CO-DEVELOPING ADAPTIVE CAPACITY IN THE FACE OF EVOLVING CLIMATE CHANGE-INDUCED COASTAL VULNERABILITY

E. LIPIEC[1], P. RUGGIERO[1], K. SERAFIN[1], A.K. MILLS[2], J.P. BOLTE[2], P.E. CORCORAN[1,3], J. STEVENSON[1], D.H. LACH[4], C.M. ZANOCCO[4]

1.COLLEGE OF EARTH, OCEAN, AND ATMOSPHERIC SCIENCES, OREGON STATE UNIVERSITY, CORVALLIS, OR
2.. BIOLOGICAL AND ECOLOGICAL ENGINEERING, OREGON STATE UNIVERSITY, CORVALLIS, OR
3. OREGON STATE EXTENSION SERVICE, CLATSOP COUNTY, OR
4. SCHOOL OF PUBLIC POLICY, OREGON STATE UNIVERSITY, CORVALLIS, OR

Background and Goals

- Sea level rise (SLR), increasing storminess, and growing development pressures are intensifying coastal vulnerability on the US West Coast, including in Tillamook County, Oregon.
- Many beaches have not fully recovered from the major El Niño of the late 1990s.

- Under Oregon Statewide Planning Goal 18, only some communities and residents may construct expensive hard engineering protective structures.
- Local decision-makers and stakeholder groups often lack the information and tools to reduce their vulnerability and increase the community's adaptive capacity or "the ability to prepare, adjust, and/or respond to changes in advance" (Gallopin, 2006).

Three ways to develop adaptive capacity in Tillamook County:

1.Build coastal Knowledge to Action Networks (KTAN).

2. Develop methodologies to project evolving coastal flooding and erosion based on adaptation strategy and climate scenarios.

3. Develop the information and tools to help county stakeholders assess impacts and vulnerability, and implement beneficial strategies.

Methods

1. Engaging the Community

- Creation of a KTAN: ~20 community members, including individuals from varying departments of state, county, and local government, non-profits, private citizens, Oregon State University (OSU) researchers, and outreach specialists.
- Formal engagements and as needed informal discussions to develop and assess narratives and scenarios.
- Presentation of results for review and comment to the broader community.

OSU researchers and outreach specialists work closely with other members of the KTAN to:

- Identify and characterize desired endpoints for the community,
- Articulate policy narratives to reach these community goals, and
- Iteratively review and assess the results of future scenario analysis (described below).

Figure 1: Iterative stakeholder-driven process of developing and evaluating future scenarios.

2. Envisioning Future Scenarios

- The spatially explicit, multi-paradigm modeling framework ENVISION is utilized to create and analyze plausible future scenarios.
- Future scenarios analysis allows for the assessment of alternative coastal management options under various population and development trends, coastal and landscape processes and feedbacks, and climate change impacts.

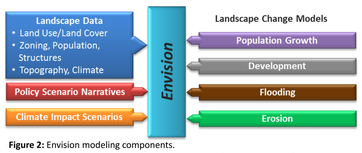

Figure 2: Envision modeling components.

3. Incorporating Climate Change Uncertainty

Climate change impact scenarios were developed using recommendations from the National Research Council for SLR on the West Coast and downscaled projected estimates for Northeast Pacific significant wave heights (Hemer et al., 2013; Wang et al., 2014). *See CLIMATE IMPACT SCENARIOS.*

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ENVISION Modeling Components

Policy Scenario Narratives

Status Quo

Continuation of present day policies.

Hold The Line

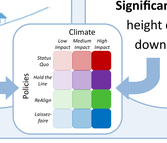
Policies or decisions are implemented that involve resisting environmental change (e.g. building or raising flood defenses, building or strengthening shoreline armor, nourishing beaches) in order to preserve existing infrastructure and human activities (e.g. beach access).

ReAlign

Policies or decisions are implemented that involve changing human activities to suit the changing environment (e.g. relocation of infrastructure and/or people, changing land use or livelihoods).

Laissez-Faire

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



Climate Impact Scenarios

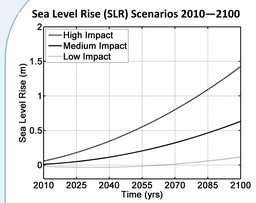


Figure 3: Regional SLR scenarios for Oregon.

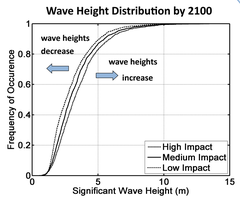


Figure 4: Future wave climate scenarios for Oregon.

Low Impact: The low climate impact scenario uses low-end estimates of regional sea level rise (SLR) of ~11cm by 2100 developed within the National Research Council's (NRC) 2012 SLR report.

Medium Impact: The medium climate impact scenario uses NRC (2012) derived mean estimates of regional SLR of ~61cm by 2100.

High Impact: The high climate impact scenario uses NRC (2012) derived high-end estimates of regional SLR, ~1.42m by 2100.

Significant wave heights for all three climate impact scenarios are based on wave height distributions developed from the variability of statistically and dynamically downscaled projected global climate model (GCM) estimates for the Northeast Pacific Ocean (Hemer et al., 2013; Wang et al., 2014).

For more details, see Poster P51—Serafin et.al

Landscape Data and Change Models

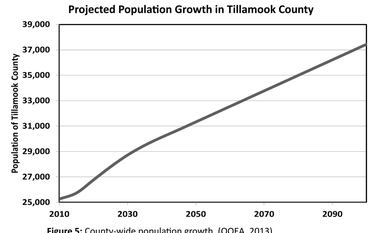


Figure 5: County-wide population growth. (OOEA, 2013).

- Land Use/ Land Cover
- Zoning
- Structures
- Topography

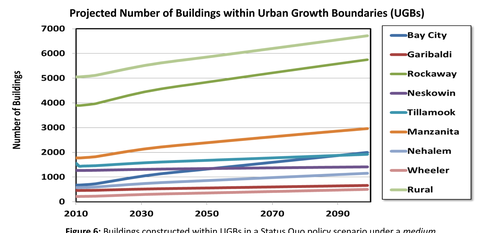


Figure 6: Buildings constructed within UGBs in a Status Quo policy scenario under a *medium* impact climate scenario.

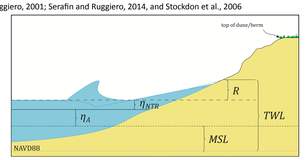
Flooding and Erosion Models

FLOODING

$$Total\ Water\ Level\ (TWL) = MSL + \eta_A + \eta_{NTR} + R$$

Ruggiero, 2001; Serafin and Ruggiero, 2014, and Stockdon et al., 2006

MSL = mean sea level
η_A = astronomical tide
η_{NTR} = non-tidal residual (e.g., storm surge, El Nino effects, etc.)
R = runup, a wave-induced water level (a function of beach slope, wave height, and wave length)



EROSION

$$Event\ Based\ Potential\ Foredune\ Erosion = \frac{TWL\left(x_b - \frac{h_b}{tan\beta_f}\right)}{D + h_b - TWL/2}$$

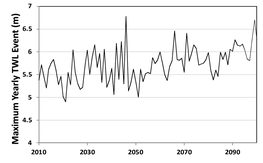
Kriebel and Dean, 1993

x_b = surf zone width
h_b = breaking wave depth
β_f = foreshore beach slope
D = vertical elevation of the dune crest above the dune toe

$$Chronic\ Erosion = (CCR_{SB} + CCR_{SLR}) * T$$

CCR_{SB} = long-term (interannual to decadal) coastal change rate associated with sediment budget factors not influenced by climate change (e.g., changes in sediment supply due to engineering structures)
CCR_{SLR} = coastal change rate associated with SLR (Bruun, 1962)
T = time period of interest

Yearly Maximum Total Water Level (TWL) on Example Transect



Yearly Maximum Extent of Erosion on Example Transect

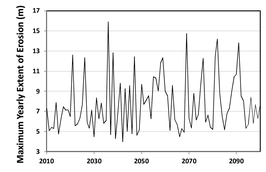


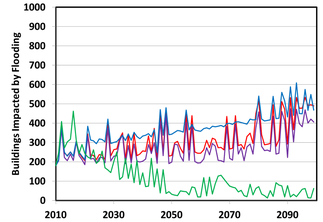
Figure 7: One example of projected maximum yearly TWL events in a *medium* impact climate scenario.

Figure 8: One example of projected maximum yearly extent of erosion in a *medium* impact climate scenario. The example only represents event based potential foredune erosion.

Example Results

How will coastal flood hazards impact buildings in the future?

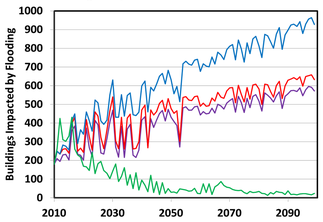
Buildings Impacted by Flooding in the *Low* Impact Climate Scenario



Figures 9 and 10: Number of buildings impacted by flooding under *low* (left) and *high* (right) impact climate scenarios from 2010 to 2100 (county-wide).

Policy Narrative Legend
Status Quo
ReAlign
Hold The Line
Laissez-Faire

Buildings Impacted by Flooding in the *High* Impact Climate Scenario



Example Conclusions:

- Different policy narratives have different development patterns and adaptation strategies, influencing the number of buildings impacted by flooding with the fewest hazard impacts occurring by 2100 in the ReAlign policy narrative (green line) for both low and high climate impact scenarios.
- Flooding impacts are variable from year to year due to irregular climate events (damaging storms), however, unique trends are evident for all four policy narratives.

When will homeowners need backshore protection structures (BPS) to protect their property?

To project future coastal hazards under a variety of adaptation strategies, OSU researchers needed to develop quantitative methods of modeling qualitative policies. To do so, we used the following Model Assumptions:

- Annually, BPS construction is limited to 30% of qualified properties to account for permit processing times, resource scarcity, etc.
- BPS are constructed under a specific set of instances:
  - The beach is dune-backed AND
  - The land behind the dune is developed AND
  - The dune toe is impacted by the maximum daily TWL >25% of the year OR the building(s) is impacted by erosion >5x in 10 years.

Locations of BPS over time in the Rockaway Beach Littoral Subcell in a *High* Impact Climate Scenario

Figures 11 and 12: Location of Rockaway Beach in Tillamook County, Oregon

Figures 13- 15: BPS constructed in a *high* impact climate scenario under Hold the Line policy narrative in the Rockaway Beach littoral subcell.

Existing BPS
New BPS necessary

Percent of Coast with BPS Construction: Rockaway Beach Littoral Subcell vs. County-Wide

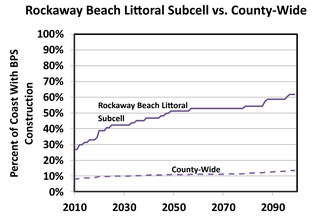


Figure 16: Percent of shoreline with BPS constructed in a *high* impact climate scenario under Hold the Line policy narrative in the Rockaway Beach littoral subcell and county-wide.

Example Conclusions:

- Under the Hold The Line policy scenario, most BPS are constructed between 2010 - 2040 than between the years 2040 and 2060.
- Over 60% of the Rockaway Beach littoral subcell coast needs protection by BPS in 2100, in comparison to Tillamook County's overall need of ~10%.

Take Home Messages

- KTAN members are concerned with developing strategies that balance shoreline development and preservation of ecosystem services such as beach accessibility.
- Future scenario analysis using ENVISION integrates stakeholder-driven strategies, physical processes data, and climate change impact information in an innovative and iterative way, and allows for the analysis of site-specific adaptation policy costs and benefits.
- Community engagement helps to fulfill KTAN members' requests for additional opportunities to engage with OSU researchers and outreach specialists and ensures that model results are "legitimate" and "salient" (Cash, et al., 2003).

Next Steps

- Continue to refine the probabilistic total water level model (Serafin and Ruggiero, 2014) that includes climate variability into ENVISION via Monte Carlo simulations.
- Continue to determine the economic costs and benefits of specific adaptation strategies, and identify "preferred" strategies (those that best support the community's goals) to model within ENVISION.
- Present information about the final "preferred" strategies to the general public to inform future implementation efforts.