# Defining total water levels (TWL)

$$\boldsymbol{TWL = MSL + \eta_A + \eta_{NTR} \quad + \quad R_{2\%}}$$

A. Thibault

=

+


E. Harris

where:
$MSL$ = mean sea level
$\eta_A$ = astronomical tide
$\eta_{NTR}$ = nontidal residual
$R$ = wave runup

# Defining total water levels (TWL)

$$TWL = MSL + \eta_A + \eta_{NTR} + R_{2\%}$$


=

+


$$\eta_{NTR} = \eta_{SE} + \eta_{MMSLA} + \eta_{SS}$$

where:
$MSL$ = mean sea level
$\eta_A$ = astronomical tide
$\eta_{NTR}$ = nontidal residual
$R$ = wave runup

where:
$\eta_{SS}$ = storm surge
$\eta_{SE}$ = seasonal signal
$\eta_{MMSLA}$ = monthly sea level anomaly

# Defining total water levels (TWL)

$$TWL = MSL + \eta_A + \eta_{NTR} \quad + \quad R_{2\%}$$


=

+


$$\eta_{NTR} = \eta_{SE} + \eta_{MMSLA} + \eta_{SS} + \eta_{Ri}$$

where:

$MSL$ = mean sea level

$\eta_A$ = astronomical tide

$\eta_{NTR}$ = nontidal residual

$R$ = wave runup

where:

$\eta_{SS}$ = storm surge

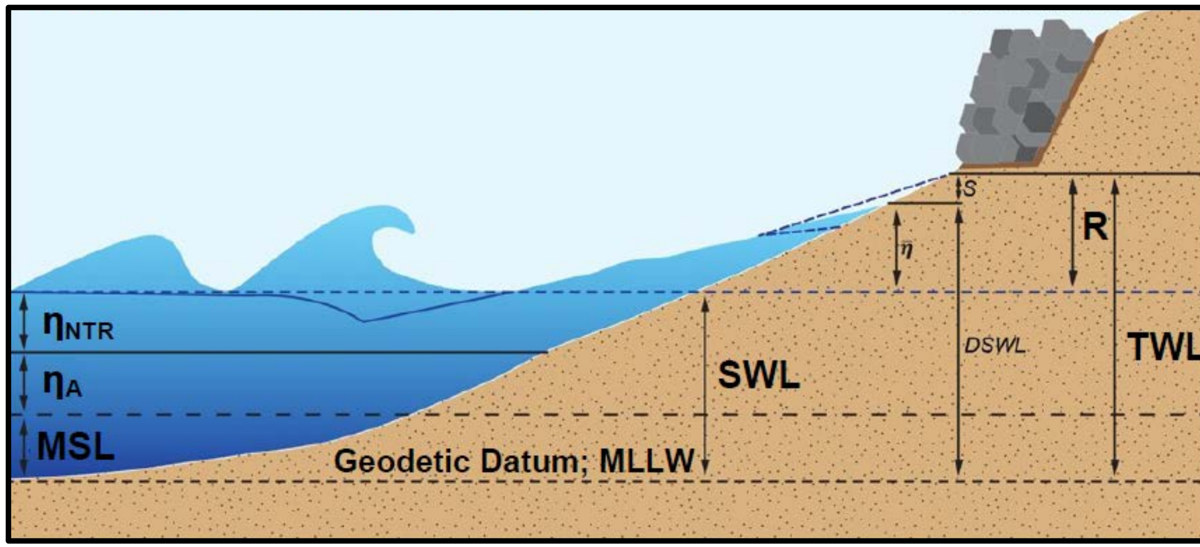
$\eta_{SE}$ = seasonal signal

$\eta_{MMSLA}$ = monthly sea level anomaly

$\eta_{Ri}$ = river influenced water level

# Defining total water levels (TWL)

$$TWL = MSL + \eta_A + \eta_{NTR} + R$$




where:

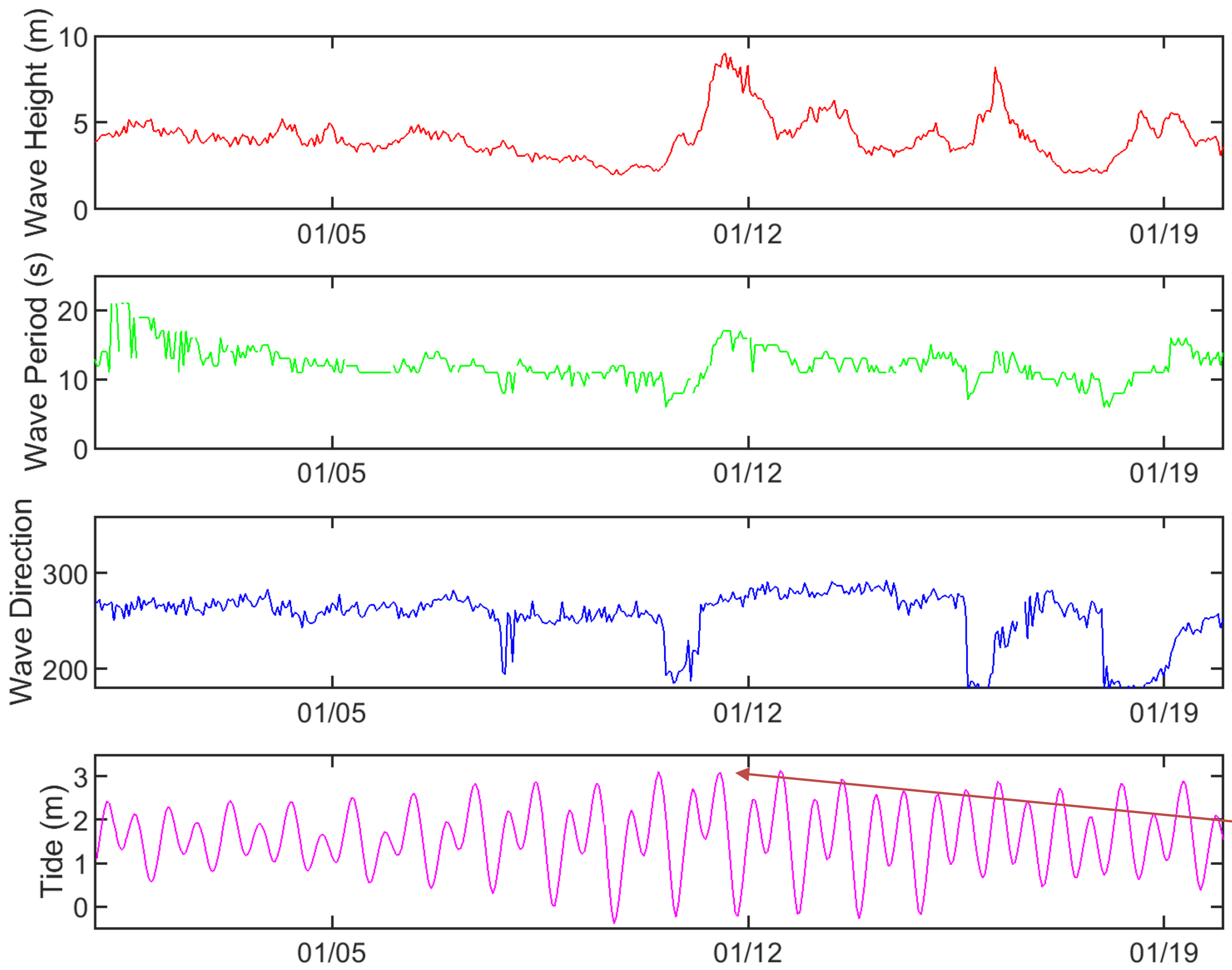
$MSL$ = mean sea level

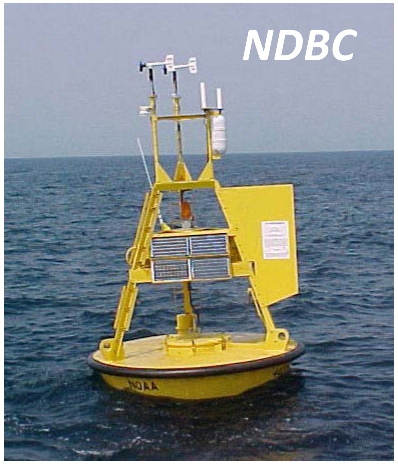
$\eta_A$ = astronomical tide

$\eta_{NTR}$ = nontidal residual

$R$ = wave runup

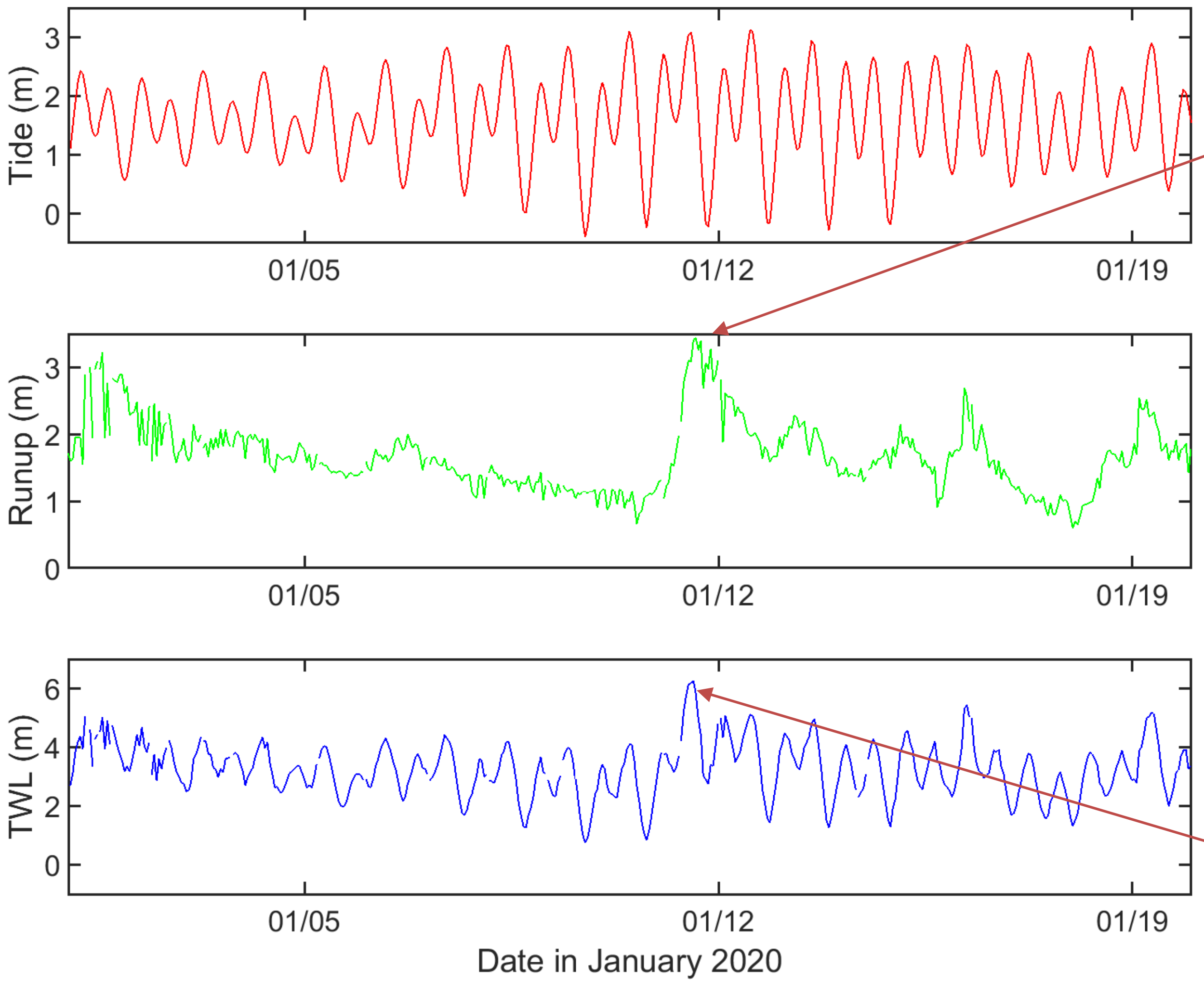
# Total water level time series




**King Tides >1.5 ft higher than MHHW!!**

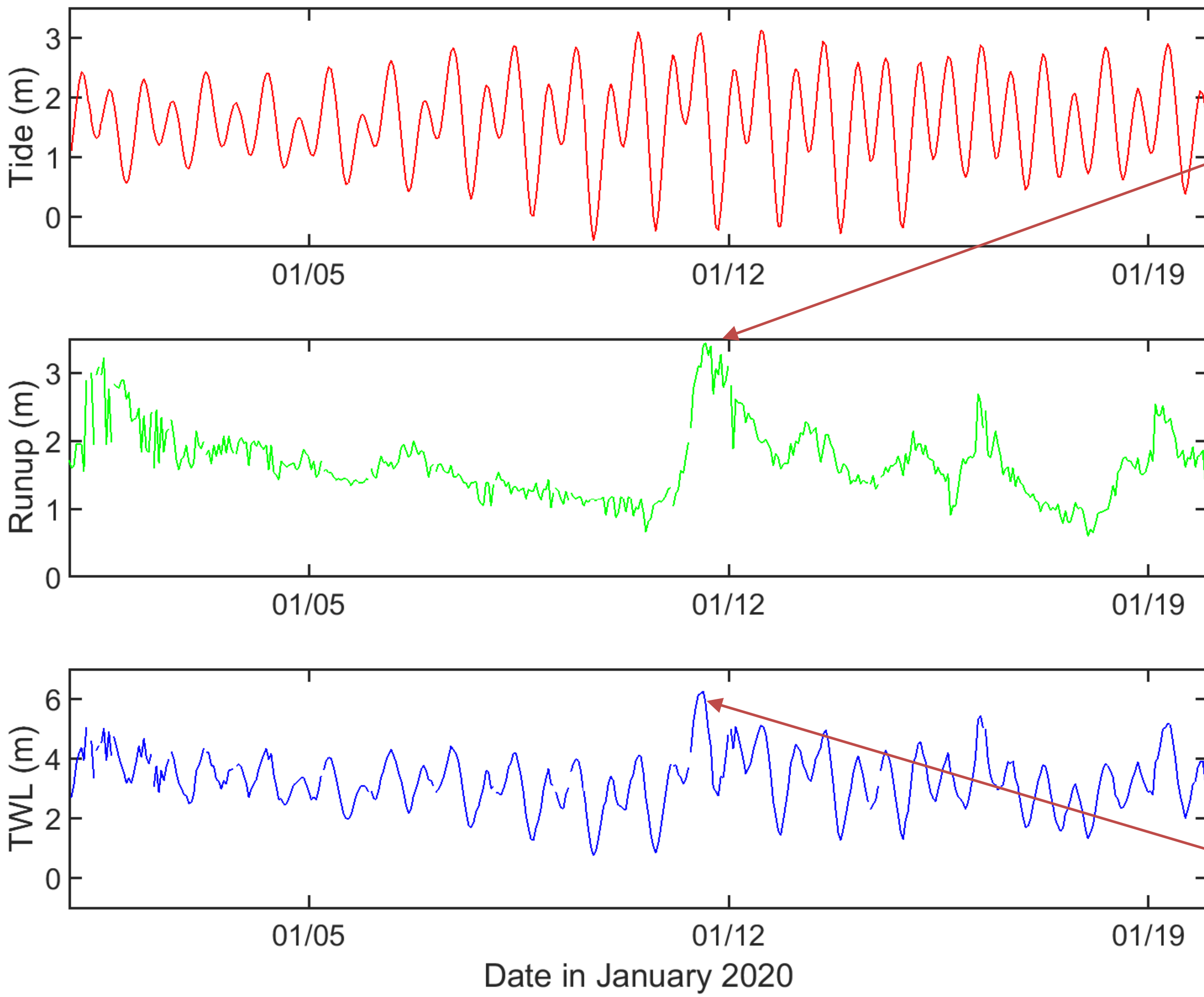
# Total water level time series




**Wave driven runup doubled total water level!**

**So TWL on the 11th was >5 feet higher than on the 10th or 12th.**

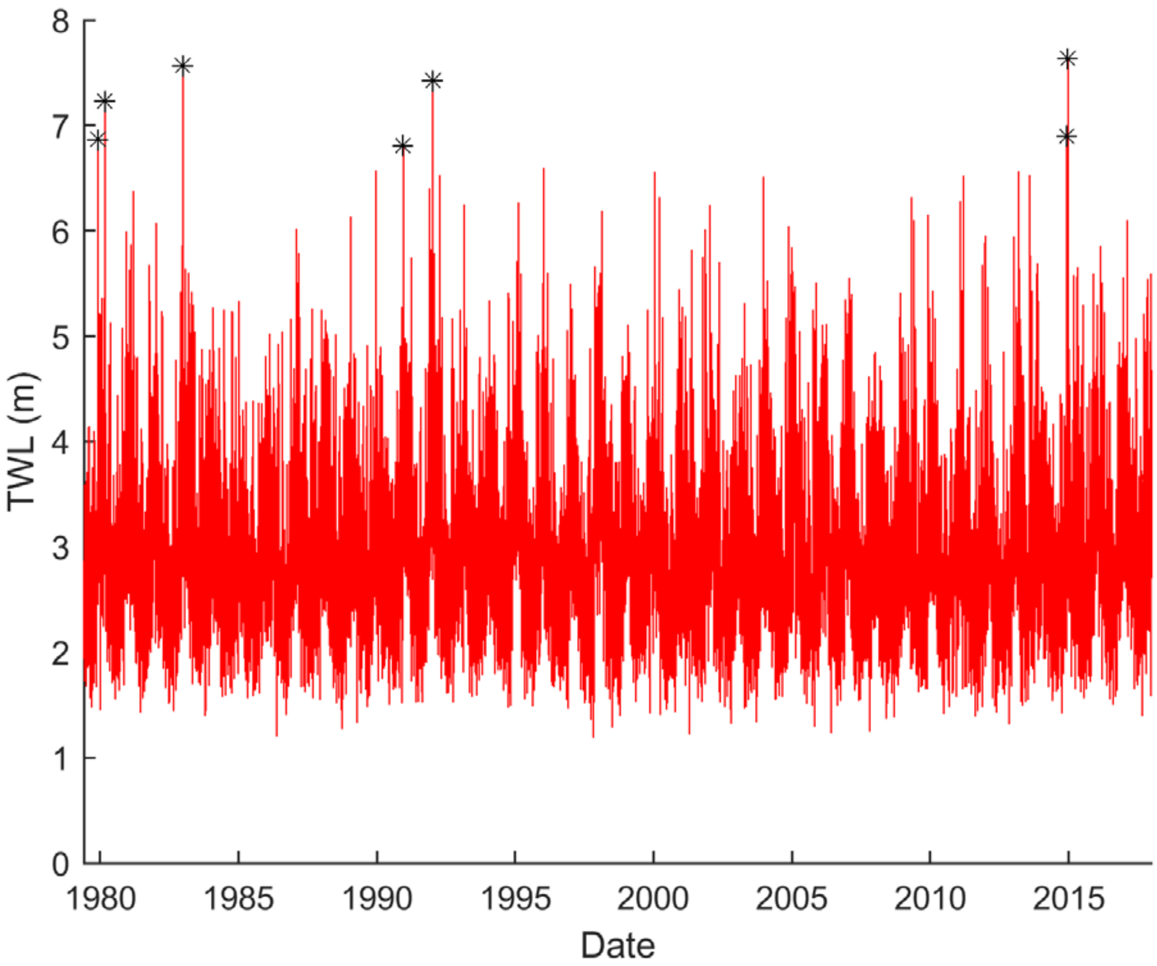
# Total water level time series




**Wave driven runup doubled total water level!**

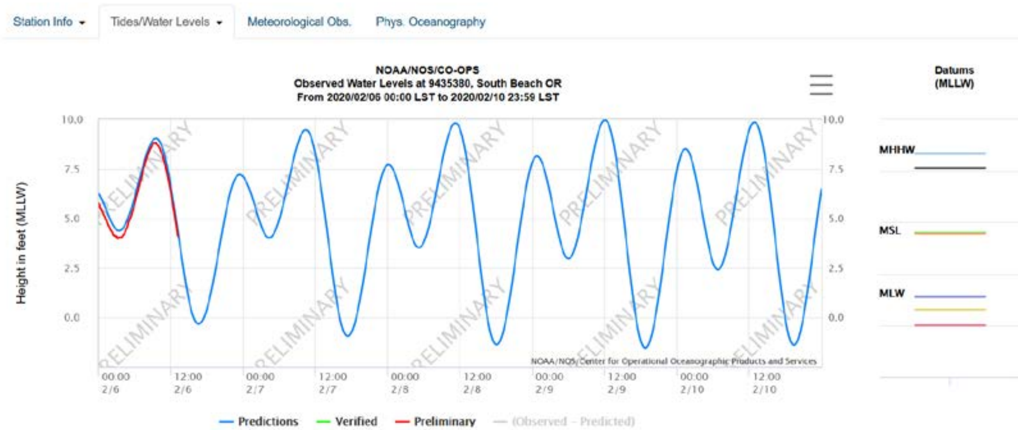
**So TWL on the 11th was >5 feet higher than on the 10th or 12th.**

# Total water level time series




**TWL on Jan 11th 2020 was in the top 10 since 1980 – At least along portions of Rockaway Beach**

# Total water level time series – Be careful this weekend!




National Oceanic and Atmospheric Administration's

## National Data Buoy Center

Center of Excellence in Marine Technology

Home About Us Contact Us

### National Weather Service Marine Forecast FZUS56 KPQR

FZUS56 KPQR 061047
CWFPQR

Coastal Waters Forecast
National Weather Service Portland OR

seas 19 ft with a dominant period of 12 seconds. Rain likely.

**SAT**
NW wind 25 to 30 kt. Gusts to 40 kt, becoming 35 kt in the afternoon. Combined seas 23 ft with a dominant period of 13 seconds. Chance of showers.

# Defining impacts of TWLs

## Impact Hours Per Year (IHPY)

How often the TWL reaches or exceeds a beach contour or other morphological threshold (dune toe height or dune crest height) can be related to a wide range of coastal hazards along the coast

# Coastal hazards on the US West coast

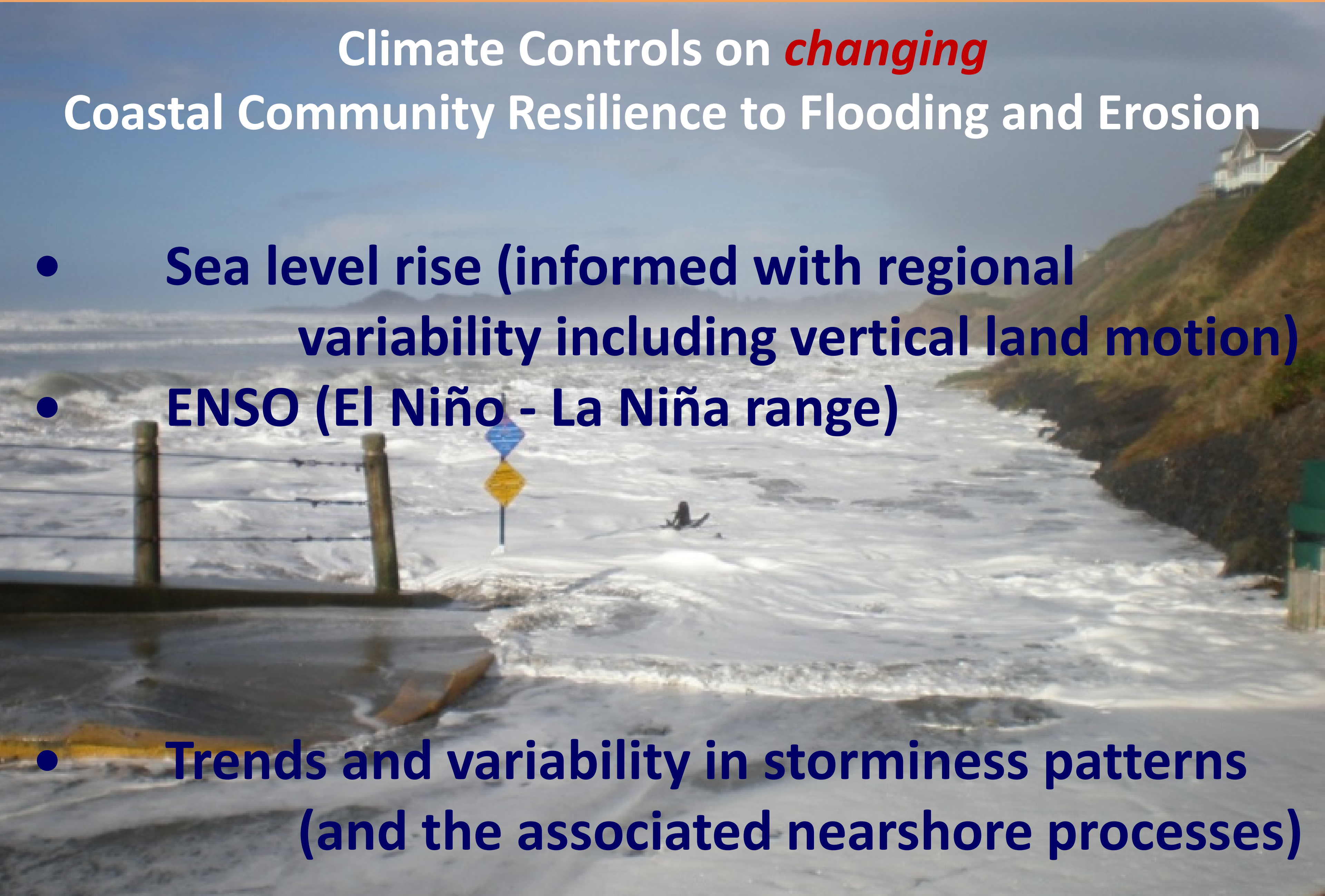
Flooding in Capitola, CA


Erosion in Ocean Beach, CA

Flooding in Aberdeen, WA


Erosion in Neskowin, OR

# Climate Controls on *changing* Coastal Community Resilience to Flooding and Erosion



- Sea level rise (informed with regional variability including vertical land motion)
- ENSO (El Niño - La Niña range)
- Trends and variability in storminess patterns (and the associated nearshore processes)

# Socio-economic Controls on *changing* Coastal Community Resilience to Flooding and Erosion

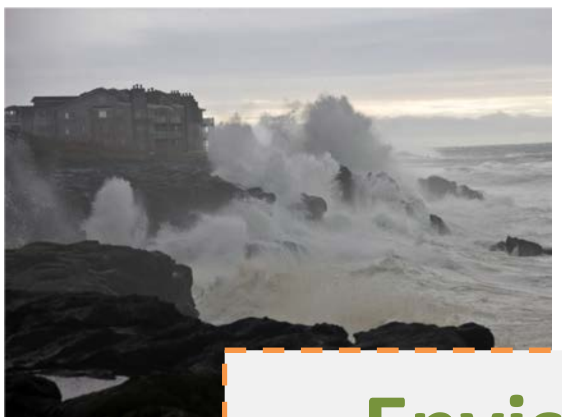
- Population growth
- Development Patterns
- Adaptation Planning

# Community Questions about Adaptation Planning?

1. Can implementing adaptation measures change how coastal flooding and erosion impact the things we care about?
2. **Can we characterize that change?**
3. How does the implementation of adaptation policies alter development? How much will it cost?
4. **When will homeowners need backshore protection structures (riprap) to protect their property? Is it legal?**
5. What is the feasibility of implementing various adaptation measures?
6. **What extent of the beach is accessible now and in the future?**

# Envisioning Resilient Coastal Futures

CIRC Climate Impacts Research Consortium · NOAA · Sea Grant Oregon · Oregon State University



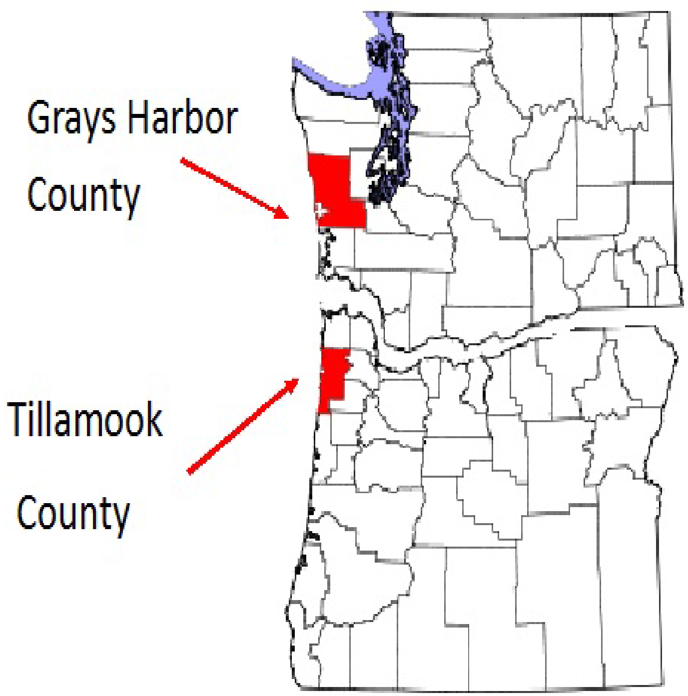
Climate

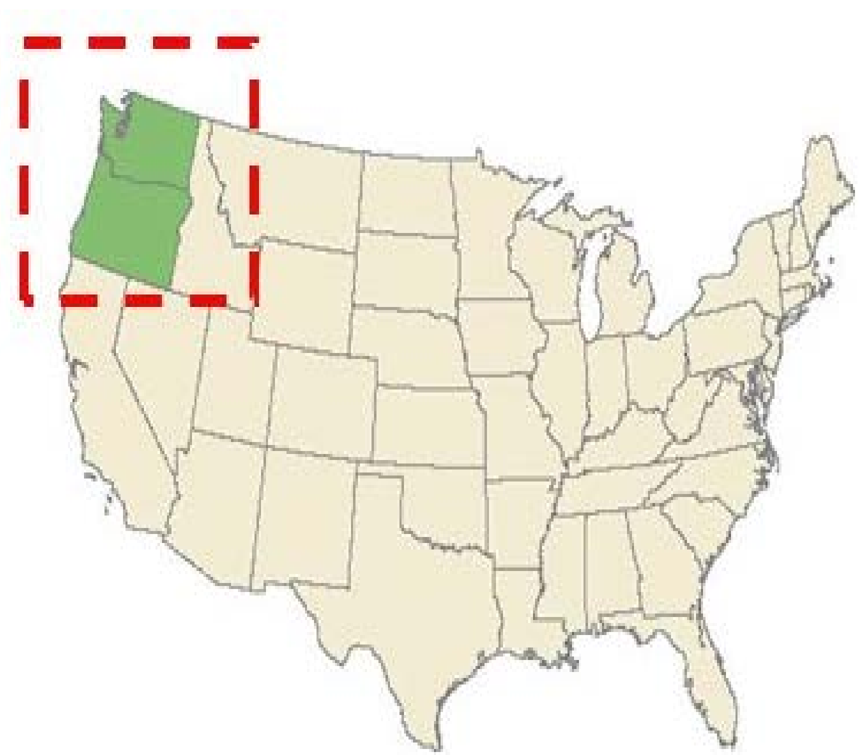
Policy

## Envisioning Alternative Futures:

Explore how complex coupled natural and human systems dynamically respond to varying adaptation and climate change scenarios.

## **Objective:** Inform climate-resilient strategies in the US Pacific Northwest

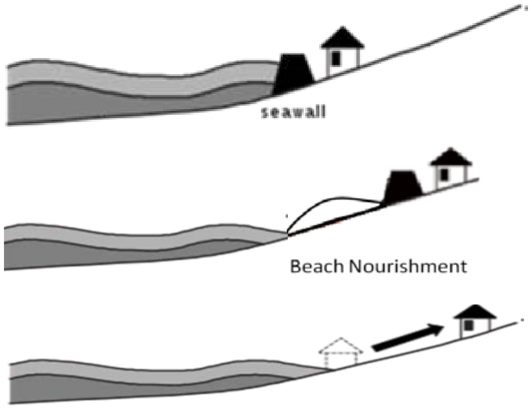


# Envisioning Resilient Coastal Futures

CIRC Climate Impacts Research Consortium
NOAA
Sea Grant Oregon
Oregon State University

## **Objective:** Inform climate-resilient strategies in the US Pacific Northwest



# Alternative Futures Analysis: *Envision*

Bolte et al., 2007, Mills et al., 2018

**Data Sources**

- Landscape Data

**Landscape Change Models**

- Population Growth
- Development
- Total Water Level
- Coastal Change Models

**Scenarios**

- Policy Scenario Narratives
- Climate Impact Change Scenarios

*Agent Based Model: Envision*

**Metrics**

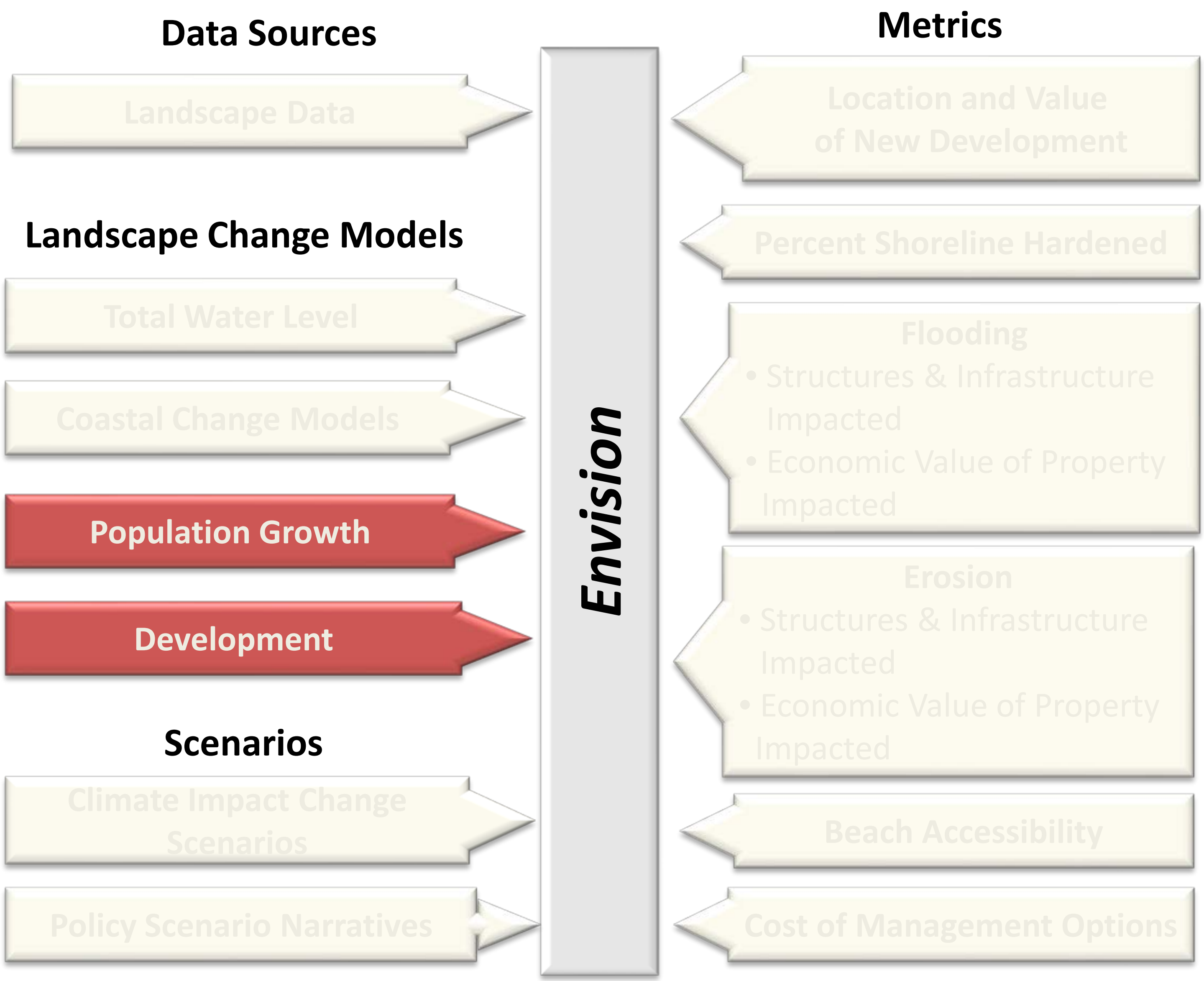
**Flooding**
- Structures & Infrastructure Impacted
- Economic Value of Property
- Impacted

**Erosion**
- Structures & Infrastructure Impacted
- Economic Value of Property
- Impacted

**Percent Shoreline Hardened**

**Beach Accessibility**

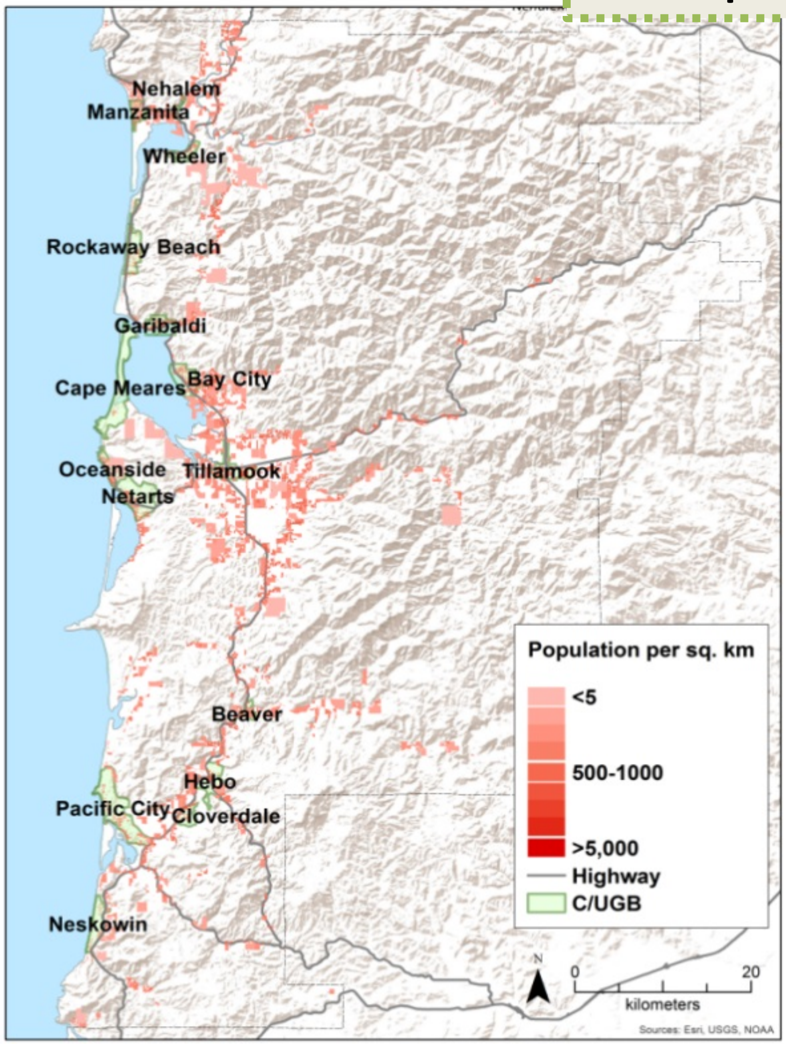
# Envisioning Resilient Coastal Futures



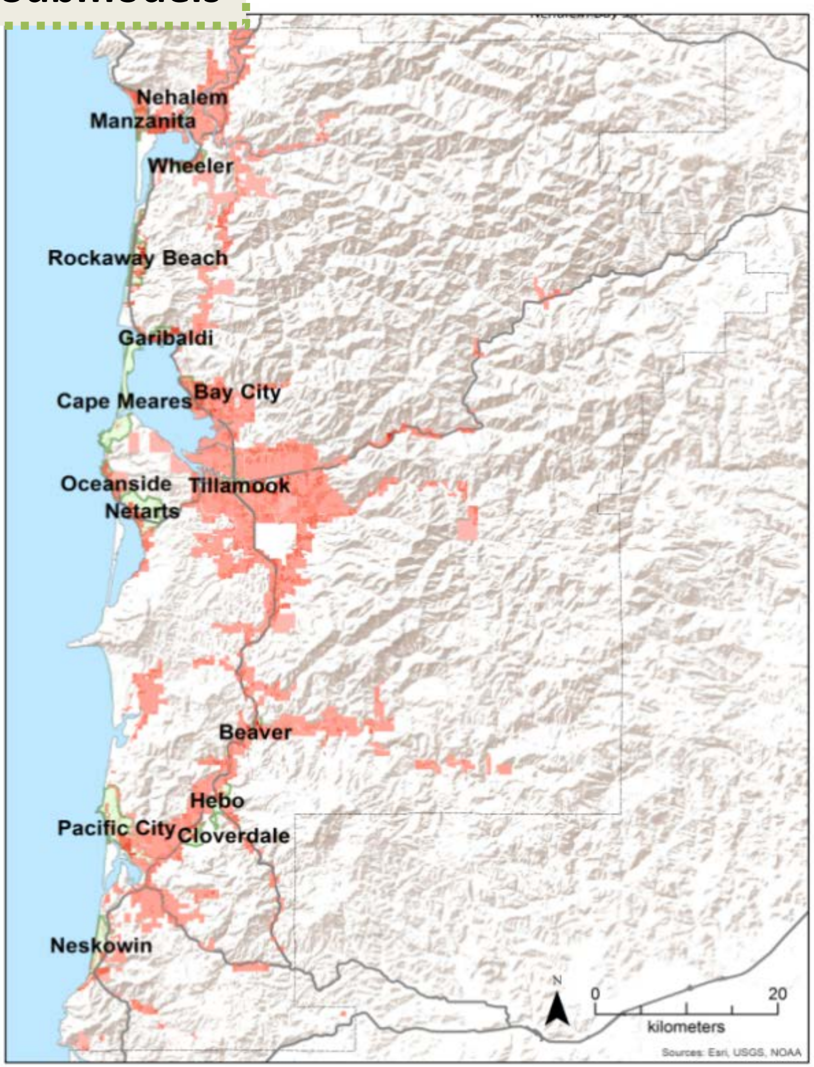
# Envisioning Resilient Coastal Futures

**Population Growth and Development Submodels**

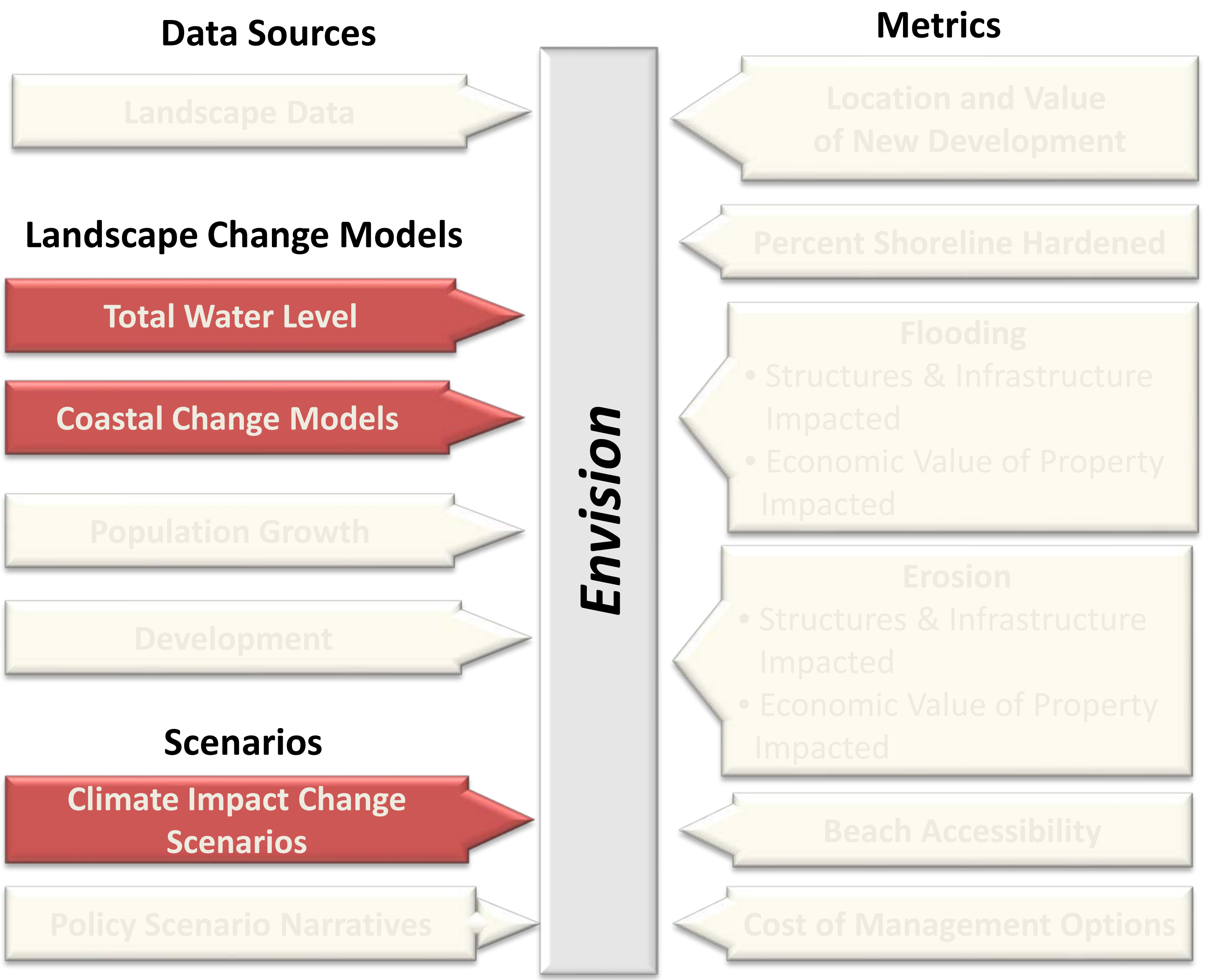
2010



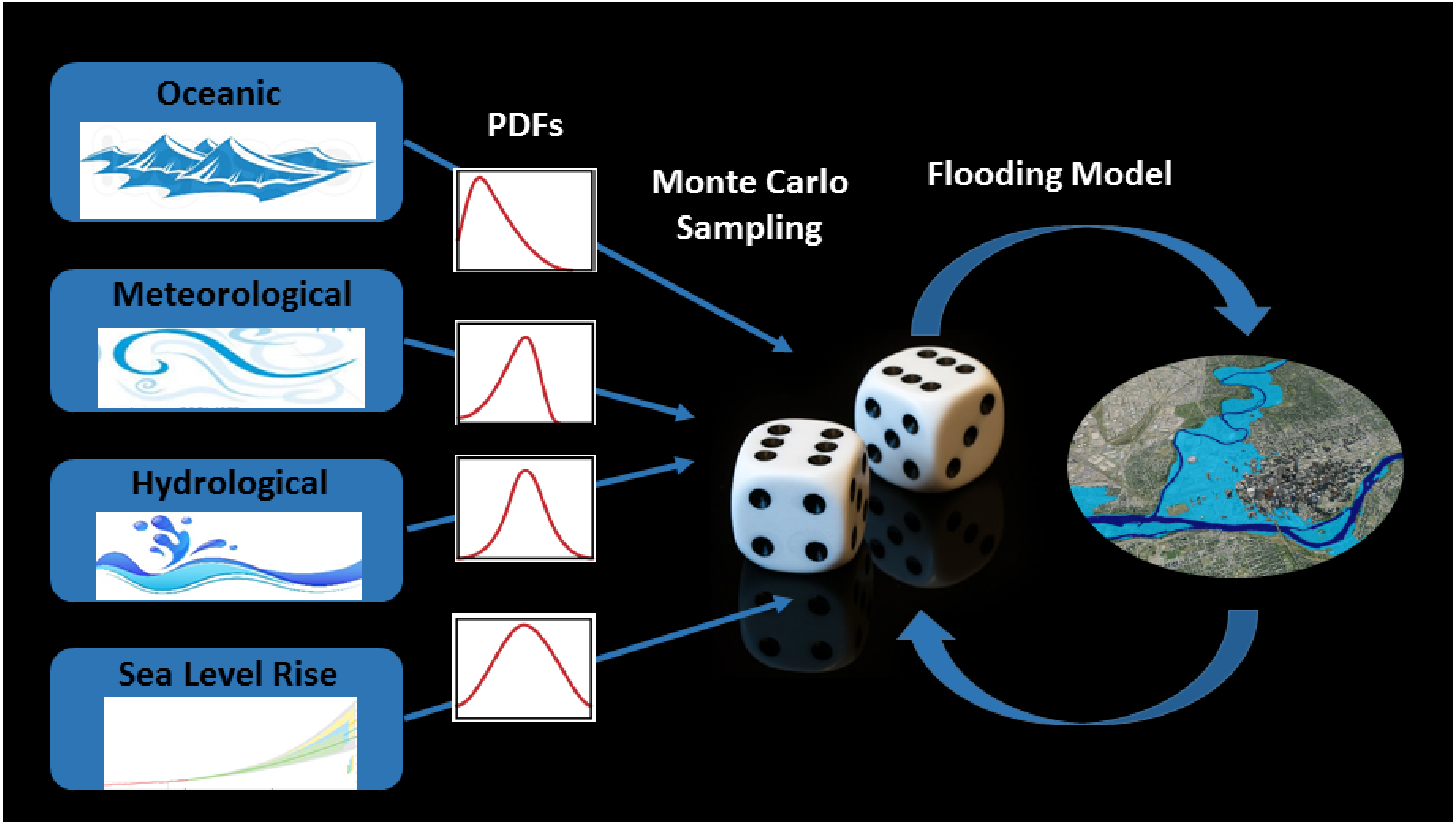

2100



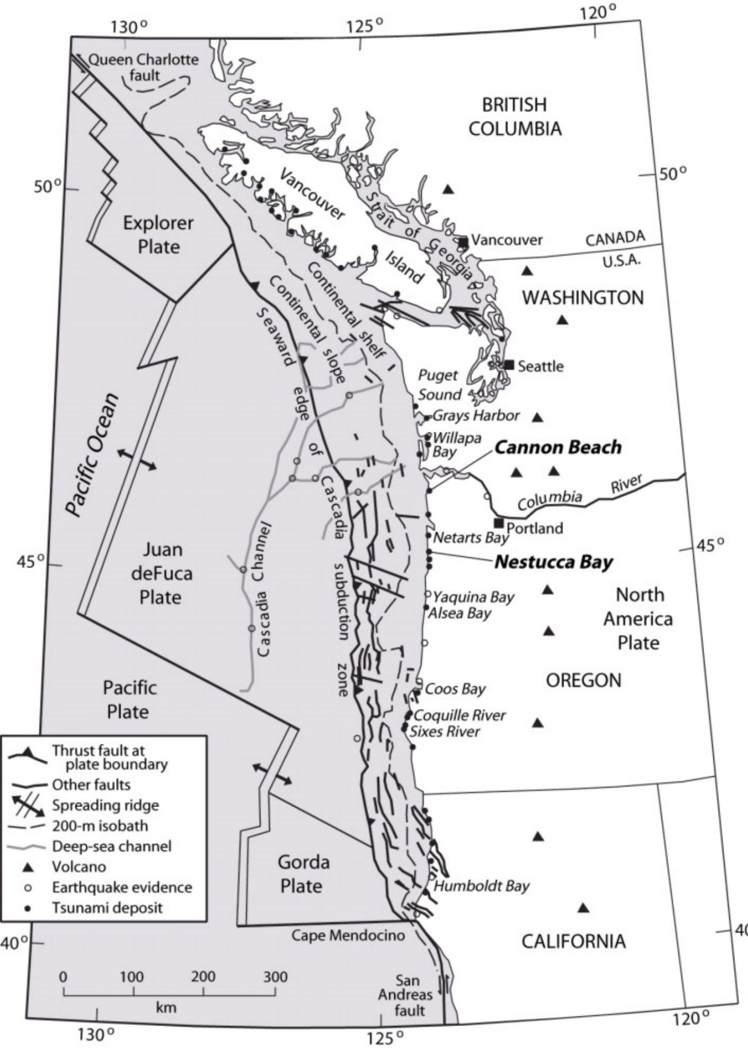
# Envisioning Resilient Coastal Futures



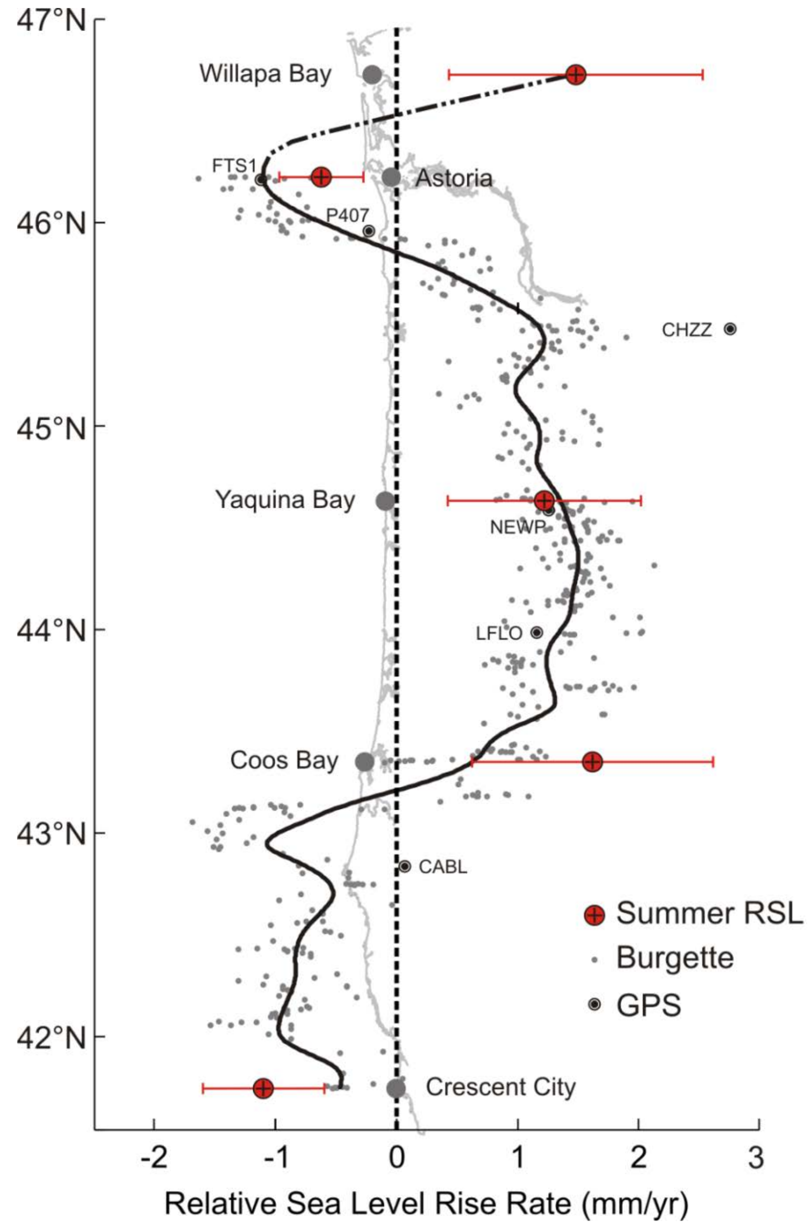
# Climate Change Scenarios/TWL Modeling




Serafin and Ruggiero, 2014, Miller et al., 2018, Parker et al., 2019.




# Geological and Hydrodynamic Setting of the PNW

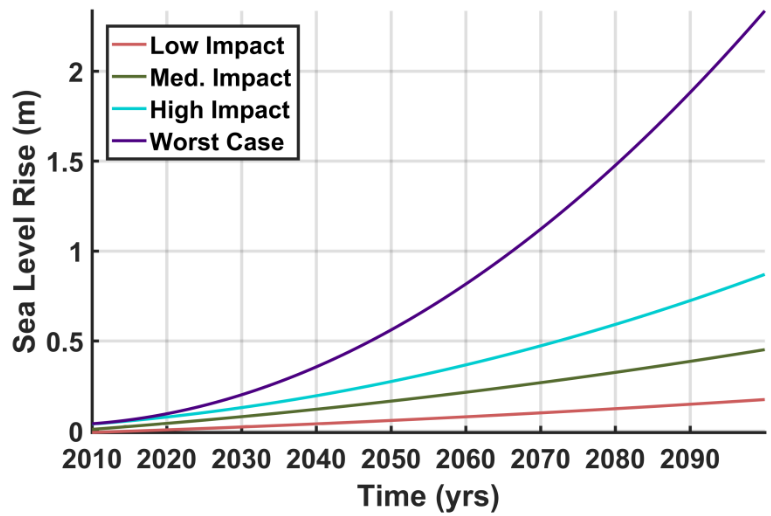



Varying rates of uplift are reflected in RSLR

**Komar, Allan, and Ruggiero, 2011.**
**after Burgette et al. 2009**

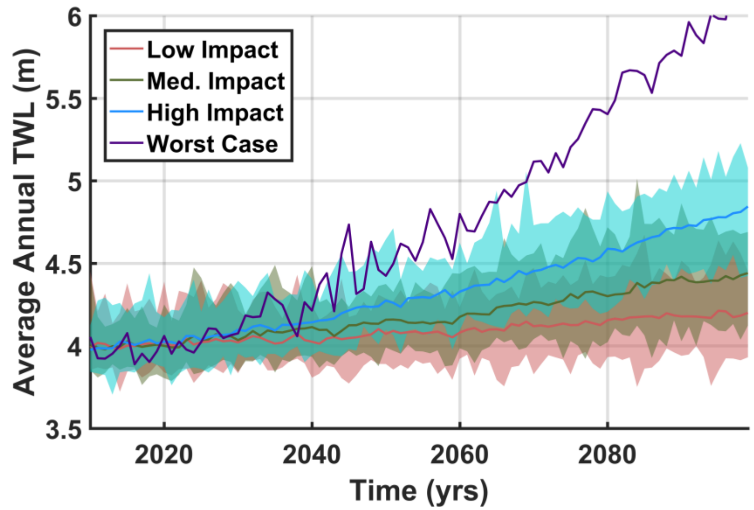
# Climate Change Scenarios/TWL Modeling

sea level rise/VLM



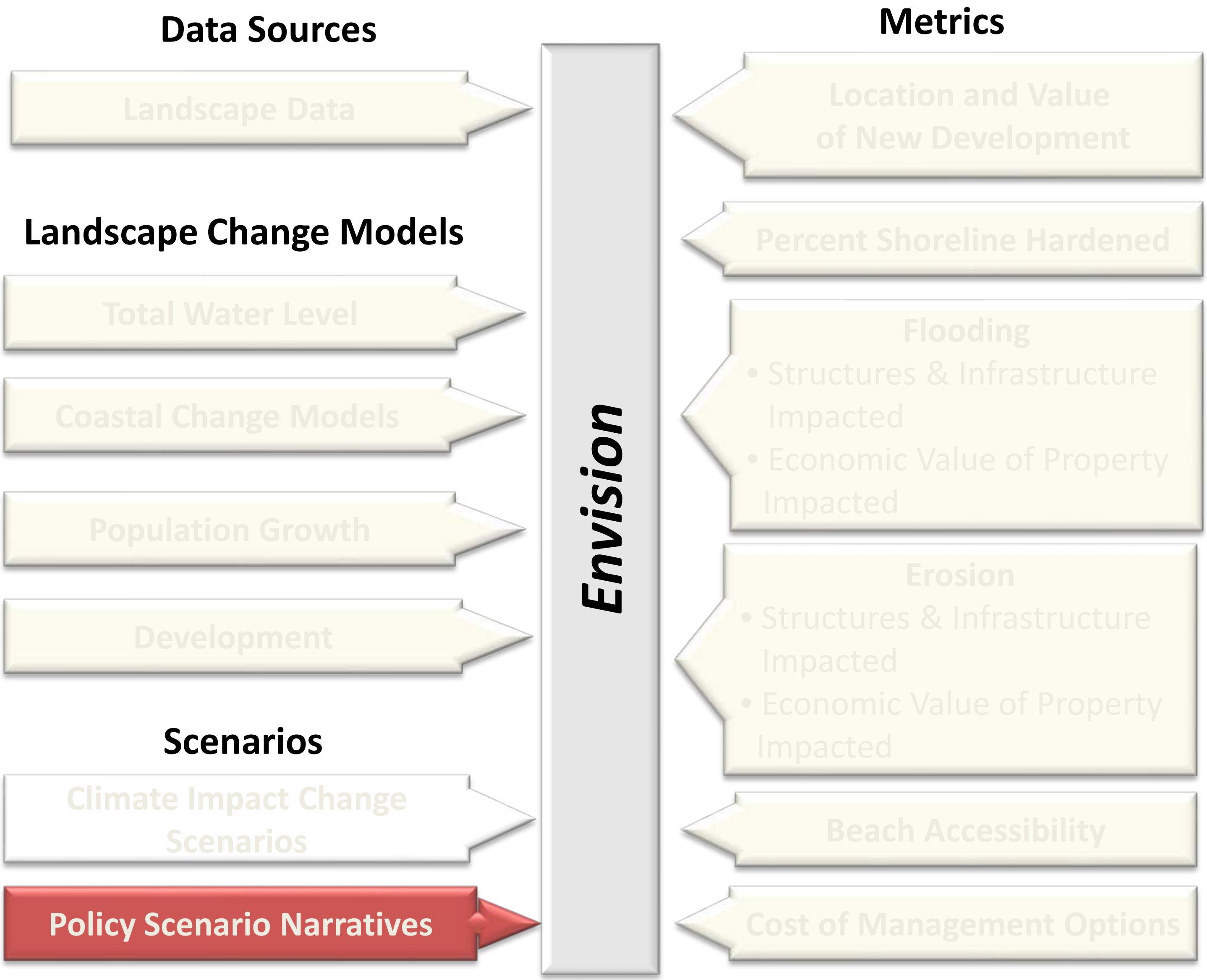

wave climate variability

El Niño variability




Sweet et al., 2017, Hemer 2013, Cai et al., 2014, Serafin and Ruggiero, 2014, Miller et al., 2018

# Envisioning Resilient Coastal Futures



# Co-development of Policy Scenarios

# Policy Scenario Narratives


## ***1. Status Quo***

*Continuation* of present-day policies.

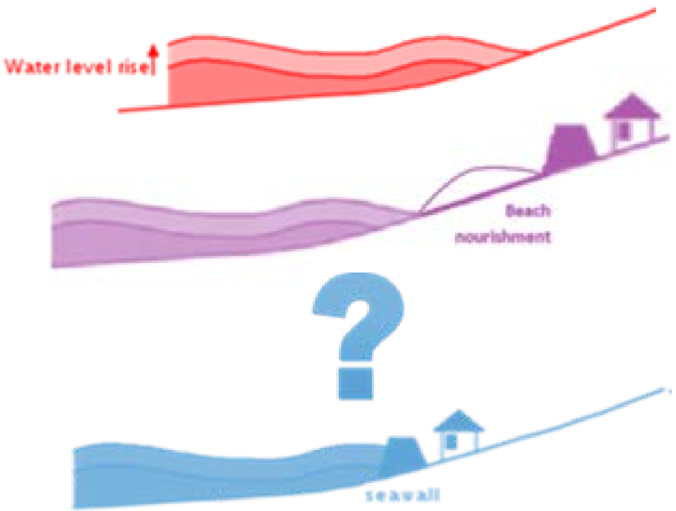
# Policy Scenario Narratives


## 1. Status Quo

*Continuation* of present-day policies.

**Example Policy: Maintain current backshore protection structures (BPS) and allow more BPS to be built on eligible lots.**

# Policy Scenario Narratives




## 1. Status Quo

## 2. Hold the Line

## 3. Laissez-Faire

Current policies (state and county) are *relaxed* such that existing homes, infrastructure and new development all trump the protection of coastal resources, public rights, recreational use, beach access, scenic views.

# Policy Scenario Narratives


**1. Status Quo**

**2. Hold the Line**

**3. Laissez-Faire**

**4. ReAlign:** *Change* human activities to suit the changing environment.

**5. Neskowin**

**6. Hybrid**

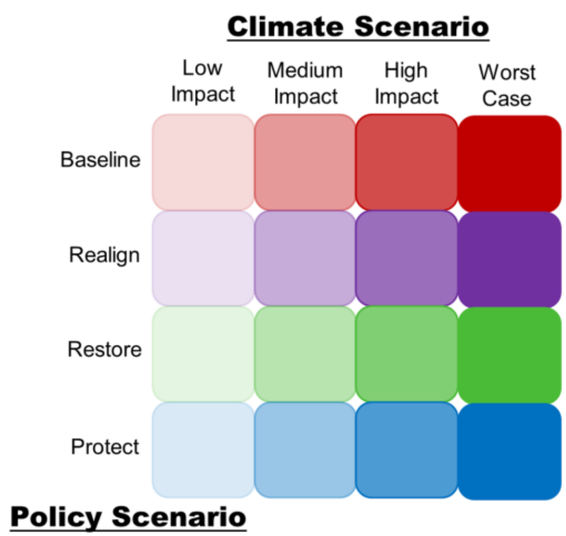
Implement policies in accordance with the **preferences established by the KTAN**

# Envisioning a Resilient Oregon Coast

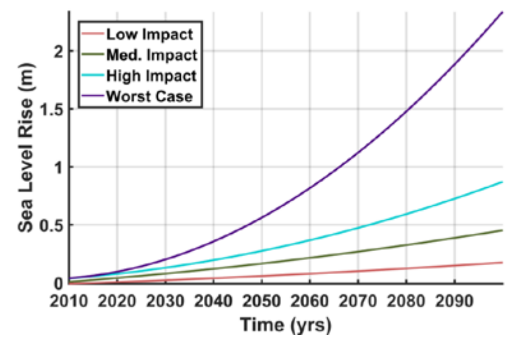
Oregon State University | Sea Grant Oregon

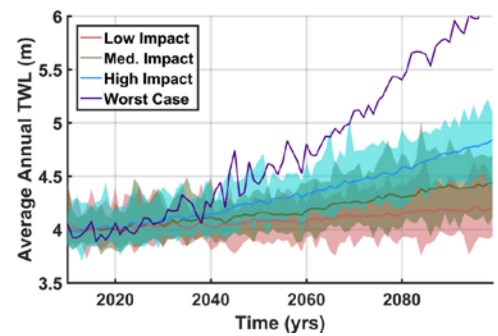
## Individual Policies

| Policy | BL | RA | RS | PR |
|---|---|---|---|---|
| BPS Constr. | | | | ■ |
| BPS Mainten. | ■ | | ■ | ■ |
| BPS Nourish. | ■ | | | ■ |
| DRP Constr. | | | ■ | |
| DRP Mainten. | | | ■ | |
| DRP Nourish. | | | ■ | |
| Hazard zone development restrictions | | ■ | | |
| Remove Buildings From Hazard Zone | | ■ | | |
| Remove Critical Infrastructure from Hazard Zones | | ■ | | |
| Raise or Move structure to a new location in the same tax lot | | ■ | | ■ |
| Raise Critical Infrastructure | | | | ■ |




## Climate Driven Forcing



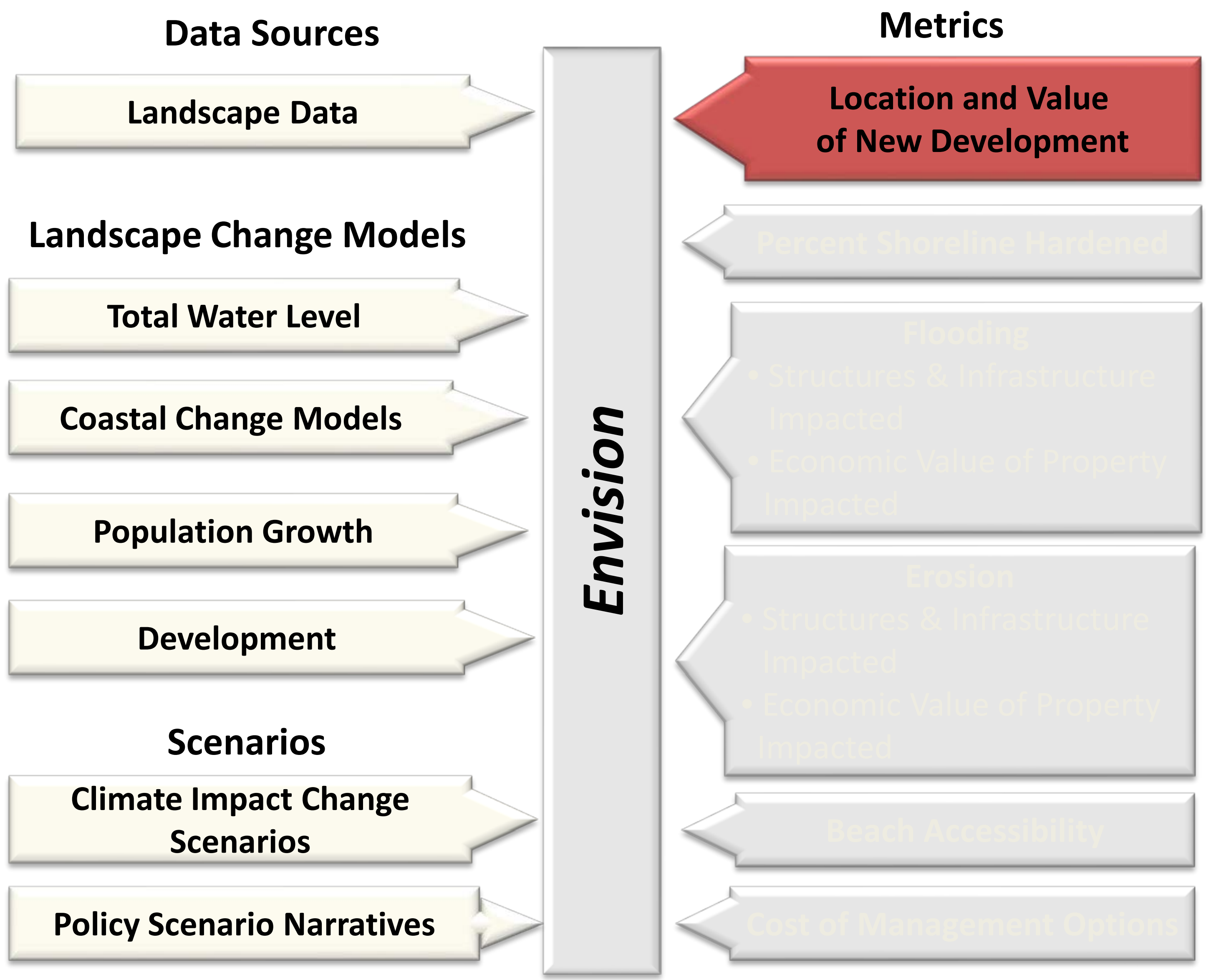

***Low Impact Scenario***
**Uses a low-end projection of SLR: Extremely likely to exceed (95%)**

***Medium Impact Scenario***
**Uses a mid-range projection of SLR: More likely than not to exceed (50% )**

***High Impact Scenario***
**Uses a high-end projection of SLR: Extremely unlikely to exceed (5%)**

***Worst Case Scenario***
**Uses a "Worst Case" Scenario: Project upper limit (0.1%)**

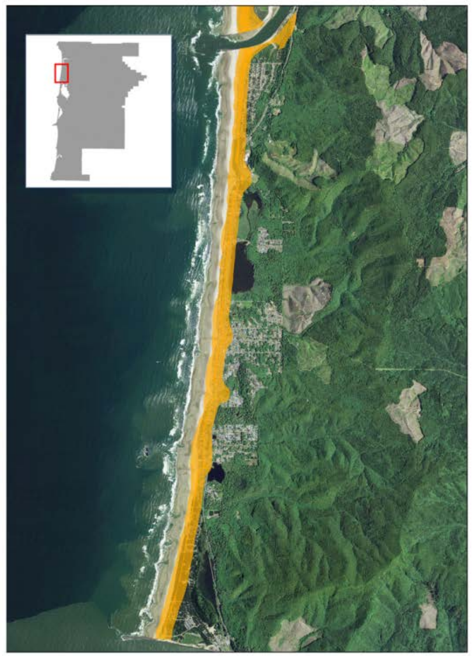
# Envisioning Resilient Coastal Futures



# The effect of policies on development patterns

Neskowin

Rockaway Beach

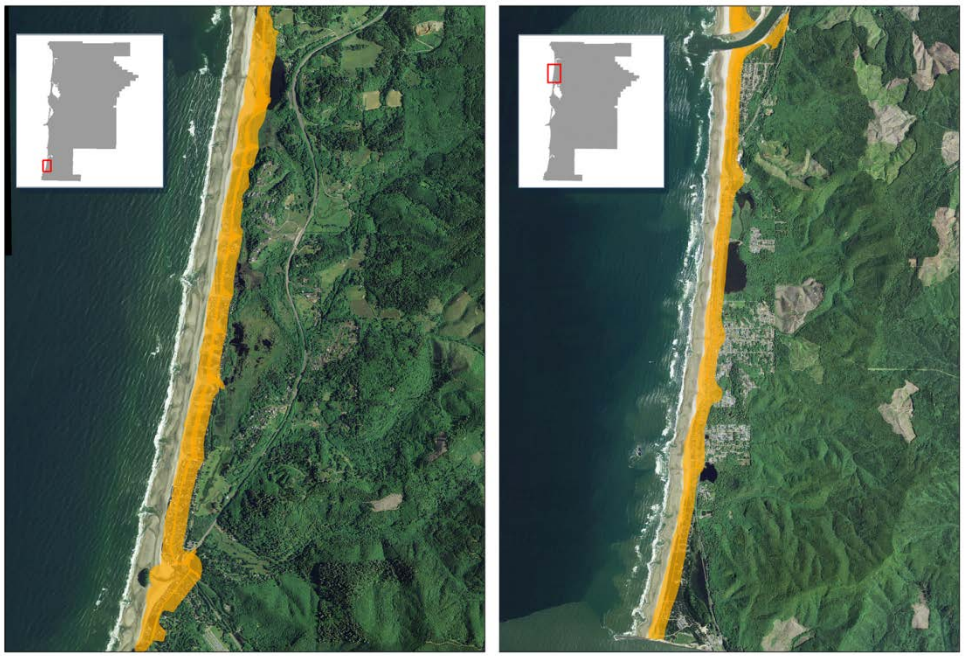


Chronic Coastal Hazard Zone - DOGAMI

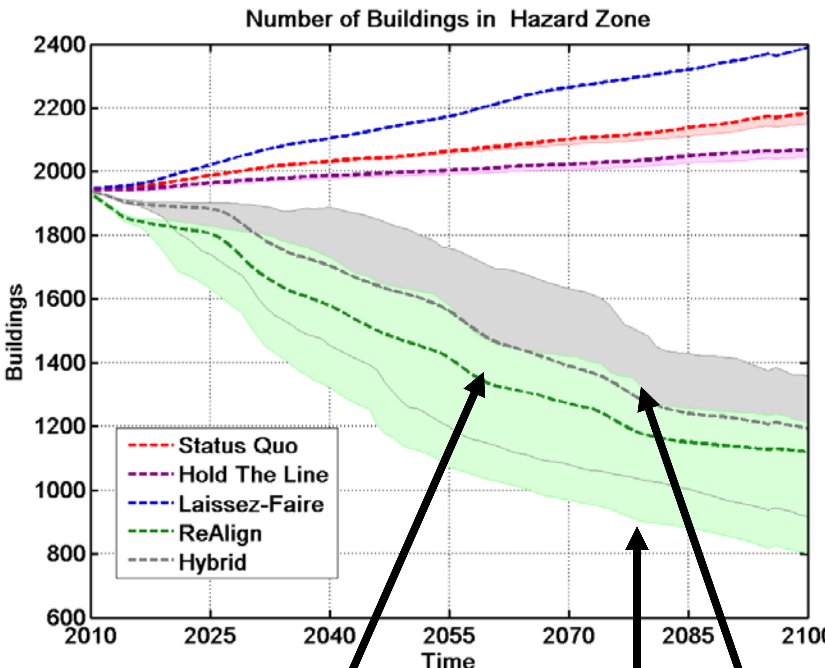
**Land Use Adaptation Policies–**

- Prevent further development within hazard zone.
- Remove buildings from hazard zones through easements, etc.

# The effect of policies on development patterns




Chronic Coastal Hazard Zone - DOGAMI

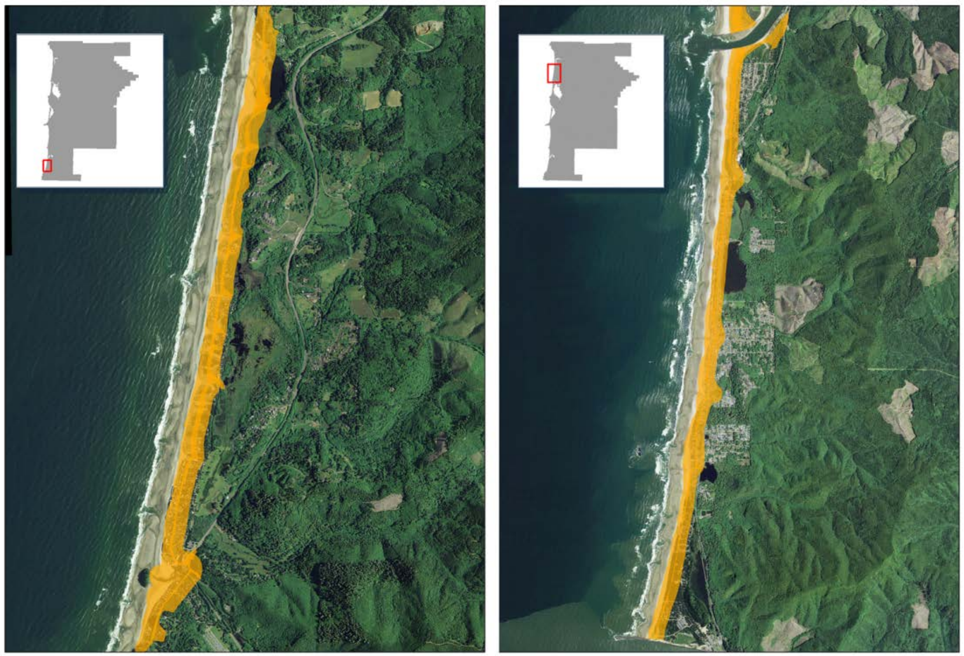



**Medium impact climate scenario**

**High and low impact climate scenarios**

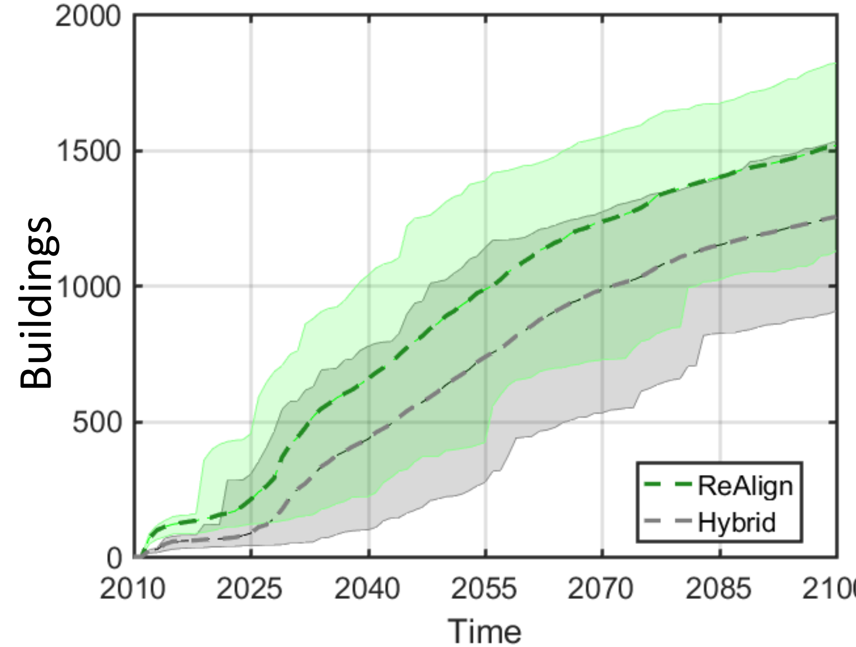
# The effect of policies on development patterns

Neskowin Rockaway Beach



Chronic Coastal Hazard Zone - DOGAMI

Buildings transitioned into easements



# Envisioning Resilient Coastal Futures

## Data Sources

Landscape Data

## Landscape Change Models

Total Water Level

Coastal Change Models

Population Growth

Development

## Scenarios

Climate Impact Change Scenarios

Policy Scenario Narratives

***Envision***

## Metrics

Location and Value of New Development

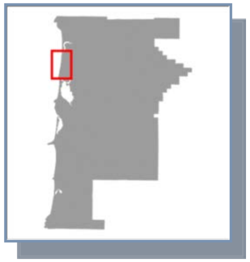
**Percent Shoreline Hardened**

Flooding
- Structures & Infrastructure Impacted
- Economic Value of Property Impacted

Erosion
- Structures & Infrastructure Impacted
- Economic Value of Property Impacted

Beach Accessibility

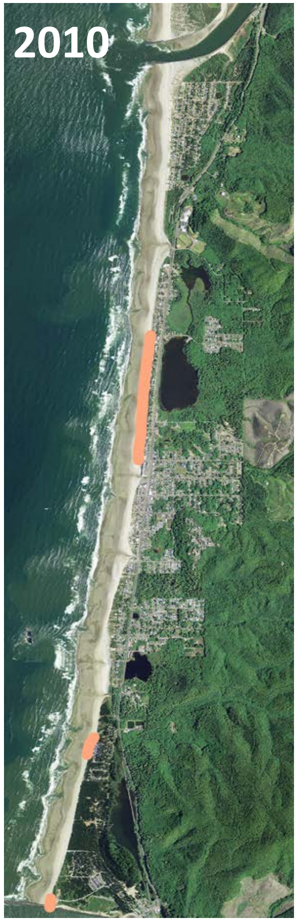
Cost of Management Options



# Coastline armored in response to erosion

## *Rockaway Beach Littoral Sub-Cell*

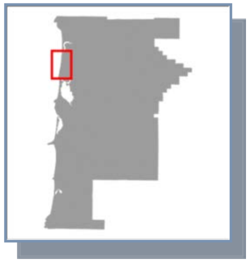
Existing BPS New BPS



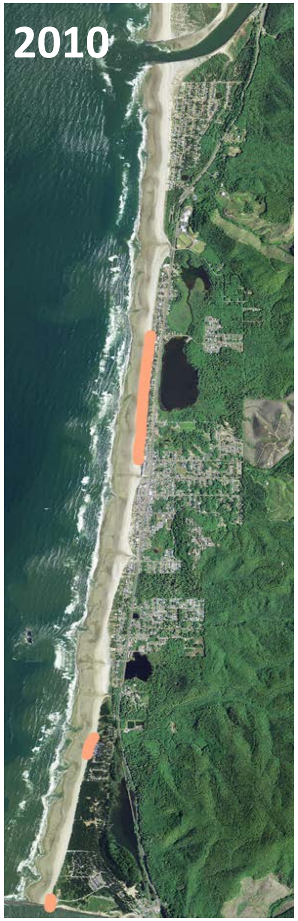

Present Day

# Coastline armored in response to erosion

***Rockaway Beach Littoral Sub-Cell***



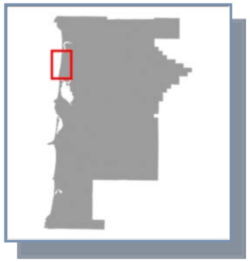
Existing BPS   New BPS




Present Day


Status Quo

**Medium Climate Impact Scenario**



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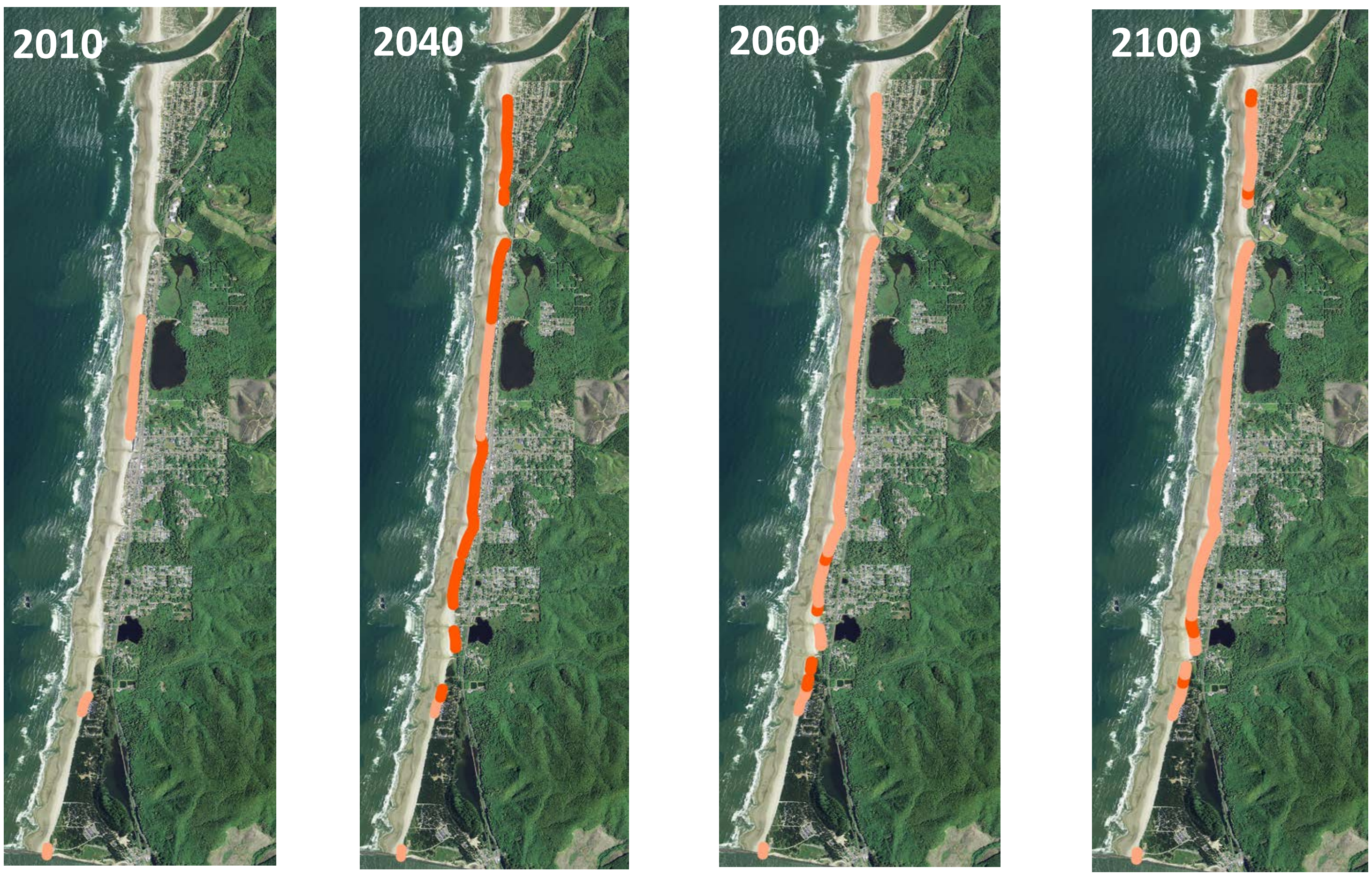


Present Day Status Quo Status Quo Status Quo

# Envisioning Resilient Coastal Futures

## Data Sources

- Landscape Data

## Landscape Change Models

- Total Water Level
- Coastal Change Models
- Population Growth
- Development

## Scenarios

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## *Envision*

## Metrics

- Location and Value of New Development
- Percent Shoreline Hardened
- **Flooding**
  - Structures & Infrastructure Impacted
  - Economic Value of Property Impacted
- **Erosion**
  - Structures & Infrastructure Impacted
  - Economic Value of Property Impacted
- Beach Accessibility
- Cost of Management Options

# Beach Accessibility

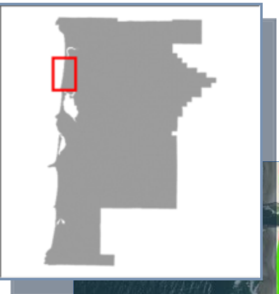

Present Day

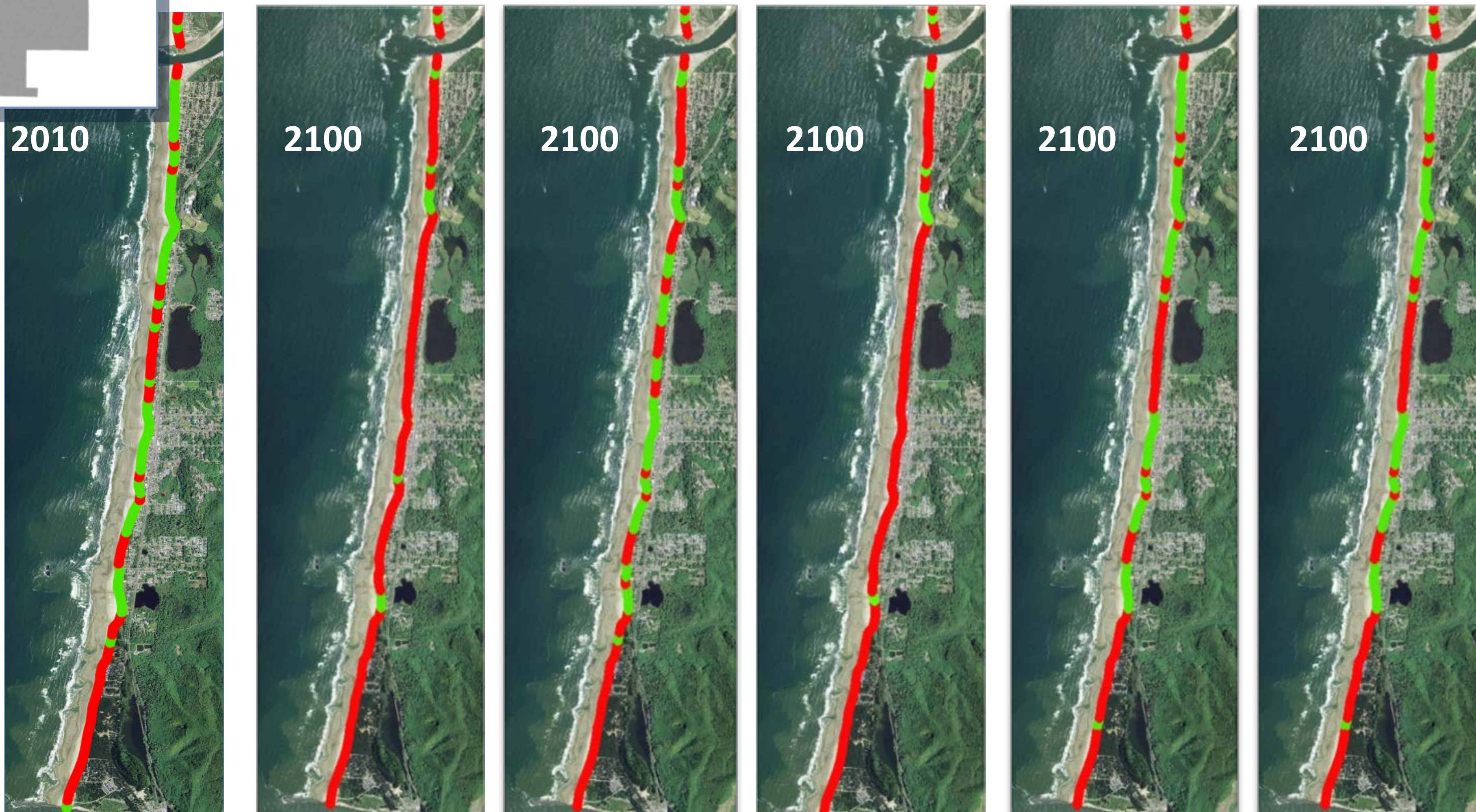
Limited Beach Access    Unlimited Beach Access

# Beach Accessibility

Medium Climate Impact Scenario

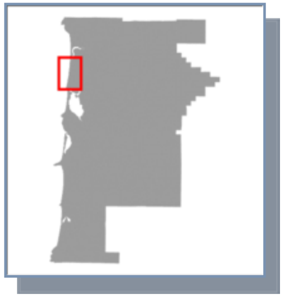
Limited Beach Access — Unlimited Beach Access

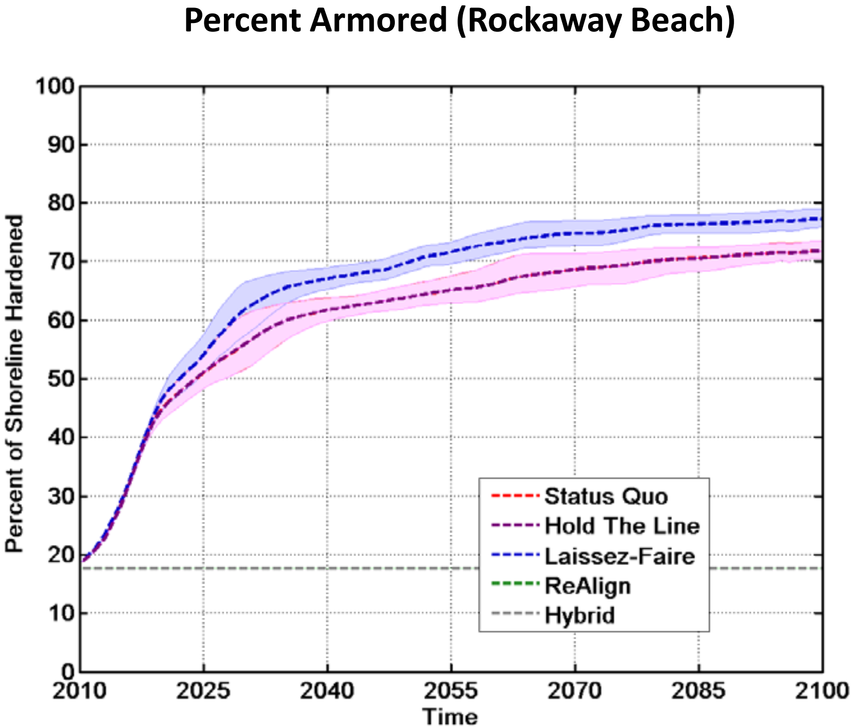


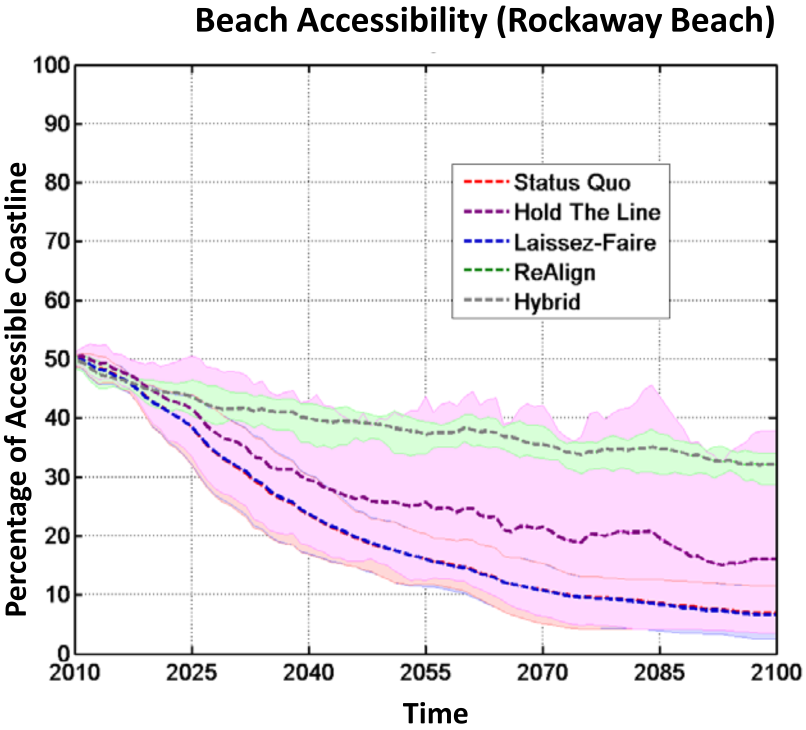



Present Day | Status Quo | Hold the Line | Laissez-Faire | ReAlign | Hybrid

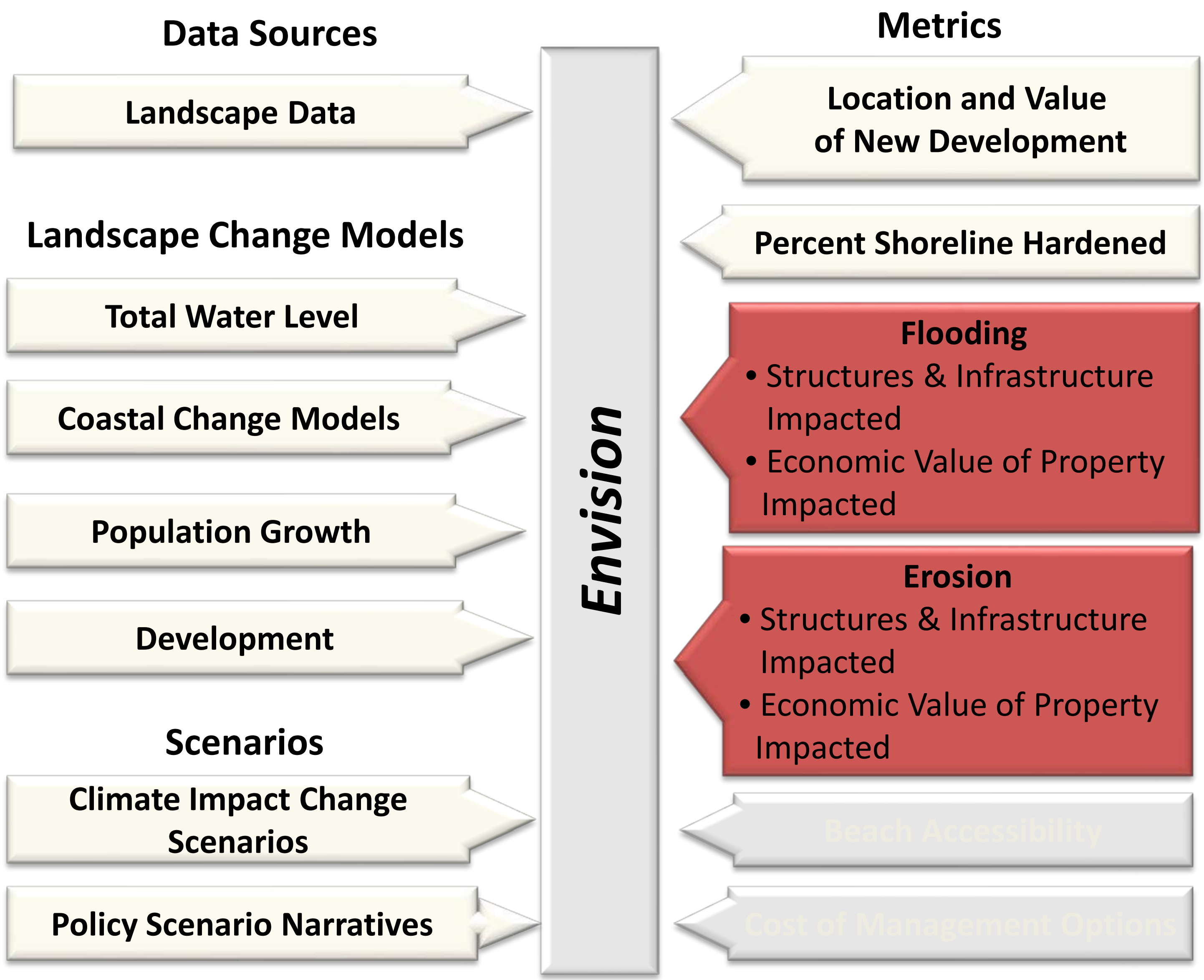
# Policy driven tradeoffs in resilience metrics



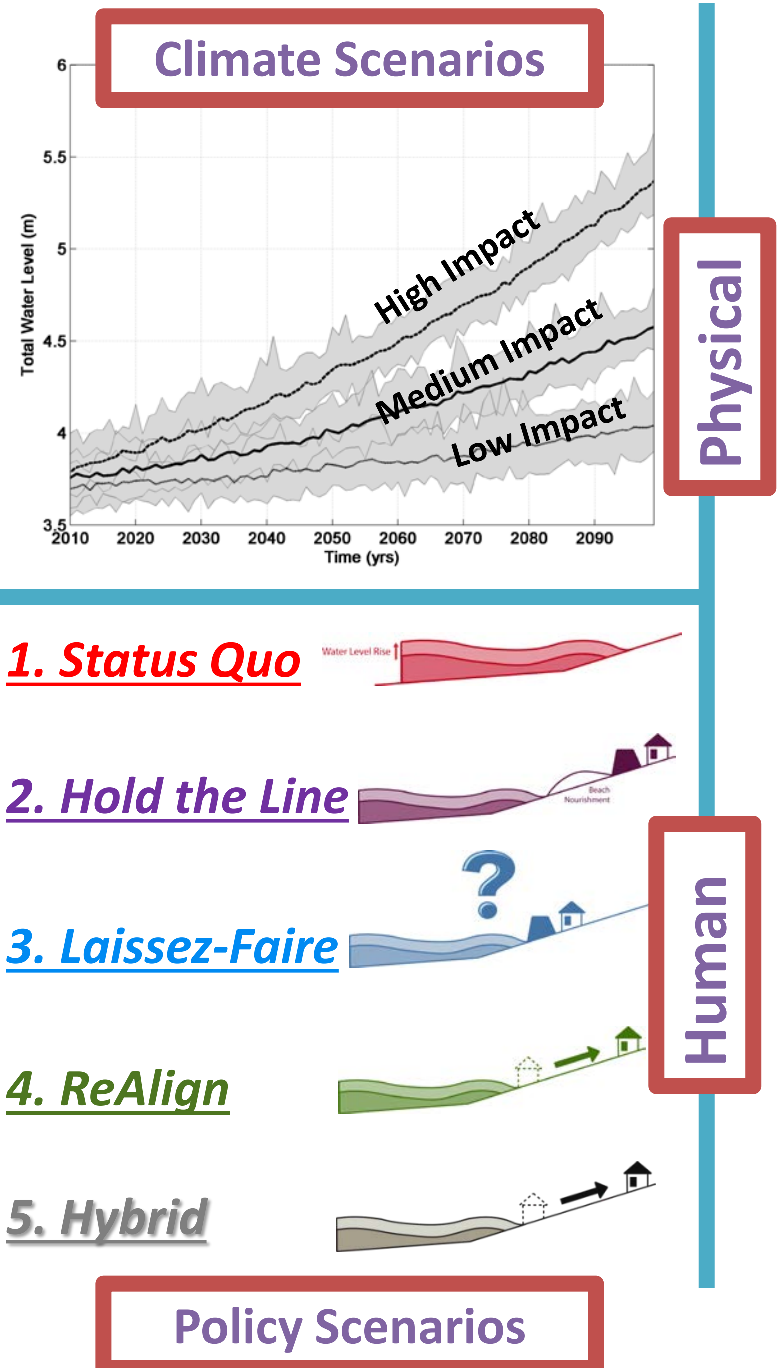


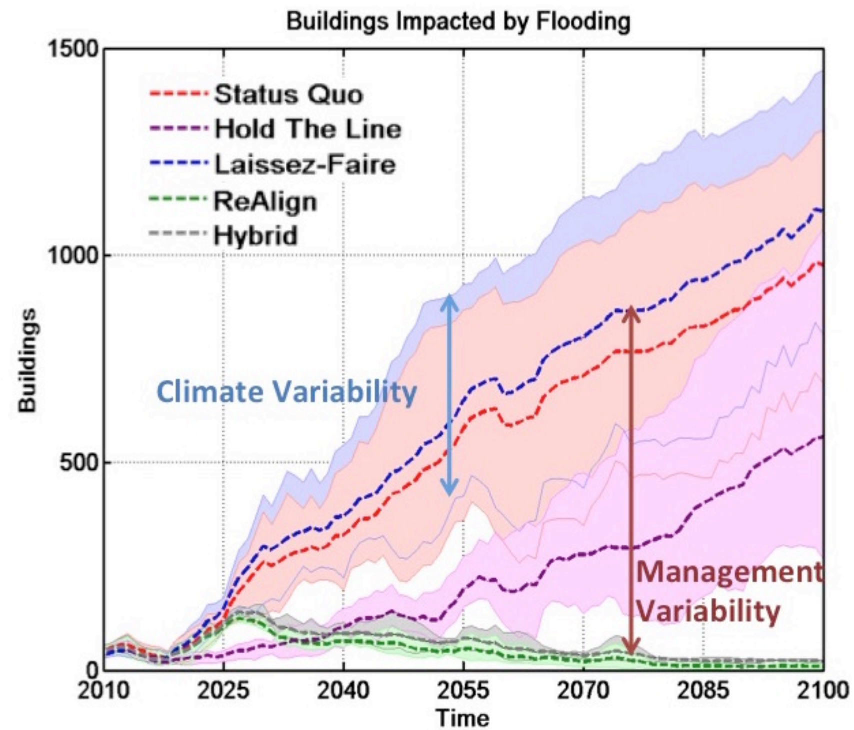



# Envisioning Resilient Coastal Futures



# Which drivers (human and physical) cause the greatest variation in stakeholder defined resilience metrics?



# Final Thoughts

- It is critical to take the long view in terms of how sea level rise and other climate change impacts may effect our communities, ecosystems and society as a whole.

- How we manage our coast can potentially have as great of an impact as climate change (at least over time scales of decades).

- Transdisciplinary research and deep engagement with a wide range of stakeholders is informing land use planning and emergency management to increase resilience to both chronic and acute hazards.

# Envisioning a Resilient Oregon Coast:

## Co-developing alternative futures for adaptation planning and decision-making