Strengthening Coastal Resilience:

Understanding the Landscape of Sea Level Rise Vulnerability Assessments in the Pacific Northwest

Prepared for:

**Washington State Department of Ecology +
Cascadia Coastlines and Peoples Hazards Research Hub**

by:

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ABOUT THE AUTHORS

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I grew up in a small town in southern Washington called White Salmon. I received my undergrad from UW in political science and environmental studies. I decided to study environmental policy because having access to public recreation lands where I grew up has been foundational to my life and I believe everyone should have that opportunity. In the past I have done research on Indigenous and ecological forestry practices, climate change impacts on frontline communities with UW EarthLab, and I am currently working on a project for UW Future Rivers on water right leasing compliance in the Walla Walla River Basin.

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I grew up in Olympia, Washington. I received my bachelor's in environmental science & resource management at the University of Washington. I am a master’s candidate at the Evans School of Public Policy & Governance and School of Marine and Environmental Affairs with UW. I’m interested in the intersection of environmental sciences & policy because of the extensive overlap of these fields in Washington state. I hope to use the skills I've developed to help make my home a better place for people and ecosystems. I currently work for Seattle Public Utilities solid waste division doing public outreach with multifamily properties and their residents to minimize food waste.

Ethan Clarke

I am from southern California. I am currently a TA at the Foster school and work as a Branch Admin at the West Seattle YMCA. In my undergrad, I majored in Communication and Spanish, which led to me some work opportunities at nonprofits throughout Latin America. I came to Evans to learn more about nonprofit management and I am planning on relocating back to my home state after graduation. I have a deep love and respect for the ocean. As an avid surfer, I am always looking to learn more about the ocean, our coastlines, and conservation efforts.

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I was the third generation in my family to grow up in Snoqualmie, Washington. I studied pre-law and received my bachelor's degree in psychology at UW. As a young adult, I lived on Prince of Wales Island in Alaska and Oahu in Hawaii, where I developed a profound respect for indigenous stewardship and sustainable ways of living. After undergrad, I served as a Peace Corps Volunteer in Ethiopia (2014-2017), where I had my first "land-locked" experience and introduction to climate threats and critical resource scarcity. During my service, I worked with adolescent girls to foster life skills and resilience. Our goal aimed for girls in our community to remain in school amidst pressure to leave early and our collective vision was for girls to have the means to thrive rather than just survive.

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NSF | COPE COASTLINES AND PEOPLE

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Cover Photo: Thompson, E. (November 17, 2015). AP Photo. *The Seattle Times*.

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EXECUTIVE SUMMARY

This study explores the current landscape of sea level rise (SLR) vulnerability assessments across coastal and Tribal jurisdictions in Washington State, with comparisons to Oregon and British Columbia. We analyzed assessments that focused specifically on sea level rise, as well as climate vulnerability assessments that included sea level rise among other climate hazards. Through a qualitative content analysis of 39 assessments (SLR-specific and climate vulnerability assessments that included sea level rise among other climate hazards) and six interviews with coastal planning professionals, we evaluate how sea level rise vulnerability is defined, measured, and applied in local adaptation planning.

We found that assessments vary significantly in scope and focus. Most emphasize physical exposure and infrastructure risk, often using downscaled SLR projections and spatial mapping to identify future inundation zones. However, social vulnerability—reflecting the disproportionate risks faced by frontline communities—and environmental justice considerations are addressed inconsistently. Tribal assessments more consistently evaluate ecological and cultural dimensions of vulnerability, identifying risks to habitat integrity, subsistence resources, and value-based assets such as sacred sites. Ecological risks such as shoreline erosion, saltwater intrusion, and habitat fragmentation are assessed unevenly, with Tribal assessments demonstrating more comprehensive approaches than those led by cities or counties.

Many assessments reference a conceptual framework that defines vulnerability as a function of exposure, sensitivity, and adaptive capacity, but no standardized methodology or quantitative index exists to apply these components consistently across jurisdictions. Scientific explanations of sea level rise are also often omitted, reflecting an internal planning focus rather than broad public communication.

Interviewees identified persistent barriers to completing and implementing sea level rise vulnerability assessments, including limited funding, staff capacity, and technical resources. Data gaps, particularly in localized sea level rise projections and asset vulnerability inventories, limit the effectiveness of policy-relevant analysis and adaptation planning. Uncertainty in sea level rise scenarios and the absence of standardized methods further complicate planning. Even when assessments are completed, they often lack clear pathways to inform regulations or adaptation measures, reducing their long-term utility.

This analysis also highlights critical gaps that warrant future research. Region-wide studies of shoreline erosion, bluff retreat, and sediment loss are needed, using high-resolution geospatial data and long-term shoreline change models to inform land use planning and coastal adaptation. Additionally, the interaction between riverine flooding and sea level rise in coastal deltas remains under-studied, despite increasing compound flood risks in areas like the Skagit and Duwamish; integrated watershed-coastal models are essential to guide equitable resilience strategies. Future research should also evaluate how sea level rise vulnerability assessments influence regulatory decisions and assess their incorporation into procedural and distributional equity.

To address these challenges and advance equitable, science-informed coastal resilience planning, we offer the following recommendations:

1) Establish a Standardized Framework for SLR Vulnerability Assessments

   Develop consistent guidelines that define core vulnerability components and hazard criteria to improve alignment and comparability across assessments.

2) Delineate the Role of SLR Vulnerability Assessments in SMPs

   Provide clear guidance on how SLR assessments should inform shoreline master programs (SMP) updates under the Shoreline Management Act, including timing and content expectations.

3) Develop Public Communication Tools to Support SLR Adaptation

   Create accessible materials that explain the science, risks, and implications of sea level rise to support public understanding and engagement.

4) Leverage Existing Networks to Expand Public Outreach and Resource Sharing

   Strengthen the use of networks like the WA Coastal Hazards Resilience Network and the Cascadia CoPes Hub to promote peer learning, share data, and coordinate resilience planning efforts.

5) Prioritize Funding and Technical Support for Under-Resourced Jurisdictions

   Direct funding, tools, and technical assistance to rural and Tribal communities to close capacity gaps and promote equitable adaptation planning.

GLOSSARY OF TERMS

Accretion: Gradual buildup of land along shorelines through the deposition of sediment transported by tidal, wave, or current action

Adaptation: Process of adjusting natural and human systems in response to current and projected impacts of climate change

Asset: Something owned that possesses value, intrinsic or otherwise

Coastal Vulnerability: A measure of people and places susceptible to disturbance caused by coastal hazards as a function of exposure, sensitivity, and adaptive capacity

Component(s): Distinct attributes and analytical features of a sea level rise vulnerability assessment that characterize how vulnerability is defined, measured, and communicated (i.e. implementation, erosion, value assets, readability, etc.)

Compound Risk: The combination of two or more related or connected risks

Environmental Justice: Fairness and equity in environmental policy and practices that ensures all communities have access to a healthy environment

Erosion: Process by which soil, sediment, or rock is detached or damaged by wave action, storm surge, precipitation, or wind, often resulting in landward retreat of shorelines, loss of protective barriers, and increased vulnerability of coastal systems and infrastructure

Frontline Community: Population that faces disproportionate exposure to climate-related risks due to systemic social, economic, or geographic disadvantages

Geomorphology: Scientific discipline concerned with the description and classification of the Earth's topographic features

Hazard: An event or condition that can cause injury, illness, or death to people or damage to assets

Holistic: An approach to climate resilience that integrates environmental, social, economic, and cultural systems, combining scientific evidence with community knowledge to address root causes of vulnerability and support equitable, adaptive policy responses

Land Use: Description of the human use of a particular parcel of land

Managed Retreat: Intentional, coordinated effort to permanently move community members, structures, and systems away from locations that are prone to prolonged or frequent climatic events

Mitigation: Act of reducing harm or making something less severe

Resilience: The ability to recover from, or adjust to, stress or change

Risk: Probability of a coastal hazard occurring over a given timeframe

Saltwater Intrusion: Landward encroachment of seawater into freshwater aquifers, estuaries, and surface water systems

Sea Level Rise: Increase in the level of the world's oceans due to the effects of global warming

Shoreline Change: Change in the boundary condition of the shore through processes like erosion, accretion, sedimentation, and sea level rise

Shoreline Retreat: Landward shift caused by a long-term erosional trend or by sea-level rise

Storm Surge: Abnormal rise in seawater level during a storm, caused by winds pushing water onshore

Subduction: Process where one tectonic plate sinks beneath another into the Earth's mantle

Subsidence: Sinking of the Earth's surface as a result of geologic or human activity

Substrate: Includes the sediment, soil, bedrock and other material, either biotic or abiotic, that comprises the bottom layer of the sea, coastline, river, or wetland

Tidal Range: The difference in height between high and low water levels in a specific location

Vulnerability: The propensity or predisposition of assets to be adversely affected by hazards

Vulnerability Assessment: A systematic process used to evaluate the degree to which a system is susceptible to, and unable to cope with, the adverse effects or exposure to hazards

Vulnerability Index: A measure of the exposure of a population or asset to some hazard

Wave Height: Vertical distance between the trough of a wave and the following crest

Wave Runup: The maximum onshore elevation reached by waves, relative to the water elevation in the absence of waves

ABBREVIATIONS & ACRONYMS

CCA: Climate Commitment Act

CHRN: Coastal Hazards Resilience Network

Cascadia CoPes Hub: Cascadia Coastlines and Peoples Hazards Research Hub

Ecology: Washington State Department of Ecology

FEMA: Federal Emergency Management Agency

GIS: Geographic Information Systems

IPPC: Intergovernmental Panel on Climate Change

MHHW: Mean Higher High Water

NOAA: National Oceanic and Atmospheric Administration

NSF: National Science Foundation

RCP: Representative Concentration Pathway

SCPG: Shoreline and Coastal Planners Group

SLR: Sea level rise

SMA: Shoreline Management Act

SMP: Shoreline Master Program

SWAN: Simulating Waves Nearshore

VA: Vulnerability Assessment

UW: University of Washington

WSDOT: Washington State Department of Transportation

REPORT GUIDE

This report begins by establishing the significance of sea level rise (SLR) in the Pacific Northwest and the need for localized vulnerability assessments.

Chapter 1 introduces the project's background, purpose, and guiding research questions.

Chapter 2 reviews academic and practitioner literature to define key concepts and assessment approaches.

Chapter 3 describes the research design, including the creation of an assessment catalog, the development of a comparative coding framework, and interviews with local government officials.

Chapter 4 presents our findings across infrastructure, social, and ecological vulnerability dimensions, highlighting trends and standout practices.

Chapter 5 includes a discussion of the findings and results presented in the previous chapter.

Chapter 6 offers recommendations for the Washington State Department of Ecology based on this analysis. The final chapter concludes with reflections on the broader implications for coastal resilience planning.

Readers seeking technical detail can reference our codebook (**Appendix I**), catalog of assessments (**Appendix II**), literature and materials provided by client (**Appendix III**), and interview protocols (**Appendix IV**).

CHAPTER 1: INTRODUCTION

1.1 PROJECT BACKGROUND

Anthropogenic greenhouse gas emissions are causing global average temperatures to increase. The IPCC 6th Assessment Report found that the global surface temperature has risen 1.1ºC above the 1850-1900 average (Oppenheimer et al., 2019). The resulting climate change is already causing widespread impacts worldwide including but not limited to irreversible losses in terrestrial, freshwater, cryospheric, and coastal ecosystems, as well as substantial damage to human development, economies, and health systems. Increasing temperatures and changing precipitation patterns are causing ice sheets and glaciers to melt. Increased temperatures are also contributing to thermal expansion of ocean waters and ocean mass gain, causing sea levels to rise (National Research Council, 2012).

Rising sea levels make coastal regions more susceptible to erosion, flooding, loss of habitats for wildlife, and economic impacts from damaged property and infrastructure. Extreme sea level events from compound high tides, storm surges, and wave runup are expected to become more frequent as the climate continues to change. **Figure 1** shows the interactions between drivers of sea level rise and its impacts. However, not all coastal regions are impacted identically by sea level rise. Local ocean dynamics, vertical land movement, and climate variability can drastically change a location's exposure to sea level rise.

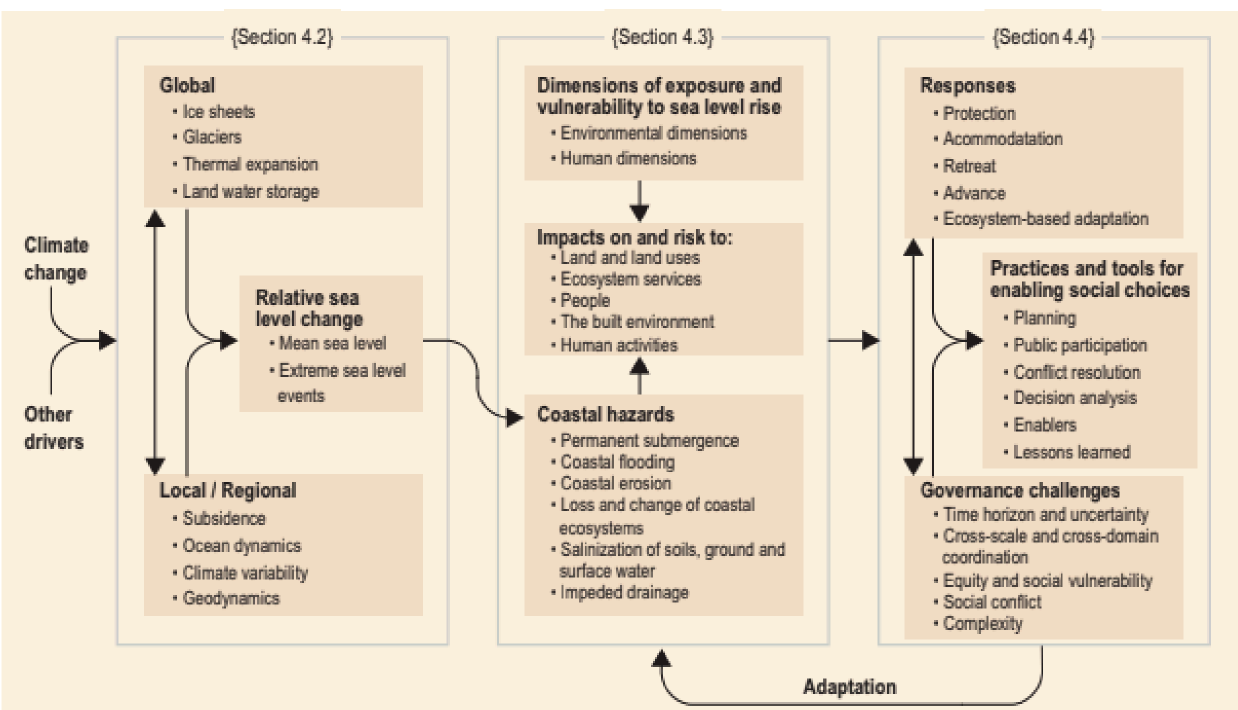

Figure 1: This Figure from the IPCC Chapter (4) on Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities shows the relationship between climate change and sea level rise as well as potential responses. (Oppenheimer et. al., 2019)

Sea Level Rise Vulnerability Assessments

Local and tribal governments often play a central role in coastal management, including planning for and responding to sea level rise. To inform adaptation strategies, these governments conduct and apply sea level rise vulnerability assessments. A sea level rise vulnerability assessment is a systematic evaluation of the extent to which a community, ecosystem, or asset is susceptible to the impacts of rising sea levels. It typically considers three key components, including:

- Exposure: whether the asset is located in a hazard zone;
- Sensitivity: how severely it could be affected;
- Adaptive capacity: the ability to respond, recover, or adjust (**Figure 2**).

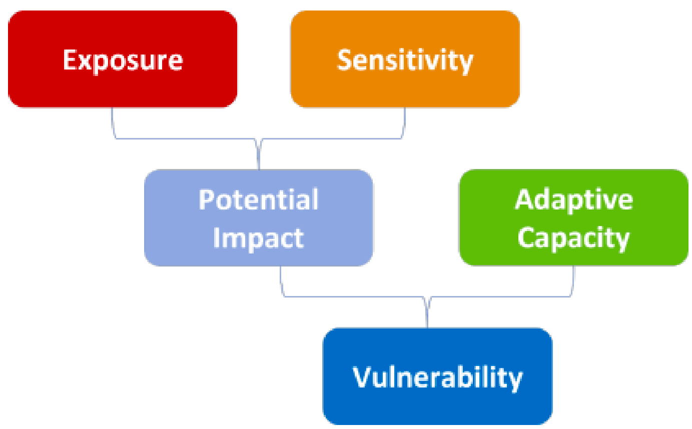

Figure 2: Common framework exhibiting the components of vulnerability.[1]

These assessments often incorporate hazards like erosion, flooding, and storm surge, alongside social and economic components such as vulnerable populations, infrastructure, and land use. Some communities broaden the scope of vulnerability assessments to include cultural, social, economic, and ecological values to enhance assessment effectiveness and relevance to diverse communities. Assessments often vary in asset identification, definitions and vulnerability metrics, reflecting differences in methods, management priorities or data limitations.

Sea level rise vulnerability assessments inform evidence-based, proactive planning. As sea levels rise due to climate change, coastal communities face increasing risks to homes, infrastructure, ecosystems, and public health. These assessments help identify high-risk assets, prioritize

[1] Source: Environmental Science Associates via City of Bainbridge Island Sea-Level Rise Vulnerability and Risk Assessment. Available: https://wacoastalnetwork.com/slr-vulnerability-assessments/ Accessed 05.21.25.

investments in adaptation (e.g., land-use changes, shoreline protection, managed retreat), and ensure that resilience strategies are equitable and data-driven. Without them, communities may face higher costs, greater damages, and reduced capacity to recover from coastal hazards.

1.2 PROJECT PURPOSE

Vulnerability assessments vary in how they assess and define vulnerability to sea level rise and related coastal hazards. Local and tribal governments, state agencies, researchers, and the private sector are increasingly conducting and using information from sea level rise vulnerability assessments in a range of contexts. However, there is not a comprehensive understanding of the current landscape of sea level rise vulnerability assessments throughout the Pacific Northwest. The Washington Department of Ecology (Ecology) and Cascadia Coastlines and Peoples Hazards Research Hub (CoPes Hub) sought to understand the landscape of sea level rise vulnerability assessments in Washington with the goal of developing recommendations for agency guidance to local governments developing their own sea level rise vulnerability assessments.

The Washington State Department of Ecology provides grants and technical assistance to local governments to support sea level rise planning. In addition, Ecology is currently developing new rules under the Shoreline Management Act (SMA) that propose establishing a requirement for local governments to use information from a sea level rise vulnerability assessment to inform policies and regulations in their shoreline master programs (SMPs).

This project condenses hundreds of pages of vulnerability assessments to a single catalog, making future reference to vulnerability assessments easier. In addition, this project systematically reviews assessments to identify best practices. This research provides Ecology with a clearer understanding of how vulnerability has been assessed throughout the Pacific Northwest and provides recommendations to Ecology to help the agency better support local governments in developing sea level rise assessments.

It also provides a foundation for researchers, policymakers, and members of the Cascadia CoPes Hub to share methodologies and build a more resilient and adaptive coastal planning framework. Our ultimate goal is to help provide practitioners with tools and insights that support more equitable and informed coastal planning.

1.3 RESEARCH QUESTIONS

Our research centers around one main question:

What best practices are currently used to develop and implement sea level rise vulnerability assessments in Washington State?

To answer this question, we developed a set of sub questions to direct our research and analysis, which are laid out conceptually in **Figure 3.**

First, we sought to understand the key elements of a sea level rise vulnerability assessment. This includes defining vulnerability, exposure, and risk. We evaluated how vulnerability assessments assess impacts to infrastructure, social structures and cultural values, and habitats and ecosystems. Finally, we assessed whether environmental justice was included in the assessment.

Second, we wanted to know if vulnerability assessments have resulted in tangible outcomes for local governments in Washington. To understand this, we first explored the challenges practitioners face in developing assessments. Through interviews, we asked about the barriers to conducting these assessments, which often shape how they are implemented. These questions helped to guide our analysis of the kinds of guidance Ecology can provide for developing sea level rise vulnerability assessments in Washington.

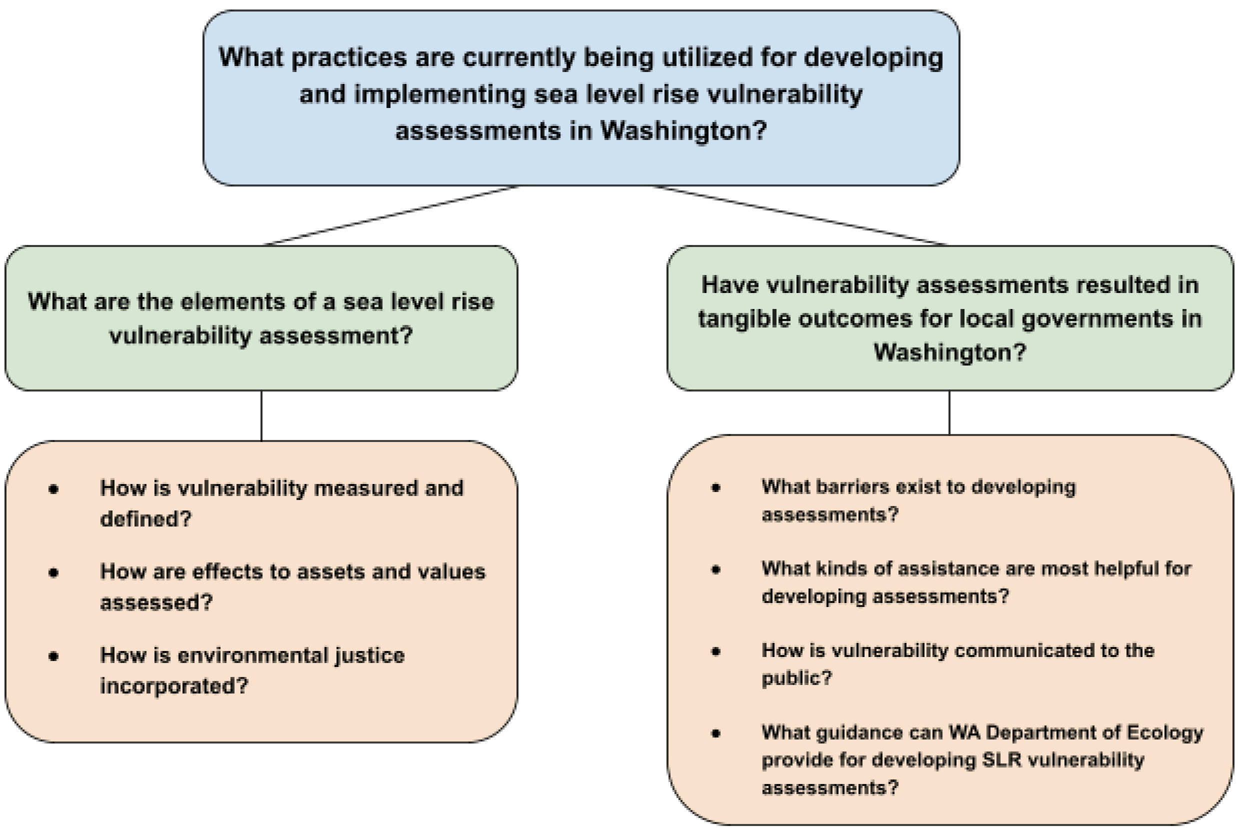

Figure 3: Project overarching research questions and related sub-questions

1.4 DELIVERABLES

To answer these questions, we developed the following deliverables:

- A literature review of academic sources, government reports, and client provided grey literature (**Appendix III**)
- A catalog of completed SLR vulnerability assessments in Washington (**Appendix II**), with comparative examples from Oregon and British Columbia.
- A codebook (**Appendix I**) to assess how each VA defines and measures vulnerability across five categories: planning capacity, exposure, geologic and ecological hazards, socioeconomic indicators, and readability.
- A comparative content analysis identifying trends, gaps, and best practices in how jurisdictions approach SLR vulnerability.
- A series of semi-structured interviews with local planners and practitioners to gather qualitative insights on challenges, outcomes, and recommendations (**Appendix IV**).
- Recommendations for the development of future analyses.

This research supports Ecology and the Cascadia CoPes Hub by highlighting current practices, identifying opportunities for standardization, and establishing a coding framework to guide future assessments.

CHAPTER 2: LITERATURE REVIEW

2.1 OVERVIEW

Adaptation to sea level rise requires a clear understanding of how vulnerability is defined, measured, and applied across coastal contexts. This chapter reviews the evolution of sea level rise vulnerability assessments and examines how diverse frameworks conceptualize exposure, sensitivity, and adaptive capacity. This chapter also assesses the strengths and limitations of current methodologies with particular attention to multi-criteria indices, spatial risk models, and frameworks that integrate biophysical hazards with social and institutional dimensions.

This literature review examines how scientific causes of sea level rise, as described in Chapter 1, are translated into actionable knowledge. It focuses on how vulnerability is defined and measured, which hazards are prioritized, and how emerging approaches incorporate compound risks, vertical land motion, land use, infrastructure sensitivity, ecological degradation, and social equity considerations.

2.2 METHODOLOGY

Articles for this literature review were sourced using a systematic search of the *University of Washington Libraries* database, utilizing keywords such as “sea level rise vulnerability assessment,” “coastal vulnerability index,” and “climate vulnerability assessment guidelines” to identify relevant studies on methodologies for comparative analysis and coding strategy. A secondary phase was conducted by inputting key articles into *Google Scholar* and *Semantic Scholar* and searching *Proquest’s Earth, Atmospheric & Aquatic Science Database* to identify additional relevant studies, expanding the review to incorporate recent and widely cited research. Additional sources were identified through reference tracing, particularly from foundational studies such as Fu et al. (2019), and from client-provided grey literature (**Appendix III**).

2.3 KEY FACTORS

2.3.1 Hazards Assessed in Sea Level Rise Vulnerability Studies

Sea level rise vulnerability assessments commonly examine geomorphological and ecological hazards, emphasizing how tidal inundation, shoreline erosion, sediment instability, and vertical land motion influence localized risk. Early studies relied on coarse indicators, such as relative sea level and wave height. More recent approaches, however, incorporate finer-scale geomorphic complexity, including coastal slope, shoreline migration rates, and barrier type, to delineate risk with greater precision (Abuodha & Woodroffe, 2010; Dey & Mazumder, 2023). These physical characteristics are crucial for identifying erosion-prone areas and differentiating between coastal forms such as cliffed coasts, barrier islands, and deltaic systems (National Research Council, 2012; Cruz-Ramírez et al., 2024). Current examinations also focus more on the degradation of wetlands, mangroves, and estuarine habitats that buffer storm surges and sustain biodiversity. These habitats are highly sensitive to salinization, erosion, and sea encroachment, particularly when inland migration is constrained by development or steep topography (Osland et al., 2015; Roy et al., 2023). Integrated frameworks now recognize that sea level rise-induced hazards are compounded by macro-climatic stressors, such as altered precipitation and sediment delivery, which destabilize ecological and geomorphic systems alike (Oppenheimer et al., 2019; Miller et al., 2023). As a result, contemporary assessments increasingly adopt multi-criteria, cross-disciplinary methodologies that account for coupled biophysical processes and the differentiated vulnerabilities of both natural and built environments.

Shoreline Change

Shoreline change is described as changes in the boundary condition of the shore through processes like erosion, accretion, sedimentation, and sea level rise. Abuodha and Woodroffe (2010) assess coastal sensitivity in Southeast Australia, finding that sandy beaches and low-lying plains are most susceptible to erosion, while rocky cliffs appear less sensitive. They also note, however, that storm-induced fluctuations can obscure long-term shoreline trends. Dey and Mazumder (2023) use shoreline change, beach width, and dune stability to assess vulnerability in India, finding that poorly protected sandy beaches with tourism infrastructure are at elevated risk of erosion and flooding. Similarly, Miller et al. (2023) identify erosion-prone, wave-exposed shorelines in Washington's Puget Sound as highly vulnerable, stressing the need for parcel-level adaptation strategies. Together, these studies highlight how geomorphology, human development, and natural coastal features shape shoreline dynamics that interact under sea level rise pressures.

Coastal Flooding

Sea level rise is expected to significantly increase the frequency, severity, and extent of coastal flooding by elevating baseline water levels and amplifying storm surge impacts. Low-lying areas face growing risks of chronic inundation and permanent submergence, particularly where vertical land movement compounds sea level rise. Without adaptation, studies project flood risks increasing by two to three orders of magnitude by 2100 (Oppenheimer et al., 2019). Vulnerability assessments consistently identify coastal flooding as a primary hazard, using frameworks that integrate exposure, sensitivity, and adaptive capacity to assess risk across physical and social dimensions (Fu & Peng, 2019; Fleming & Regan, 2022).

Saltwater Intrusion

Saltwater intrusion refers to the landward encroachment of seawater into freshwater aquifers, estuaries, and surface water systems as a result of rising ocean levels. This poses a threat to coastal zones by degrading freshwater aquifers and increasing inland flooding. Elevated sea levels can lead to saline intrusion into groundwater systems, compromising water quality, increasing soil salinity, and exacerbating the loss of arable land and ecosystem integrity (Arujo & Dias, 2021). When groundwater tables ascend alongside sea-level rise, hydrostatic pressure intensifies, pushing flooding into previously dry areas (Miller et al., 2023). The compounded effect of saline intrusion and groundwater rise can degrade infrastructure, damage ecosystems, and limit the efficacy of drainage systems, particularly in urban and estuarine environments.

Vertical Land Motion

Tectonic uplift and subsidence fundamentally shape sea level rise trajectories and coastal flood risk. Subsidence, often accelerated by groundwater extraction and other human pressures, raises relative sea levels and amplifies flooding and erosion, especially in densely populated deltas and coastal cities (Oppenheimer et al., 2019). Conversely, uplift can temporarily offset these hazards by lowering relative water levels. Along the west coast in the U.S., spatial differences in vertical land motion account for much of the variability in sea level rise projections (National Research Council, 2012).

Precipitation

Changing precipitation patterns, including more intense atmospheric rivers, altered snowfall, and increased runoff, escalate risks to coastal and upland communities. Ecology (2024) highlights that climate change is shifting snowpack and streamflow patterns, increasing the frequency and severity of compound events like heavy precipitation coinciding with high tides. These changes strain local infrastructure, intensify flooding, and complicate shoreline management. The IPCC Special Report (Oppenheimer et al., 2019) also notes that altered precipitation regimes can amplify coastal impacts by increasing runoff and stormwater volumes, especially when combined with sea level rise and extreme weather events.

Compound Risks

The combination of two or more related or connected hazards can create compound risk. These emerge when multiple climate hazards interact, intensifying overall impacts beyond what each would cause individually. Ecology (2024) identified compound events, such as extreme precipitation coinciding with high tides, as an increasing threat, exacerbating coastal flooding and challenging infrastructure resilience. Oppenheimer et al. (2019) similarly emphasize that sea level rise, when combined with storm surges, high waves, or anthropogenic subsidence, creates more frequent and severe coastal disasters. These overlapping hazards amplify exposure and strain adaptive capacity, particularly in low-lying and socially vulnerable communities.

Land Use

Differentiated risk based on land use type is a critical component of sea level rise vulnerability assessments, as land use influences both exposure and adaptive capacity. Miller et al. (2023) demonstrated that sea level rise vulnerability in Puget Sound is highly concentrated in parcels characterized by low elevation, critical infrastructure, agricultural use, or habitat migration potential, with urban deltas like the Duwamish exhibiting elevated risk due to compounding social vulnerabilities. Dey and Mazumder (2023) found that unregulated tourism development along sandy beaches in West Bengal significantly increased vulnerability by degrading natural dune and vegetation buffers. Arujo and Dias (2021) further identified that both urban centers and ecologically sensitive areas, such as mangroves, face heightened risk due to their low elevation and exposure to coastal flooding and erosion.

2.3.2 Integrated Sea Level Rise Vulnerability Assessments

Sea level rise vulnerability assessments increasingly recognize that coastal resilience depends on a nuanced understanding of environmental processes alongside social, cultural, and economic systems (Fleming & Regan, 2022). Oppenheimer and Glavovic et al. (2019) discuss in the IPCC Special Report how the multifaceted threats posed by sea level rise, including intensified flooding, erosion, and loss of cultural sites, demand integrated approaches that incorporate or center human and natural systems. Other studies show that identifying social vulnerability is not simply a matter of mapping inundation risk; it entails locating socially marginalized groups whose capacity to prepare for and recover from coastal hazards is disproportionately limited (Stafford & Abramowitz, 2017). The Washington State Legislature has also recognized the need to integrate social vulnerability with physical hazards associated with climate change. The 2023 session passed HB 1181 requiring local governments to plan for climate change impacts by including emissions mitigation and resiliency enhancement in their comprehensive plans. The law requires engagement with overburdened communities to address social, economic, and built environment factors (Adaptation Clearinghouse, 2023). It also requires shoreline master programs to assess sea level rise impacts to people, infrastructure, and natural resources.[2]

Emerging frameworks increasingly adopt integrated approaches that account for the interconnectedness of environmental, social, cultural, and economic systems. These models move beyond traditional, exposure-based analyses by incorporating factors that shape community sensitivity and adaptive capacity, such as governance capacity, infrastructure conditions, population density, economic activity, and cultural heritage (Alcántara-Carrió et al., 2024; Pramanik et al., 2021; Cruz-Ramírez et al., 2024).

Place attachment, trust in government, mental health, and other social dimensions are now understood as critical to resilience, particularly in contexts of displacement and relocation (Abu et al., 2024). Structural barriers such as inadequate long-term funding, limited technical assistance, and fragmented policy implementation further compound risks, particularly for Indigenous and frontline communities (Hasert et al., 2024; Jenicek et al., 2023). Composite indices that integrate socioeconomic and biophysical metrics are essential for identifying spatially concentrated vulnerabilities and directing adaptation investments where they are most needed (Fleming & Regan, 2022; Miller et al., 2023).

[2] RCW 90.58.630

Frameworks like *Adapting to Rising Tides* integrate structured assessments with stakeholder input to create locally grounded evaluations of governance, infrastructure, and social conditions (Adapting to Rising Tides, 2015). Recognizing that vulnerability is fundamentally shaped by institutional dynamics and historical inequities, these approaches prioritize the inclusion of marginalized communities and culturally specific knowledge.

Policymakers and emergency management agencies can fail to incorporate these nuances when key cultural or historical dimensions are omitted from risk models. Jenicek et al. (2023) highlight how federal disaster policy often overlooks Indigenous communities' specific needs and values, creating significant gaps in preparedness and recovery funding. Inclusive approaches that balances social, cultural, economic, and environmental values more accurately reflects what is at risk from coastal retreat and supports more just, lasting adaptation strategies (Oppenheimer et al., 2019; Fleming & Regan, 2022; Hasert et al., 2024; Jenicek et al., 2023; Cruz-Ramírez et al., 2024; Alcántara-Carrió et al., 2024).

2.3.3 Multi-Criteria Frameworks

Multi-criteria frameworks have gained prominence for systematically evaluating the strengths and gaps of climate adaptation and resilience planning efforts. Fu et al. (2019) demonstrated how a structured coding protocol can be used to compare 64 sea level rise vulnerability assessments conducted by U.S. coastal communities, highlighting the importance of examining not only biophysical exposure but also social and institutional factors that influence vulnerability. This approach helped identify the degree to which assessments defined vulnerability, prioritized adaptation measures, and acknowledged shifting local conditions over time. Building on that work, Fu and Li (2022) developed a set of 71 indicators to assess resilience in 50 U.S. climate adaptation plans, using a five-category scheme of system thinking, collaboration, uncertainty, coping capacity, and adaptive capacity. By applying a binary (0 or 1) coding protocol and achieving 87% inter-coder agreement along with a Krippendorff's alpha of 0.65, they ensured a robust and replicable process that minimized subjective bias while revealing consistent themes—such as the widespread mention but incomplete operationalization of "resilience" strategies.

These multi-criteria approaches can be augmented when researchers systematically identify which variables and indicators reliably capture coastal vulnerability. Cruz-Ramírez et al. (2024) reviewed 60 vulnerability assessments spanning a 30-year period, finding that the number and complexity of variables used varied significantly. Most studies focused on "minimum indispensable" indicators related to ecology, geomorphology, and marine climate, while more nuanced or "ideal" socioeconomic dimensions (e.g., legislation, land-use patterns, community engagement) were often overlooked. This tendency leads to underestimation of human and institutional factors that fundamentally shape how well a community can withstand or recover from climate hazards. In line with coding protocols presented by Fu et al. (2019), Cruz-Ramírez and coauthors underscored the importance of expanding beyond biophysical factors by incorporating broader ecological, socioeconomic, and governance indicators to foster a comprehensive and standardized basis for comparing and improving coastal vulnerability assessments.

These insights can help researchers and planners avoid narrow, exposure-based assessments that miss systemic interdependencies and equity concerns. Structured, indicator-based frameworks offer a replicable means of comparing adaptation efforts and pinpointing gaps in local or regional planning. They also highlight the need for integrating social dimensions of vulnerability and resilience, including the capacity of local institutions, community engagement mechanisms, and considerations of climate justice. In doing so, these frameworks help guide more effective and equitable climate adaptation planning, ensuring that coastal communities plan proactively not only for rising seas but for the complex social and environmental challenges tied to a changing climate.

2.4 GAPS IN AVAILABLE RESEARCH

Despite progress in sea level rise vulnerability assessments, key gaps remain that limit effectiveness. Methodologies, including multi-criteria frameworks (Fu et al., 2019) and the Integrated Coastal Vulnerability Index (Alcántara-Carrió et al., 2024), lack standardization, creating limitations for cross-study comparisons. Most assessments rely on static models rather than dynamic, long-term projections, and social vulnerability factors remain under-examined (Fleming & Regan, 2022). Additionally, Indigenous communities' voices are largely absent from the literature, despite facing disproportionate risks from sea level rise. This is consistent with other disaster planning findings (Jenicek et al., 2023; Mix et al., 2024) . Without integrated social, cultural, economic and environmental considerations, assessments fail to fully capture long-term community resilience needs. Addressing these gaps through standardized methodologies and equitable adaptation strategies will strengthen guidance for Washington's coastal resilience planning.

2.5 CONCLUSION

This review highlights the development of approaches for more comprehensive sea level rise vulnerability assessments that integrate physical, ecological, and social dimensions of hazards and risk. Narrow, hazard-focused frameworks overlook marginalized populations, including tribal communities, which can exacerbate inequities. Structured multi-criteria methodologies (e.g., Fu et al., 2019; Cruz-Ramírez et al., 2024) enable standardized comparisons and continual refinement of adaptation strategies. By adopting broad criteria—geomorphology, habitat health, socioeconomic factors, and cultural heritage—local governments can identify high-risk areas.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 ASSESSMENT CATALOG

Our first goal in this study was to develop a comprehensive catalog of extant sea level rise vulnerability assessments in Washington state. The client began this process and compiled an initial list of sea level rise vulnerability assessments from Washington state municipalities, counties, agencies, and Washington Tribes. A variety of approaches were used by the Dept. of Ecology to compile the initial list. Local government assessments were obtained through submissions to the WA Department of Ecology that were funded by the Shoreline Planning Grant Program. Others were found through keyword internet searches, reviews of local government web pages, and through ongoing partnerships and collaboration with local governments and Tribes. To add to the catalog, the student consultant team carried out a systematic search of coastal county and city websites using keyword searches of "sea level rise," "climate," "vulnerability assessment," and "hazard."

Assessments were included if their specific focus was on sea level rise or if sea level rise was included in a broader analysis of climate impacts or hazard mitigation. We excluded projects from our analysis that were not complete before February 7th, 2025, or were available but still in draft form. The student consultant team selected five Tribal assessments from the Dept. of Ecology compiled list based on their geographic distribution across the Puget Sound region and whether the assessments were publicly available. Permission was obtained to include these five tribal assessments from the Tribal governments themselves via Ecology. We also included for comparison three examples each from Oregon and British Columbia, selected from Google search results and suggestions from our client team. We decided on three examples in the interest of time, deeming them sufficient for any comparisons that might be made with Washington assessments.

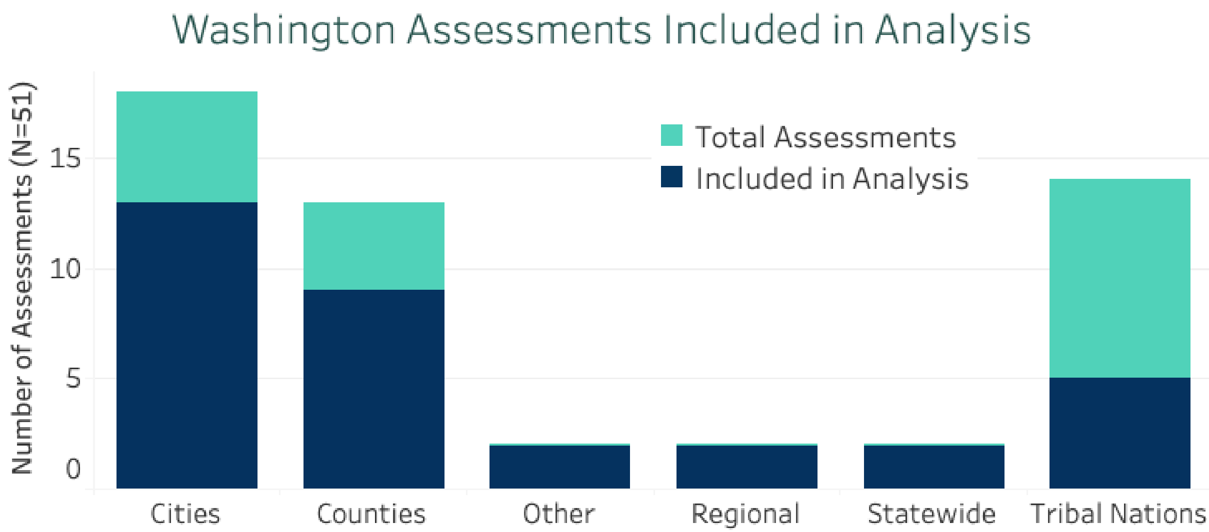

Figure 4: Shows all of the assessments identified in Washington according to jurisdiction type. The total height of the stacked bar is the total number of the assessments while the darker bar is the number of assessments included in the analysis.

In our catalog, we identified 51 vulnerability assessments currently completed, in draft, or in progress in Washington State as of May 2025 (**Figure 4**). Of these, 14 vulnerability assessments were of tribal Nations, 13 vulnerability assessments were at the county level, 4 at the state or regional level, and 18 at the city level of government. Two outliers were the Port of Bellingham and the Skagit Delta, because they focused on discrete locations with a narrow focus. In total we narrowed our analysis to include 39 assessments, 33 of which were located in Washington. Of these, 5 were from Tribes, 13 were cities, 9 counties, and 6 were statewide or regional. For comparative purposes, we also included three examples from Oregon and three examples from British Columbia. These allowed us to see if vulnerability and sea level rise are being examined differently in other nearby states and provinces. Twelve assessments were excluded either because they were still in draft form or permission was not obtained. **Figure 5** details their spatial distribution across the region. A full list of assessments included in our analysis and their associated information can be found in **Appendix II**.

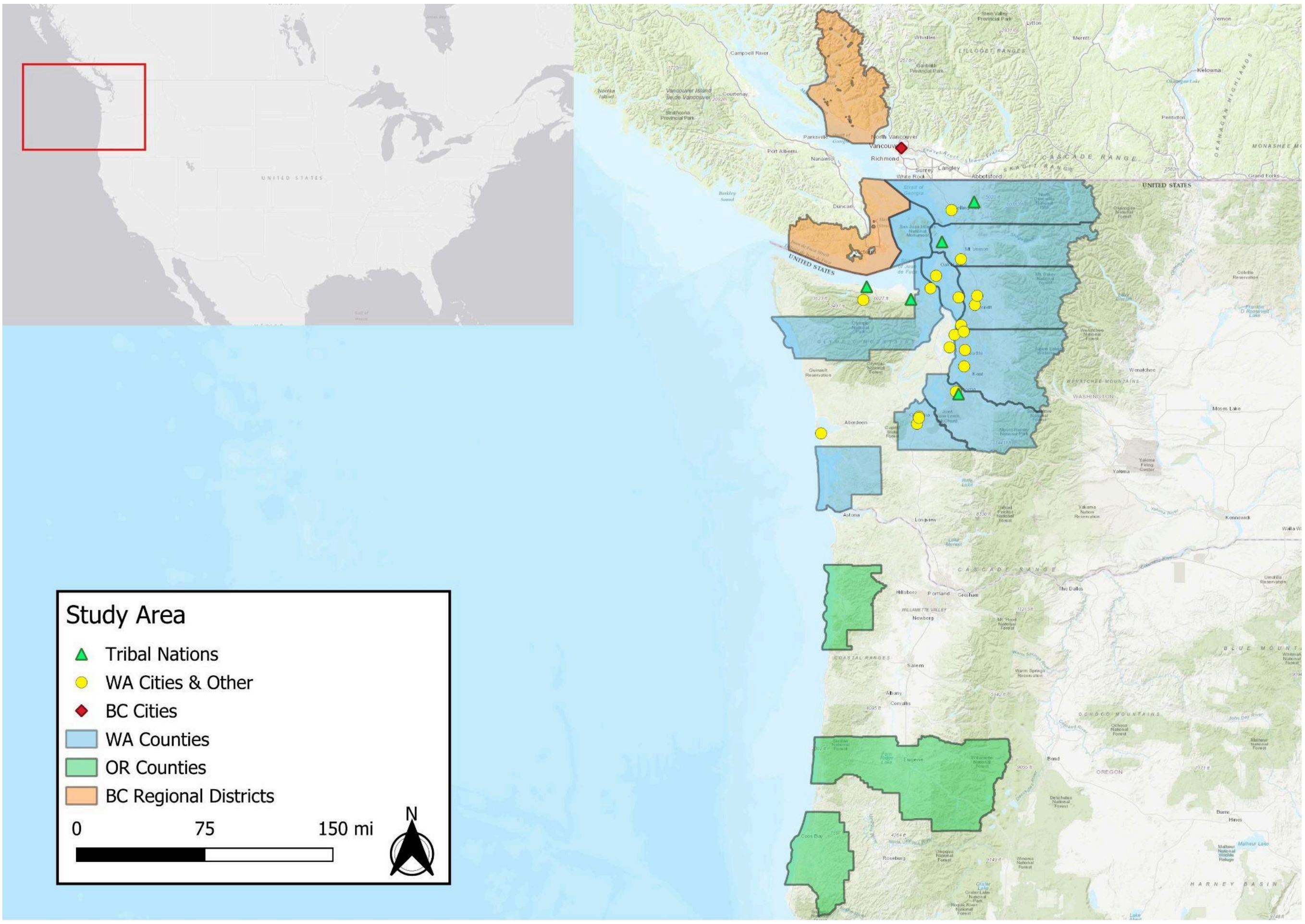

Figure 5: Study area and locations of assessments selected for analysis.

3.2 ASSESSMENT CONTENT ANALYSIS

We utilized a content analysis approach to identify common similarities and differences within assessments. Content analysis techniques can be used to systematically convert qualitative content into a quantitative analysis (Johnson, 2014). We adapted a content analysis methodology based on the approach developed by Fu et. al. (2019) in *Evaluating Sea Level Rise Vulnerability Assessments in the USA*. The authors created a codebook to systematically compare the content of vulnerability assessments, evaluating across what they considered three core components: screening for vulnerability, assessing vulnerability, and planning for adaptation.

Drawing on insights from our literature review, client requirements, and the Fu et. al. (2019) framework, we tailored our codebook (**Appendix I**) to compare vulnerability assessments based on motives for the assessment, how vulnerability is defined, and whether assessments center infrastructure, ecological, or social vulnerability. We developed a set of 50 codes to measure sea level rise vulnerability assessment components across six categories: background information, planning capacity, exposure, geologic and ecological hazards, socioeconomic indicators, and readability (**Table 1**). Most of our components are coded as a binary to indicate their presence or absence in the assessment. Others are text coded to capture more detailed information such as funding sources and the type of climate projections used.

We worked in pairs to code the assessments. As a first step, all coders were thoroughly versed in the coding guidelines and criteria. One randomly chosen assessment was selected as an initial trial run of the codebook and the coding procedure. After we all coded this assessment independently, we met as a group to resolve any disagreements in the evaluations and ensure everyone fully understood the procedure and code definitions. Each coding pair was then randomly assigned half of the total assessments to evaluate. Within each coding pair, each coder then independently coded five assessments within our random assignments. We then met an additional time to cross-compare these results and try to resolve definitional differences. Finally each coding pair then independently coded all assessments in their randomly assigned list. After all assessments were coded, the intercoder reliability of each pair was tested by calculating Krippendorff's alpha coefficient using the ReCal2 software[3] developed by Deen Freelon Ph.d.. We decided on the use of Krippendorff's alpha because we used more than two coders in our analysis and it accounts for chance agreement. Alpha scores range from 0 - 1 where a higher score indicates higher agreement (Krippendorf, 2022). Initially, the first pair had an intercoder reliability of 82% and Krippendorff's alpha of 0.52. The second pair had 89% intercoder reliability and 0.68 Krippendorff's alpha coefficient. Coding pairs then met to resolve disagreements and agree on final codes, producing our final data set.

Our analysis centered around the three overarching research questions we developed initially. What are the best practices for sea level rise vulnerability assessments in Washington, what are the key elements of a vulnerability assessment, and have vulnerability assessments resulted in tangible outcomes for local governments (**Figure 3**)? To understand the key elements of sea level rise vulnerability assessments we generated summary statistics for all binary codes using Excel. As we coded, we identified standout examples of vulnerability assessments and methodologies. We analyzed results based on the presence or absence of key elements included in vulnerability assessments, and how they assess infrastructure, social, and ecological vulnerabilities.

[3] Krippendorf's alpha is a statistical measure of the agreement achieved when coding a set of units of analysis. The software for obtaining Krippendorf's alpha and instructions for its use can be found on Deen Freelon's website: https://dfreelon.org/utils/recalfront/recal2/. Accessed 04.04.25.

Table 1: Codes for Assessment Components

Code Category	Code Title	Brief Definition
Background Information	Government Name	Agency, city, county, etc.
	Year Published	
	Authoring Entity(s)	Was assessment written "in-house" or by a consultant?
	Level of Government	Jurisdictional scale of assessment.
	Median Household Income	Median income according to the most up-to-date U.S. Census data.
	Total Population	Total population according to most up-to-date U.S. Census data.
	SLR Data Source	Which study, report, tool, or dataset provided the sea level rise data.
	Assessment Timeline	How long the assessment took to complete.
Planning	Implementation Steps	Are next steps, plans for future research, or road maps for mitigation included?
	Mitigation/Adaptation Strategies	Does the assessment refer to specific policy changes, projects, or actions to mitigate risks identified in assessment?
	Definition of Vulnerability	Is a definition present, and does it include exposure, sensitivity, and adaptive capacity?
	Sea Level Rise Specific	Is the assessment specific to sea level rise, or is SLR vulnerability included in a broader climate assessment?
	Managed Retreat as Option	Is managed retreat considered as an adaptation strategy?
	Project Funding	Total funds allocated for the assessment.

Code Category	Code Title	Brief Definition
	Funding Source	Funding organization.
Exposure	Scientific Uncertainty	Are uncertainties surrounding data or projections acknowledged or addressed?
	Definition of Exposure	Is exposure defined and identified in the assessment?
	Definition of Risk	Is risk defined and identified in the assessment using probability?
	Vulnerability Index	Does the assessment make use of a vulnerability index?
	Community Rating System	Is the municipality a participant in the FEMA Community Rating System?
	Climate Perception	The percentage of adults concerned with climate change (county level).
	Sea Level Rise Scenario(s)	Number of SLR scenarios used in assessment.
	Projections Timeline	How far into the future projections are modeled.

Code Category	Code Title	Brief Definition
Geologic and Ecological Hazards	Sea Level Rise Measured	Measures of sea level rise and flooding.
	Precipitation Changes	Are the risks of future changes in precipitation patterns considered?
	Saltwater Intrusion	Are impacts of saltwater intrusion into freshwater surface and ground waters considered?
	Differing Impacts by Land Use	Are risks differentiated by land use type?
	Assessed Shoreline Change	Are measures shoreline change such as erosion or accretion included?
	Compounding Effects	Are the effects of multiple hazards working in conjunction considered?
	Subsidence Impacts	Are risks associated with anthropogenic subsidence or seismic subduction included?
	Tsunami Impacts	Are tsunami risks and their possible impacts considered?
Socioeconomic	Infrastructure Vulnerability	Are risks/vulnerability to infrastructure considered in the general sense?
	Built Assets Identified	Are risks to specific built assets listed or analyzed?
	Estimates of Economic Impacts	Are estimates of potential economic loss included in the assessment?
	Impacts on Shoreline Access	Are future impacts to shoreline access points assessed?
	Ecological Assets Identified	Are risks to specific environmental assets listed or analyzed?
	Impacts on Ecosystems	Are effects / losses to coastal ecosystems and habitat assessed?

Code Category	Code Title	Brief Definition
	Impacts to Endangered Species	Are the impacts/risks of sea level rise on endangered or threatened species taken into account?
	Value-Based Assets Identified	Are risks to specific culturally valuable assets listed or analyzed?
	Social Vulnerability	Are measures of social vulnerability included in the assessment?
	Consideration of Tribal Impacts	Did the assessment include tribal considerations?
	Impacts to Frontline Communities	Are risks to communities who are the most affected by environmental hazards and climate change assessed?
	Environmental Justice Considered	Is environmental justice considered in the assessment?
Readability	Data Visualizations	Are visuals used to convey the data or concepts in the assessment?
	Publicly Available	Is the assessment publicly available?
	PDF Accessibility	Is the assessment available as a PDF document or a website?
	Community Outreach Conducted	Was public outreach conducted as part of the assessment process?
	Science Communication	Are the underlying science and causes of sea level rise communicated to the reader?

3.3 SEMI-STRUCTURED INTERVIEWS & ANALYSIS

In addition to understanding the landscape of vulnerability assessments, Ecology sought to discover whether assessments resulted in tangible outcomes for local governments and what barriers local governments faced when conducting assessments. The student consultant team conducted a limited set of semi-structured interviews with planning and management practitioners affiliated with organizations either experienced in completing sea level rise vulnerability assessments or not. Interview subjects were selected randomly from a stratified sample of local government contacts provided by our client team at Ecology. Contacts were stratified into jurisdictions that had previously completed an assessment and those that had not. These subsets were then sorted by geography (Pacific Coast, North Puget Sound, and South Puget Sound) and jurisdiction type (city or county). Six contacts were then selected randomly from each list and Ecology facilitated an introduction. We decided to randomly select interview subjects from our stratified sample lists in order to minimize bias. In total we were able to complete six interviews, five with jurisdictions that had completed assessments and one with a jurisdiction that has not.

The interviews focused on gathering insights related to best practices, assessment methodologies, and outcomes of completed vulnerability assessments. Specifically, the team explored experiences with developing and implementing assessments, the elements they consider essential, and any tangible impacts or policy changes resulting from their assessments. Additionally, we sought input on challenges encountered, lessons learned, and recommendations for improving future assessments. Our interview protocol used a path dependent design with open-ended questions to encourage detailed responses, while also ensuring coverage of key topics aligned with our research questions (**Appendix IV**).

For those agencies that had not completed an assessment, our questions were designed to provide insights into barriers to conducting assessments, perceptions of their value, and the factors that influence decision-making regarding coastal resilience planning. Questions explored participants' awareness of existing assessment methodologies, their capacity and resource constraints, and any preliminary steps taken toward understanding sea level rise impacts. Additionally, we sought input on what types of guidance, tools, or resources would be most useful to support their future assessment efforts.

Interviews were recorded, transcribed, and analyzed using inductive thematic analysis techniques. We chose to adapt the "reflexive thematic" analysis approach developed by Braun & Clark (2006) (**Figure 6**). We re-read transcribed interviews several times to locate any initial patterns. Patterns relevant to our research questions were grouped into broader themes. We then pulled quotes from the interview transcripts that spoke directly to the themes for further analysis. These quotes were aggregated into generalized statements to protect anonymity. Our findings informed our comparative analysis and agency recommendations. This method was selected for its adaptability and close connection between themes and data, giving it ability to identify key themes and insights from the varied perspectives present in our interviews.

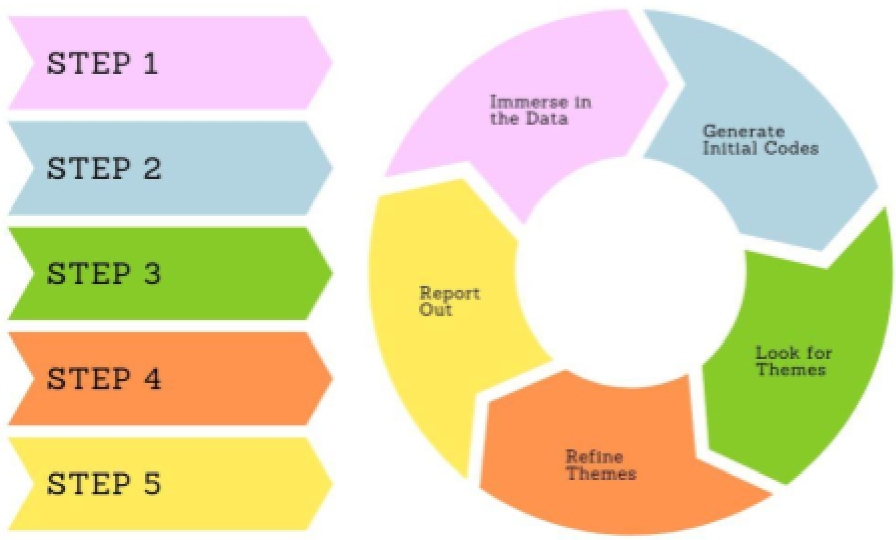

Figure 6: Thematic analysis process as developed by Braun & Clark, (2006)

CHAPTER 4: FINDINGS

4.1 OVERVIEW

This chapter presents the results of our comparative analysis of sea level rise vulnerability assessments in Washington State, with some comparative examples from Oregon and British Columbia. The results indicate commonalities and differences between assessments, are not positional, and are not intended to indicate measures of quality. The results present a landscape level analysis of vulnerability assessments with some examples of how each of the components appeared in the assessments.

4.2 KEY FINDINGS

- Thirteen assessments were published in 2023, more than any other year. Many of these were funded by the Ecology Shoreline Planning Competitive Grant Program.
- Most jurisdictions define vulnerability as a function of exposure, sensitivity, and adaptive capacity. Depending on the focus of the assessment, they may place more emphasis on exposure to hazards, sensitivity of assets, or adaptive capacity of the community.
- There is no common, standardized framework or index for assessing vulnerability.
- The science behind sea level rise is not commonly explained. Vulnerability assessments are often intended more for an internal planning audience rather than the general public.
- Most assessments measure hazards associated with rising sea levels including estimates of high water mark, inundation zones, and assets vulnerable to flooding. However, not as many assess other hazards such as erosion, saltwater intrusion, subsidence, or tsunamis.
- Tribal assessments tend to assess vulnerability in terms of infrastructure, social, and ecological vulnerability. Assessments from other jurisdictions are less likely than Tribes to define ecological and value-based assets in addition to built environment assets.
- Infrastructure assets are the most commonly assessed for vulnerabilities.
- Few assessments address environmental justice specifically, but many do acknowledge the heightened vulnerability of frontline communities and differences in socioeconomic status. Many jurisdictions are thinking about the disparities between groups that make adaptation difficult, but Tribes include more social vulnerability components than any other jurisdiction type.
- Of the jurisdictions that have completed vulnerability assessments, more have a median household income below the Washington average than above.

- Barriers to completing and implementing sea level rise vulnerability assessments include who is responsible for this work, limited timelines, and data gaps. Funding is a limiting factor for the depth and breadth of vulnerability analysis, public engagement, and using sea level rise vulnerability to change planning practices or update legal codes. Staff capacity also limits which assets are included and the overall satisfaction of the jurisdiction with the assessment's results.

4.3 ANALYSIS

4.3.1 Strategy

Our full research methodology can be found in Chapter Three of this report. Our analysis is organized by first providing a general overview of the landscape of vulnerability assessments in Washington, including some Tribal and indigenous nations. Additional examples from Oregon and British Columbia are also included in their own section. Next, we turn to an analysis of the key elements of vulnerability assessments. This section examines how local governments assess vulnerability to different sectors of the community including infrastructure and the built environment, social and cultural values, and the environment. Through interview data we were able to identify and analyze tangible effects and outcomes of developing vulnerability assessments. We also identify barriers that have prevented local governments from developing sea level rise assessments for their jurisdictions.

4.3.2 Washington Vulnerability Assessment Landscape

About half of the assessments identified were specifically assessments of sea level rise, while the other half were more general assessments of climate change vulnerabilities. The first assessment identified was a climate vulnerability assessment published by the Washington State Department of Transportation (WSDOT) in 2011. Generally one to two assessments were published each year until 2022 when 4 assessments were published, and 2023 when 13 were published. Of the assessments published in 2023, a majority were funded by either the Washington Department of Ecology Shoreline Planning Competitive Grant Program or the Washington Department of Commerce. Other common funding sources include the Bureau of Indian Affairs, US Environmental Protection Agency, and Federal Emergency Management Agency. Funding information was not available for many of the assessments, but grant awards ranged from $50,000 to nearly $300,000.

To control for different community demographics we collected Census data on population and median household income for those assessments representing discrete jurisdictions (cites/counties). When compared to the Washington state median household income,[4] 8 jurisdictions have higher median household incomes, while 19 are below the state average (6 had

[4] $94,952 in 2023 dollars according to Census data: https://www.census.gov/quickfacts/fact/table/WA.

no income data for the assessment jurisdiction boundaries). This indicates that wealthier jurisdictions are not necessarily more likely to engage in sea level rise planning. Population also revealed no surprising trends. Coastal communities in Washington tend to be small outside of Puget Sound; 11 of the jurisdictions we identified have populations below 25,000 people. An additional 9 have between 25,000 and 100,000 people, and 5 have a population greater than 500,000.

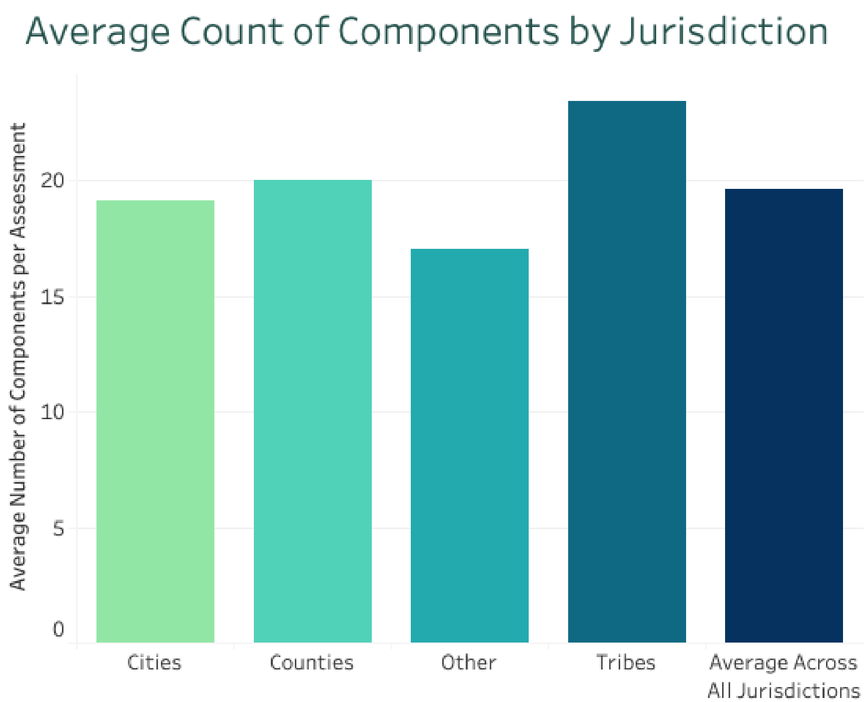

Figure 7: The average number of components, out of a total of 33, present in assessments for cities, counties, and Tribes in Washington. On average, Tribal assessments included more components than other jurisdictions.

The assessments themselves varied significantly in content, focus, and depth. Our codebook consisted of 50 total coded components, 33 of which were coded based on their presence or absence, while for the remaining we recorded qualitative data. On average, assessments included information corresponding to 19.6 out of the 33 binary codes (**Figure 7**). The assessments conducted by Tribes included information corresponding with more components (23.4), compared to cities (19.1), counties (20), or other assessments (19). **Figure 8** lists a description of each binary code and how often that component was included in the 39 assessments we analyzed. Our codebook was designed to systematically assess the elements of vulnerability that are commonly included in sea level rise and climate vulnerability assessments in the Pacific Northwest. We grouped our components into six categories: background information, planning components, exposure components, geologic and ecological components, socioeconomic components, and readability components. The categories helped to organize our data and find patterns among the assessments.

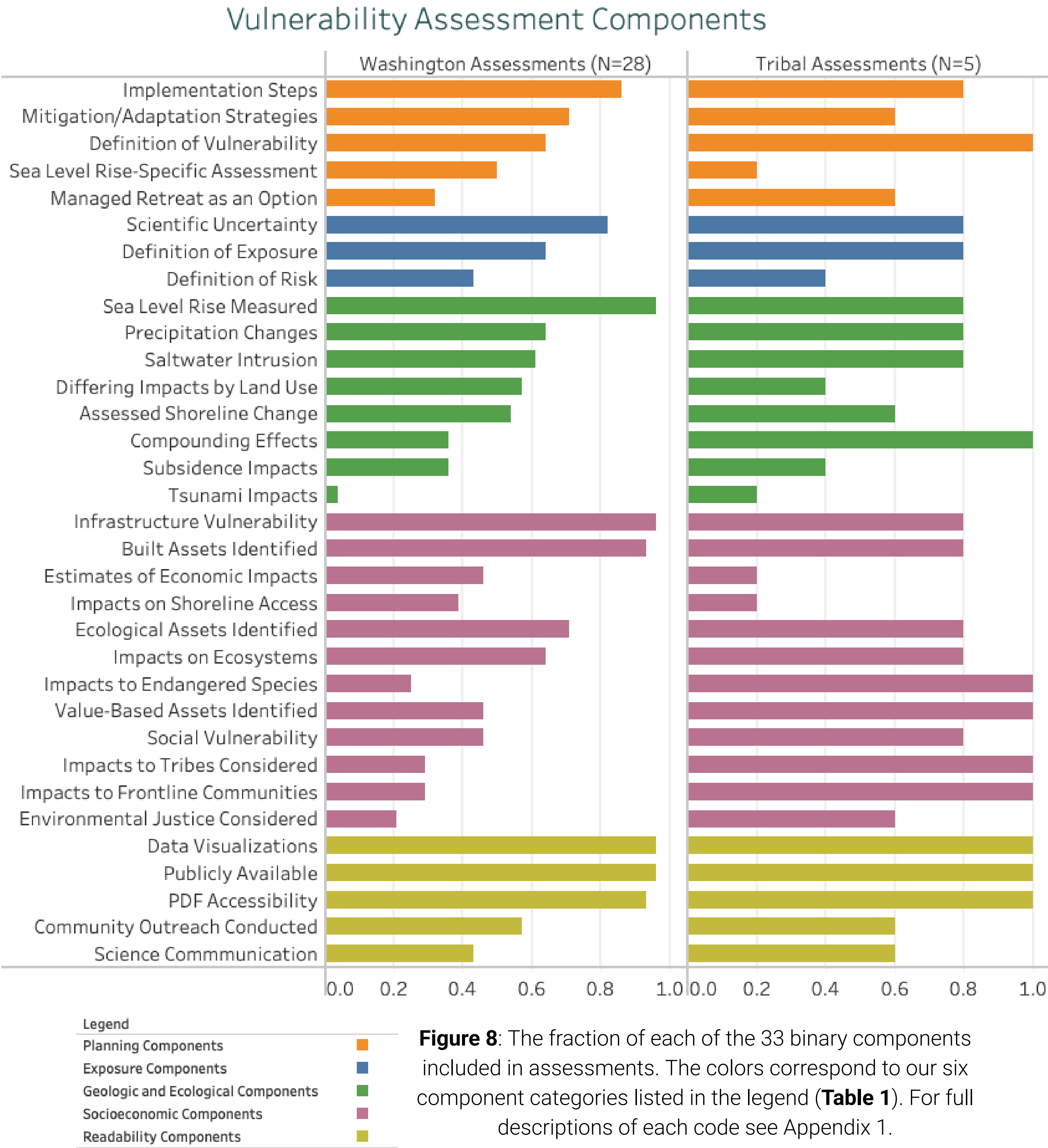

Figure 8: The fraction of each of the 33 binary components included in assessments. The colors correspond to our six component categories listed in the legend (**Table 1**). For full descriptions of each code see Appendix 1.

Figure 9 shows the average of how many components were present in assessments conducted by each type of jurisdiction, separated by code category. For example, on average, assessments conducted by cities included 2.8 of the 5 planning components. Assessments conducted by Tribes include the highest average count of components per category, except the exposure category. This suggests that tribes are sometimes assessing vulnerability more comprehensively than cities or counties. On average, all jurisdictions include at least half of the components in each category. Overall, these results suggest that in general, assessments are evaluating and discussing many aspects of vulnerability, based on the components included in this study. However, we also observe that many jurisdictions are conducting highly specific vulnerability assessments of a certain type of asset, government-owned infrastructure, or a specific ecosystem. Some jurisdictions intentionally choose to narrow the focus of their vulnerability assessments in order to gain specific insights into the hazards they face and their adaptation options.

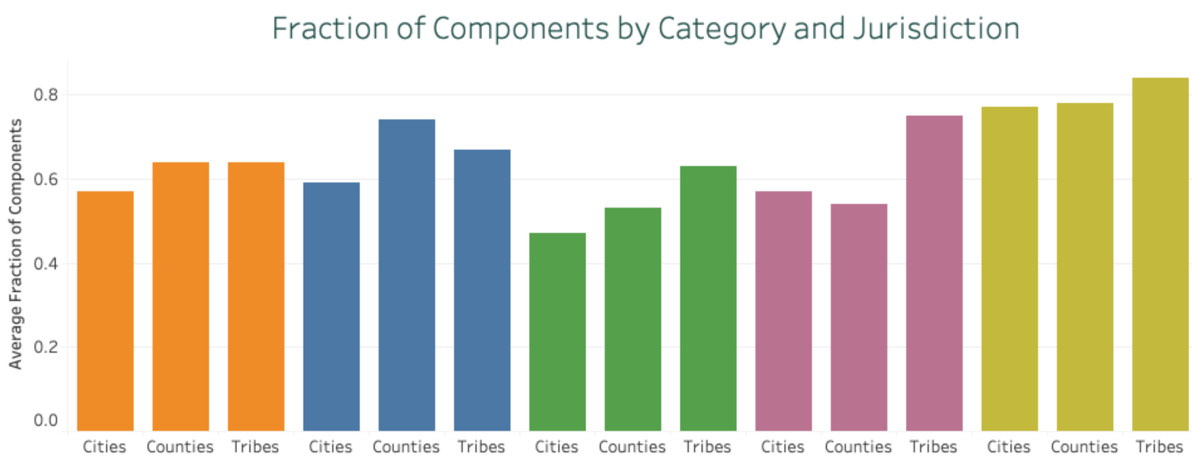

Figure 9: Distinguishes the fraction of components included in assessments for each Washington jurisdiction type by category. The categories include planning components (orange, N = 5), exposure components (blue, N = 3), ecological components (green, N = 8), socioeconomic components (purple, N = 12), and readability components (yellow, N = 5).

4.3.3 Sea Level Rise Projection

By far the most common data source for sea level rise projections was Miller et. al. (2018), "*Projected Sea Level Rise for Washington State,*"[5] which provides projections of sea level rise for locations around the state. This source has been used by 20 out of 26 assessments published

[5] Access the report on the Climate Impacts Group website: https://cig.uw.edu/projects/projected-sea-level-rise-for-washington-state-a-2018-assessment/.

since 2018. Three assessments used a more recently published sea level rise assessment (Sweet et al. 2022).[6]

4.3.4 Exposure

Assessments in Washington evaluated vulnerability using between 0 and 6 sea level rise scenarios. These planning scenarios are mostly based on the representative concentration pathway 8.5 (RCP8.5)[7], and many included an additional extreme water level value to represent impacts associated with a worst case scenario. Assessments tend to choose more conservative (greater sea level rise) scenarios when projecting impacts. The majority of assessments included between 2-3 sea level rise scenarios as shown in **Figure 10**. The scenarios define estimates for sea level rise based on different confidence levels. Some assessments also included an additional scenario for storm conditions including 10-year and 100-year events. Generally, sea level rise projections ranged from 6 inches to 5 feet, with extreme events up to 8.3 feet. The projections range from 2010 to 2150 with less certainty the farther out on the time horizon. We found that projections to 2100 were the most common.

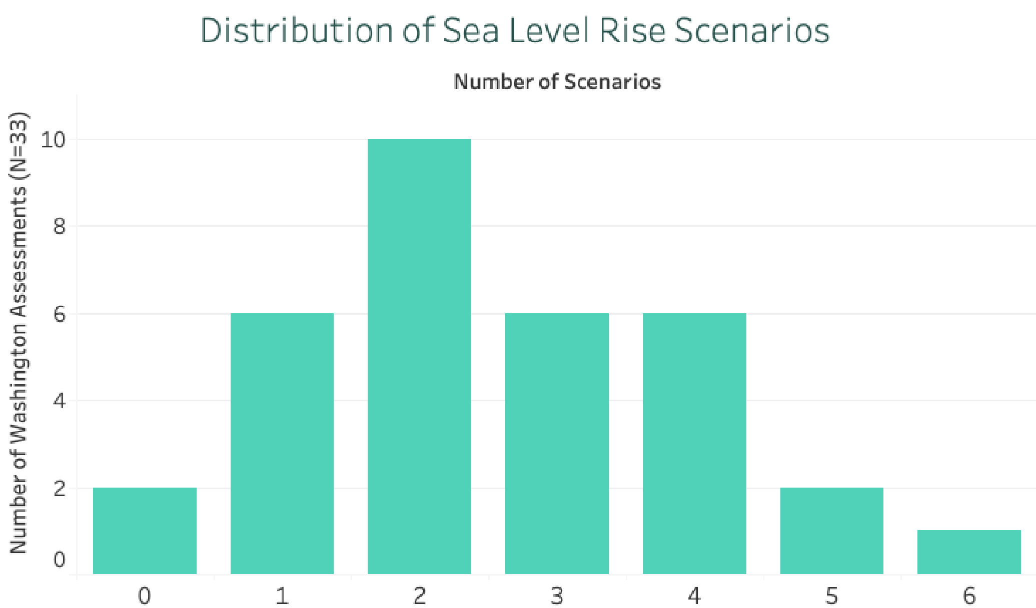

Figure 10: The distribution of sea level rise scenarios included in all Washington assessments.

[6] The full report is available here: https://earth.gov/sealevel/us/resources/2022-sea-level-rise-technical-report/.
[7] RCPs are scenarios that include time series of emissions and concentrations of greenhouse gases, as well as land use projections to develop climate models and predict future warming. RCP8.5 is commonly used by the IPCC to represent a high greenhouse gas emissions scenario, in the absence of policies to combat climate change, leading to continued and sustained levels of warming. (IPCC, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate)

Scenarios were generally chosen based on a low, medium, and high probability of occurrence. We defined risk by the inclusion of a probability-based estimate of hazards within a given timeframe. So if an assessment included probability of exceedance estimates for different scenarios of sea level rise, we determined that to be a definition of risk. In total, 39.4% of assessments defined risk in this way, but some did so in extra detail as is shown in **Figure 11**.

	Probability of Exceedance (RCP 8.5)									
YEAR	**99.9**	**99**	**95**	**75**	**50**	**25**	**5**	**1**	**0.2**	**0.1**
2010	-0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3
2020	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.4
2030	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7
2040	0.1	0.2	0.3	0.5	0.6	0.6	0.8	0.9	1.1	1.3
2050	0.1	0.3	0.5	0.6	0.8	0.9	1.1	1.4	1.7	2.1
2060	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.9	2.5	3.0
2070	0.3	0.6	0.8	1.1	1.3	1.5	1.9	2.5	3.4	4.1
2080	0.4	0.7	0.9	1.3	1.6	1.9	2.4	3.2	4.5	5.3
2090	0.4	0.7	1.1	1.5	1.9	2.2	3.0	4.0	5.8	6.8
2100	0.3	0.8	1.2	1.8	2.2	2.7	3.6	4.9	7.1	8.4
2110	0.8	1.1	1.4	1.9	2.4	2.9	3.9	5.6	8.4	9.8
2120	0.9	1.2	1.6	2.2	2.7	3.3	4.6	6.7	10.1	11.8
2130	0.9	1.3	1.7	2.4	3.0	3.7	5.3	7.8	11.8	13.8
2140	0.9	1.4	1.9	2.7	3.3	4.2	6.0	8.9	13.6	16.1
2150	0.9	1.4	2.0	2.9	3.7	4.6	6.8	10.1	15.7	18.5

Figure 11: An example of a probability of exceedance table for Island County for 2010-2150.[8] The table ranges from 99.9% certainty to 0.1% certainty of predicted sea level rise relative to the current MHHW tidal datum in feet.

This table from Island County estimates a 99.9% probability of exceedance which would be nearly certain to occur, to a 0.1% probability of exceedance, for which sea level is unlikely to go any higher. The 99.9% level indicates a high level of risk tolerance, while the 0.1% is a low level of risk tolerance because it is an extremely conservative estimate of the maximum amount of sea level rise likely to occur.

4.3.5 Definition of Vulnerability

Vulnerability is generally understood to be a function of exposure to a hazard, sensitivity to the effects, and capacity to adapt to the impacts (**Figure 2**). Our comparative analysis included components for defining vulnerability and exposure. Vulnerability was explicitly defined for 70% of assessments while exposure was defined in 67% of assessments. While the definitions of vulnerability do follow some patterns, there is also a lot of variation in how it is defined, reflecting a broader theme of variation in the approach to assessing vulnerability.

[8] Miller, I. et. al. (2016). Sea Level Rise and Coastal Flood Risk Assessment: Island County, Washington.

Table 2 highlights some of the definitions of vulnerability used by various assessments. Common themes are bolded to show patterns across the definitions. The framework shown in **Figure 2** was featured in several assessments, and nearly all included at least two of the three components of vulnerability. We see "susceptibility" as a synonym for exposure and sensitivity, as well as "cope" with or instead of adaptive capacity.

Table 2: Shows some examples of how different assessments define vulnerability. Common words are bolded.

"Degree to which a system is **susceptible** to or unable to **cope** with **adverse** effects of climate change. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is **exposed**, its **sensitivity**, and its **adaptive capacity"** (Puyallup Tribe of Indians)	"Combination of **exposure** to a changing climate, the inherent **sensitivity** of people or environments to a changing climate, and the **capacity** of the community and place to **cope** with the impacts of a changing climate" (Burien)	"A community's vulnerability is a function of its **exposure** and **sensitivity** to a hazard or environmental change and its **adaptive capacity** or resilience. Adaptive capacity is a function of local context and refers to a community's ability to adapt to potential impacts, as well as **cope** with specific events, based on its social, economic, and institutional resources" (Langley)
"Climate vulnerability is defined as the climate **risks** and impacts moderated by the capacity to adapt and **cope** to those impacts" (Port Townsend)	"Climate vulnerability is the propensity or the predisposition to be **negatively** affected by climate change and climate-related hazards" (Seattle)	"Vulnerability refers to the degree to which a system is **susceptible** or unable to **cope** with the **adverse** effects of climate change, including variability and extremes" (Vancouver, BC)
"Vulnerability refers to the **susceptibility** of a given asset, service, or group to **harm** arising from climate change impacts" (Sunshine Coast, BC)	"Openness or **susceptibility** to harm; a function of both **exposure** to coastal hazards and **sensitivity** if exposed" (Washington State Parks)	"Vulnerability is a function of **exposure**, **sensitivity**, and **adaptive capacity** to a given hazard or stressor" (Jefferson County)

4.3.6 Indices

Despite relatively similar definitions of vulnerability, nearly every assessment created a custom index to assess vulnerability to identified hazards. A vulnerability index is a matrix used to systematically assess vulnerability across different hazards and assets. Indices can help jurisdictions prioritize assets or projects to focus on the most vulnerable. Only one assessment used a vulnerability index from another source, the Climate Change Vulnerability Index from NatureServe.[9] The custom indices varied from a simple table to ranking categories to complex formulas to GIS maps. Some indices classified vulnerability just by the exposure of an asset to sea level rise while others included exposure, sensitivity, and adaptive capacity. The variation in indices made it difficult to compare how vulnerability was measured across jurisdictions.

Jefferson County developed a scoring system for exposure and sensitivity of assets to potential hazards based on input from stakeholders. Each asset was given a hazard exposure grade, a hazard sensitivity grade, and an adaptive capacity grade ranging from high to low. These grades were then applied to each asset identified and combined into a total vulnerability score. The Jamestown S'Klallam Tribe used a similar approach to assign key areas of concern a sensitivity ranking and an adaptive capacity ranking ranging from 0-4. The rankings then correspond to a vulnerability matrix that ranks vulnerability (**Figure 12**).

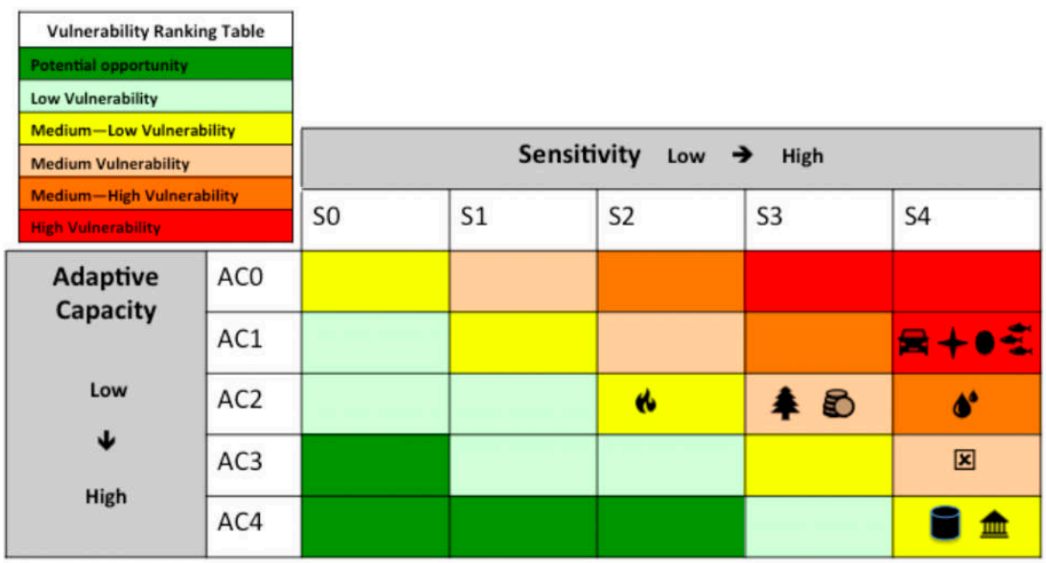

Figure 12: The vulnerability index from the Jamestown S'Klallam Tribe's climate vulnerability assessment.[10]

In addition to variation in the construction of indices, there is significant variation in the ranking of vulnerability. Neither the literature nor the comparative examples we assessed included a consistent way to define and differentiate high vulnerability versus low vulnerability. In the previous example from Jefferson County, a grade of low vulnerability indicates little to no

[9] NatureServe provides biodiversity data throughout North America. The CCVI is a tool for evaluating vulnerability for plant and animal species. https://www.natureserve.org/ccvi-species

[10] Jamestown S'Klallam Tribe. (2013). Climate Change Vulnerability Assessment and Adaptation Plan. Peterson, S. et. al. (editors). *Jamestown S'Klallam Tribe in collaboration with Adaptation International.*

impact, medium vulnerability indicates minor damage, and high vulnerability indicates major damage. However, these measures are highly subjective and context-dependent. This makes them difficult to compare across assessments, scales, hazards, and assets.

4.3.7 Geologic and Ecological Hazards

We included in our analysis vulnerability assessments specific to sea level rise hazards and climate change vulnerability assessments that included sea level rise as one of many climate-related stressors. Sea level rise vulnerability assessments included more detailed information on the hazards that a community expects to face due to rising water levels. Climate change vulnerability assessments included additional hazards beyond those associated with sea level rise, but often with less specificity. We analyzed 15 sea level rise vulnerability assessments and 18 climate vulnerability assessments. All but two assessments specifically included measures of the hazards of rising sea levels. These two assessments included sea level rise in their analysis of climate hazards but did not include information specific to sea level rise. This includes hazards like flooding from increases of the high water mark, storm surge, wave height, wave runup, or changes to tidal range.

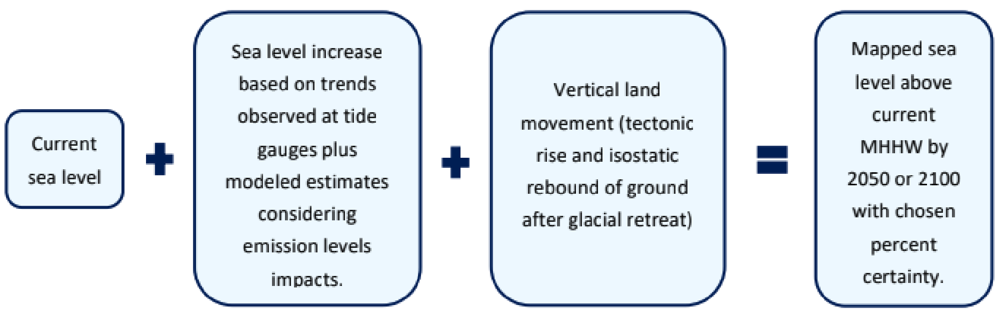

Figure 13: This graphic shows how Pacific County estimated Relative Sea Level Rise.[11]

The approach to measuring sea level rise varies by data availability, jurisdiction priorities, and consultant expertise. Pacific County used the method shown in **Figure 13** to estimate relative sea level rise using historic tide gauge data. Pacific County attempts to account for wave runup by adding an additional extreme flood level prediction to the model. Other common ways of estimating sea level rise impacts include adding projection heights to the FEMA 100-year flood zone maps, the current Mean Higher High Water (MHHW) mark, or the NOAA 2022 High Projection scenario for 2100. The Port of Bellingham used a beta version of the Puget Sound

[11] Pucci, D. & Plum, A. (2023). Sea Level Rise Risk Assessment Pacific County Final Report. *Pacific County Department of Community Development*.

Coastal Storm Modeling System (CoSMoS)[12] to use oceanographic and geomorphic models to estimate future sea level rise impacts. This tool is expected to be publicly available soon.

Assessments used different approaches to model inundation. The City of Bainbridge Island used the Simulating Waves Nearshore (SWAN) model to simulate wave conditions and determine the total water level.[13] This model includes factors such as wind, water level, and geography to estimate wave heights for the entire island shoreline. The City of Coupeville used a “bathtub model” to compare sea level rise inundation level to the ground elevation to map areas susceptible to flooding. This assessment also included a storm surge scenario using the maximum historic non-tidal residual which estimates the difference between measured water level during storms and predicted astronomical tide.

An additional hazard of sea level rise is how it changes shorelines by accelerating erosion or accretion. In our analysis, 55% of assessments considered changes to the marine shoreline due to sea level rise. The Lower Elwha Klallam Tribe’s assessment estimated potential coastal bluff erosion due to rising water levels and increased wind waves. The bluffs are an important source of sediment for nearshore habitat. Jefferson County used the FEMA 2016 Technical Methods Manual methodology to estimate sea level rise with a morphology adjustment. Morphology is measured by the erodibility of the shoreline, ranging from non-armored sandy shorelines highly susceptible to erosion to bluff-backed or armored shorelines less likely to migrate inland. Historic erosion data can be used to estimate future erosion rates. San Juan County used historic erosion rates to develop erosion estimates. They then cross-referenced their beach estimates using the Bruun Rule of shoreline recession.[14]

We analyzed three other common hazards associated with sea level rise: saltwater intrusion, subsidence, and tsunamis. Saltwater intrusion occurs when seawater contaminates freshwater, often through coastal underground aquifers. We found that 64% of assessments included some recognition of the hazards of saltwater intrusion. The City of Seattle’s climate vulnerability assessment rated their stormwater, wastewater, and drinking water as moderately vulnerable to saltwater inflow based on the infrastructure’s susceptibility to flooding. Subsidence, also known as sinking land, was included in 36% of assessments. The City of Olympia notes that large portions of the downtown area were built on artificial fill that is susceptible to subsidence and flooding from sea level rise. Hazards associated with tsunamis were included by just 6% of assessments. The Lower Elwha Klallam Tribe includes a discussion of hazards related to an earthquake on the Cascadia Subduction Zone of sufficient magnitude to trigger a tsunami. As a result, they have relocated critical facilities to higher ground to make their community tsunami-ready.

[12] https://www.usgs.gov/centers/pcmsc/science/ps-cosmos-puget-sound-coastal-storm-modeling-system
[13] Total water level is the total elevation of the water surface where it meets land plus wave runup.
[14] The Bruun Rule estimates beach loss for coastal shorelines. The rule is beach loss = increase in sea level / beach slope. The rule assumes that the shoreline moves landward proportional to sea level rise.

Another area of interest was whether assessments analyzed hazards differently in areas with different land uses. Sea level rise can have very different effects on urban versus rural areas, and ecosystems have different adaptive capacities. We found that 55% of assessments defined at least two different land use types and differentiated their analysis between them. This most often included a differentiation of developed land versus open space. Burien included an analysis of how climate change is expected to affect zoning and development. Pierce County also included a land use assessment including urban, rural, and working lands and potential changes and impacts of climate change.

Finally, sea level rise vulnerability can exacerbate or be affected by other hazards such as changing precipitation patterns, landslides, and wildfire. To determine if assessments included additional risks for these interactions we coded for precipitation and compound effects. Precipitation changes were included in 67% of assessments and compounding hazards in addition to sea level rise were analyzed in 45% of assessments. Overall, tribal assessments tended to be more comprehensive and on average included more hazards when compared to city and county assessments.

4.3.8 Communication

Few assessments took the time to explain the underlying causes of sea level rise. Only 45% of assessments included scientific explanations of the components of climate change contributing to sea level rise such as ocean thermodynamics and melting glaciers and ice sheets. The assessments generally only included high-level explanations of the causes of sea level rise and did not include detailed scientific background information.

There was also significant variation in public participation. Nearly 58% of assessments included some form of public outreach in the development of their assessment. Some local governments formed stakeholder advisory committees or brought together local experts. Other assessments included public meetings, webinars, or workshops to solicit feedback on the plan, identify hazards, or locate assets important to the community. Whatcom County developed a public participation plan to understand community concerns and priorities.

Many of the differences outlined above ultimately depend on the overall focus of the vulnerability assessment. In the next section we identify three primary targets of vulnerability assessments: infrastructure, social, and ecological vulnerability. The main focus of the assessment ultimately determines how vulnerability is defined and which assets are prioritized.

4.4 Oregon and British Columbia Vulnerability Assessment Comparisons

Oregon assessments used projections from the "Sixth Oregon Climate Assessment"[15] produced by the Oregon Climate Change Research Institute. The Canadian assessments use data from the Institute of Ocean Sciences, a division of the government agency Fisheries and Oceans Canada. The Oregon and British Columbia assessments were different from Washington assessments and each other in some key ways (**Figure 14**).

The assessments from British Columbia included one city and two regional districts. Overall these assessments included less components than both Washington and Oregon assessments. They were more economically focused, with impacts to infrastructure and value-based assets identified. The assessments focused on impacts to infrastructure and human systems but did not consider ecological vulnerability as much.

The Oregon assessments we included tended to be more inclusive of infrastructure, social, and ecological vulnerability, including more components overall than Washington or British Columbia. These assessments had a larger focus on ecosystems, especially estuaries. They also included more socioeconomic components on average including tribal consideration, impacts to frontline communities, and environmental justice. These assessments also included more community outreach than assessments conducted in Washington, conducting collaborative listening sessions, stakeholder workshops, and interviews.

Notably, none of the Oregon or British Columbia assessments included managed retreat as a response to sea level rise vulnerability. The Oregon and British Columbia assessments were also less likely to include impacts from saltwater intrusion, but more likely to include risks associated with tsunamis than Washington assessments (**Figure 14**). One caveat to these findings is the limited number of assessments that we reviewed.

The Coos County Climate Hazards Assessment assesses climate hazards (including sea level rise) across the natural world, the built environment, public health and social systems, and cultural heritage. This comprehensive assessment includes economic impacts and compounding effects of climate change. The assessment individually evaluates the exposure, sensitivity, and adaptive capacity of each asset. The report also includes impacts to vulnerable populations and tribal heritage sites. The final chapter outlines adaptation strategies and actions to take.

[15] Access the report on the Oregon Climate Change Research Institute website: https://blogs.oregonstate.edu/occri/oregon-climate-assessments/.

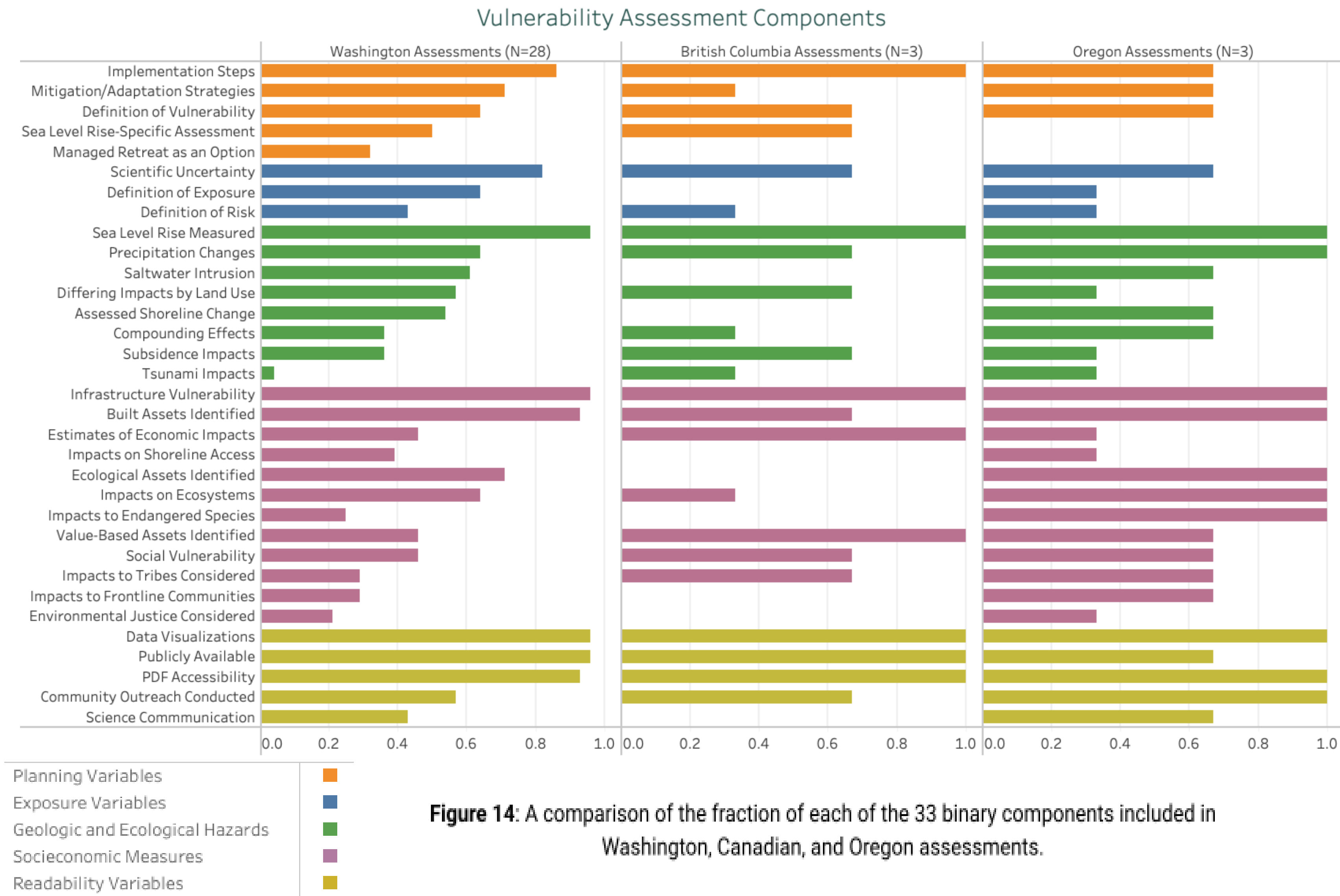

Figure 14: A comparison of the fraction of each of the 33 binary components included in Washington, Canadian, and Oregon assessments.

4.5 Key Elements of Vulnerability Assessments

Through our review of the literature we identified three types of vulnerability that are commonly assessed: infrastructure vulnerability, social vulnerability, and ecological vulnerability. When designing our codebook (**Appendix 1**) we purposefully developed codes to assess these three components of vulnerability. **Figure 15** shows how the definition of vulnerability including exposure, sensitivity, and adaptive capacity are measured by our codebook as well as the different components of infrastructure, social, and ecological vulnerability are incorporated into the assessment. When considering the three vulnerability types together, infrastructure is the most commonly assessed. However, tribal assessments tend to include more components overall and take a broader approach that considers all three vulnerability typesThat being said, most jurisdictions include components from at least two if not all three categories of vulnerability. Only four Washington assessments focused specifically on one vulnerability type (3 infrastructure, 1 ecological).

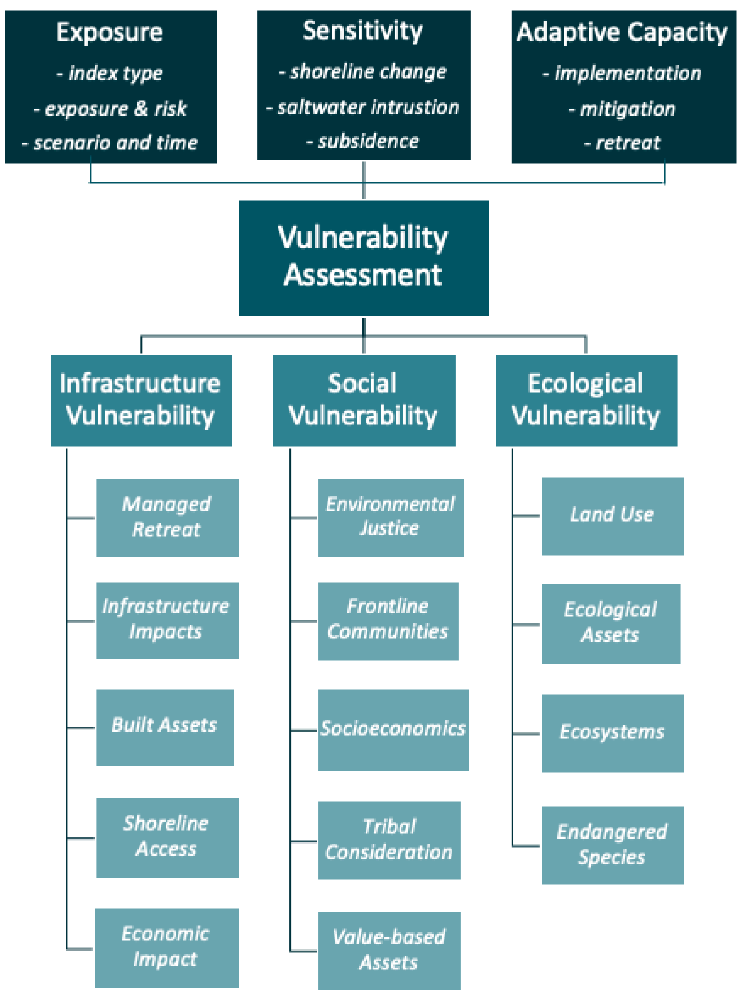

Figure 15: This figure shows how the components that we assessed measure different elements of vulnerability assessments.

4.5.1 Infrastructure Vulnerability

The sea level rise vulnerability assessments included in this review focused most heavily on impacts to infrastructure and the built environment.

We used five components to represent assessment of impacts to infrastructure: managed retreat, infrastructure impacts, built assets, shoreline access, and economic impact estimates. These components were chosen to represent infrastructure vulnerability because they measure how assessments are thinking about impacts to structures. Managed retreat measures whether an assessment includes relocating vulnerable assets away from the hazard. Infrastructure impacts and built assets indicate what kinds of infrastructure are vulnerable to sea level rise in a jurisdiction and which assets are valued highly in a community. Shoreline access captures when assessments are thinking specifically about infrastructure used to access the shoreline. We chose to include economic impacts as a measure of infrastructure vulnerability because a majority of the assessments we reviewed applied economic loss impacts to built assets. Together, these components are used as a proxy for the ways that infrastructure and the built environment are vulnerable to sea level rise.

A majority of assessments included at least half of the infrastructure components, **Figure 16** shows the average number of components that jurisdiction types included out of five. In total, 36% of assessments considered managed retreat, 94% assessed impacts to infrastructure, and 91% considered specific built assets. Only 36% considered shoreline access. The City of Langley considers public access to community assets likely to be impacted by sea level rise and includes a recommendation to adapt these sites. Economic impact estimates were included in 42% of assessments. Tribal assessments, on average, had slightly less emphasis on infrastructure when compared to assessments done by cities and counties.

Olympia's Sea Level Rise Response Plan includes quantitative measures of the economic consequences of flooding. The report estimates flood fighting costs, commuter delay costs, and tree loss costs associated with a 100-year storm event. The report also includes estimated costs to construct physical sea level rise adaptation options. Potential funding sources are also identified.

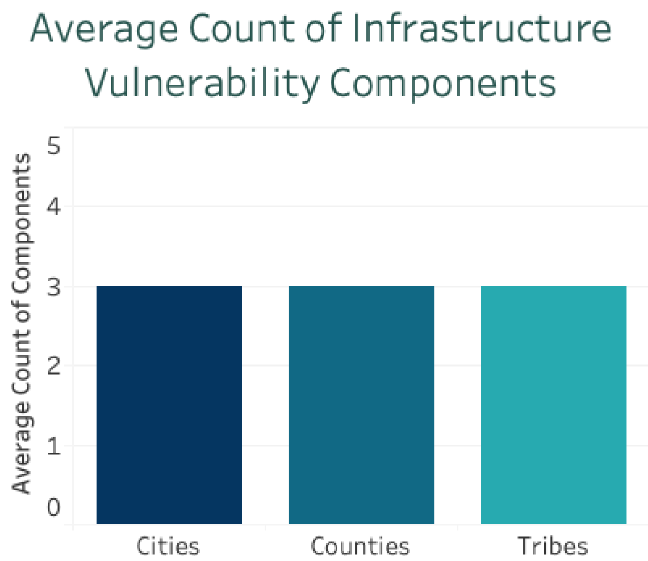

Figure 16: Average count of infrastructure related components by jurisdiction type. There are five infrastructure codes possible.

4.5.2 Social Vulnerability

Our literature review identified social vulnerability as an area of emerging research. Social vulnerability considers how overburdened or frontline communities have different levels of exposure and adaptive capacity to cope with changes. Frontline communities have lower levels of adaptive capacity due to being socially marginalized or overburdened. The social and economic barriers these communities face can be exacerbated by climate change.

We used five components to assess social vulnerability: environmental justice, consideration of frontline communities, socioeconomics, consideration of impacts to tribal members and resources, and value-based assets. These components were chosen to represent social vulnerability because they measure the more intangible ways that jurisdictions are thinking about community vulnerability to sea level rise. The environmental justice code indicates whether an assessment acknowledges or includes principles of environmental justice. Assessments measured socioeconomic status differently, but most recognized vulnerabilities of older people, children under five years old, low-income families, immigrant communities, Black, Indigenous and people of color (BIPOC), and people with preexisting health conditions. Some indigenous communities are especially vulnerable to sea level rise as they are located in vulnerable areas and have livelihoods that depend on nearshore habitats. The tribal consultation code captures whether assessments included specific vulnerabilities to Tribes or included tribal interests in their considerations. Value-based assets are defined as places that serve as community gathering spaces, provide a sense of place, or are recreational hubs. **Table 3** shows that assessments that included tribal considerations were more likely to also include value-based assets.

Tribal Consideration to Value Assets			
	Yes Tribal Consideration	No Tribal Consideration	Sum
Includes Value-Based Assets	38%	15%	54%
Omits Value-Based Assets	5%	41%	46%
Sum	44%	56%	100%

Table 3: Contingency table comparing assessments that were coded for inclusion of tribal consideration and value based assets

Due to its emerging nature, we initially assumed that social vulnerability would be less commonly assessed than other types of vulnerability. However, our results suggest some jurisdictions are thinking about the disparities between groups that make adaptation difficult. Cities and counties included at least two out of five social components while Tribes included four out of five, on average (**Figure 17**). In total, 27% of assessments mentioned environmental justice, 39% considered impacts to frontline communities, 39% considered impacts on tribal communities, 52% included socioeconomic variability, and 63.6% identified vulnerabilities of value-based assets. When considering only tribal assessments, these percentages increase for all five components. All of the tribal assessments we analyzed included frontline communities, tribal considerations, and value-based assets.

Pierce County used the Washington State Environmental Health Disparities Map[16] as well as a custom Equity Index with 29 indicators to map the relative equity of census tracts within the County. Seattle's assessment includes a social and economic climate vulnerability assessment that includes climate exposure, access to parks, a race and social equity index, and disruptions to critical facilities. Other assessments acknowledge disparate impacts to vulnerable populations without performing a full social vulnerability analysis.

[16] The Washington State Department of Health developed the Environmental Health Disparities Map that provides an index rating across census tracts for various disparities. Access the tool at: https://fortress.wa.gov/doh/wtnibl/WTNIBL/

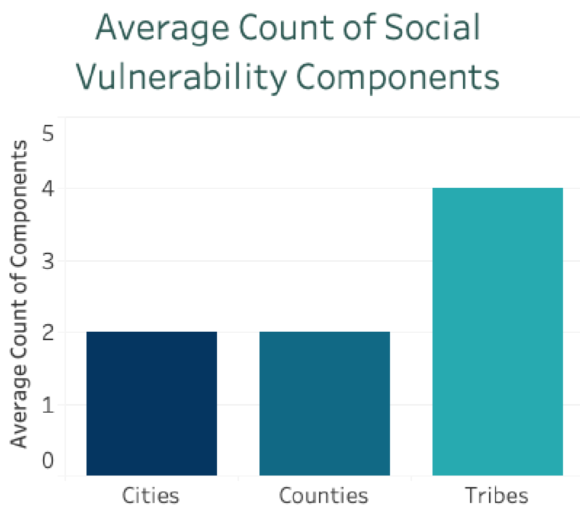

Figure 17: Average count of social vulnerability components by jurisdiction type. There are five possible social codes.

4.5.3 Ecological Vulnerability

Washington State relies on natural resources for employment as well as recreation and sense of place. As such, we anticipated that vulnerability assessments would consider impacts from sea level rise to ecosystems and the natural environment.

We used four components to measure inclusion of ecological vulnerability: land use, ecological assets, impacts to ecosystems, and impacts to endangered species. These components were chosen to represent ecological vulnerability because they show how jurisdictions think about the ecological effects of sea level rise. Land use measures whether assessments differentiate hazards between different land use types including developed land, open space, farmland, etc. Ecological assets include specific habitats, recreation areas, or species that will be affected by sea level rise. The ecosystem component captures more diffuse impacts to coastal ecosystems. Finally, impacts to endangered species codes for how specific endangered species will be affected. Together, these components measure the ways that sea level rise has effects on ecological systems in addition to human systems and infrastructure.

On average, cities included 50% of the ecological components, counties 50%, and Tribes included 75% (**Figure 18**). In total, land use was considered by 55% of assessments, and ecological assets were identified in 73% of assessments. Ecosystems were considered by 67% and endangered species by 36%. The Samish Indian Nation completed habitat site profiles for key cultural sites that included an assessment of the habitat type, room for migration, the degree to which sea level rise impacts habitat function. However, most assessments simply acknowledged general vulnerability of habitats to sea level rise. Unsurprisingly, tribal assessments included endangered species 100% of the time, as the most commonly identified species was salmon, an important tribal resource. Cities were more likely to differentiate impacts based on land use, often through the use of GIS mapping.

The Coos Bay assessment specifically included a salmonids vulnerability assessment measuring direct climate effects and adaptive capacity. Two assessments focused exclusively on ecological vulnerability, one primarily on ecosystems and the other on species. One assessed impacts of sea level rise on the Skagit River Delta, and the Nooksack Tribe's assessment analyzed impacts to species in estuary, forest, alpine, marine nearshore, riparian, and wetland habitats.

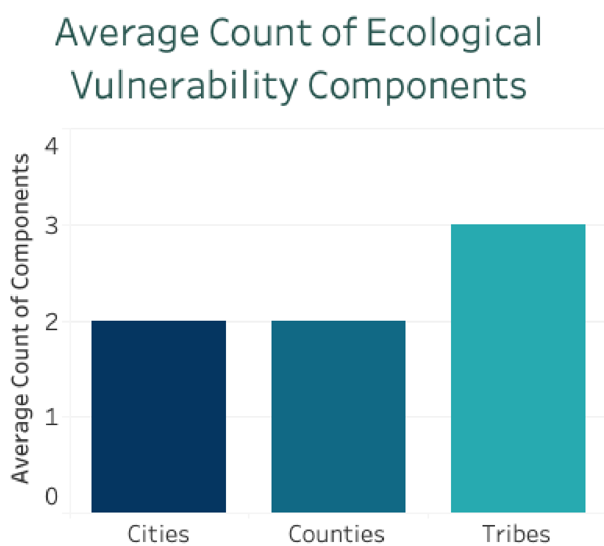

Figure 18: Shows the average count of ecological components by jurisdiction type. There are four ecological codes possible.

4.6 Vulnerability Assessment Applications

Vulnerability assessments are most useful if they are put to use to inform planning processes and communicated to the public. To understand these practical implications we conducted 6 interviews with local government practitioners around Washington. These interviews allowed us to understand the barriers to developing sea level rise vulnerability assessments, what kinds of assistance is or would be helpful, and how vulnerability is communicated to the public. We were also better able to understand why local governments conduct vulnerability assessments and how they use them to inform local government actions and planning.

4.6.1 Barriers to Developing Assessments

We expected that the most common barriers to developing a sea level rise vulnerability assessment for jurisdictions would be funding and staff capacity. While these were mentioned in all of the interviews we conducted, other barriers were more unique to each jurisdiction. We spoke with rural counties for whom staff capacity is such a constraint that even if they were able to apply for more grant funding they wouldn't be able to use it without hiring an additional person. Because of these limits on workload, code updates are only done in cycles and some places have not been able to update their codes, Comprehensive Plans, or Shoreline Master Plans with the updated sea level rise vulnerabilities from their assessments.

Additionally we spoke with a large city that experienced challenges assigning responsibility for sea level rise planning due to their governance structure. Planning for and addressing vulnerabilities related to sea level rise does not fall under the purview of any one department. So to do this work someone has to create the responsibility and then find ways to fund it because there is no dedicated staff for it. Another jurisdiction had a similar issue where they were in conflict with a local utility over ownership and responsibility for critical infrastructure, making it difficult to engage with stakeholders and address vulnerabilities.

In some ways it is easier to do this work at a smaller scale. One small city we spoke to was able to integrate their sea level rise vulnerability assessment recommendations into their Shoreline Master Plan (SMP) relatively quickly because the same person was in charge of developing the assessment and updating the SMP at the same time. However, even if a consultant is doing the work, staff capacity is necessary to oversee the development of the vulnerability assessment. One person we spoke to had a background in biology and pushed the consultant to include more information about impacts of sea level rise on the natural environment. Another interviewee expressed concern that due to the short timeline and limited funding for the project, the final vulnerability assessment contained flaws in the methodology. With additional time and/or staff to review the report during the development phase, these errors may have been addressed before it was finished.

For others the issue is more political. One city we spoke to has historically been unable to engage with sea level rise planning due to a lack of political will from their city council. Only now that the council members have changed has this coastal city been able to recognize the hazards they face from sea level rise and begin the planning process.

4.6.2 Limitations of Assessments

Another common refrain from the interviews included limitations in data, knowledge, and assets included in the assessments. Each vulnerability assessment had different stated objectives from an introduction to thinking about climate change along marine shorelines, to protecting city-owned infrastructure, to addressing public health, to assessing the future economic viability of the community. For counties, it is challenging to address the variability of large geographic areas with unique vulnerabilities. One county was concerned that they were not accounting for differences in sea level rise along the outer coast versus along the Puget Sound. Another county acknowledged differences in tourism-dominated communities versus agriculture-dominated economies but struggled to map the differences in vulnerability among the two.

Other limitations were more due to data availability, such as limited records of private well and septic locations. One county mentioned that the majority of population centers are located at the confluence of rivers and the Sound, but their assessment did not include any estimates of fluvial interactions with sea level rise, especially considering changing precipitation and snowmelt patterns. Another community had stated concerns about bluff landslides due to erosion but there was not enough available data about wave action and erosion rates.

Some jurisdictions were more limited by data variability. For one county, the smallest unit of change for the sea level rise projections was 1 foot which makes .3 ft and .7 ft look the same despite having different impacts. Several jurisdictions acknowledged how helpful statewide projection information published by Ecology and University of Washington has been for planning, but expressed that it can be challenging to bridge the gap between state level data and developing site specific analysis. The scientific uncertainty of sea level rise is inherently difficult to plan for.

4.6.3 Communicating Vulnerability

Communicating sea level rise vulnerabilities with the public is another piece of the puzzle that can be overlooked. This kind of work often depends on whether the grant funding requires it or not. Without grant funds for public communications, many jurisdictions do not have the time to do it. Understanding sea level rise is only so helpful without being able to communicate the impacts to the people it will affect. One jurisdiction that we spoke to said that property owners have been surprised that sea level rise has affected them. It was not something that they considered when planning the scope of their property development.

This sentiment was reflected by jurisdictions that expressed the challenge of managing sea level rise when so much of the shoreline is private and beyond their control. There is a concern that private landowners do not have the capacity to address future contingencies, yet they are liable for maintenance and failure of flood infrastructure in some cases. Additionally, the complex layers of state and federal agencies that have jurisdiction over shorelines add further complications to sea level rise planning and adaptation. Another interviewee highlighted the value of being able to show where the vulnerabilities are and have data to back it up. This jurisdiction also specifically chose to use a higher confidence level for their sea level rise projections so that they can communicate with more certainty to the public. Some communities benefit from highly engaged residents with high levels of civic capacity and participation, but this is not the case everywhere. Several jurisdictions emphasized the importance of sea level rise education to show the public that their communities are vulnerable to rising seas.

4.6.4 Other Challenges

Another consideration raised by one of our interviewees in a more urban jurisdiction is the intersection between sea level rise and environmental contamination. Some federal partners like the Army Corps of Engineers will not engage in flood risk planning unless contaminated soils are mitigated. Unfortunately, this creates an environmental justice issue because the communities where contaminated soils are located are often also low-lying areas vulnerable to sea level rise flooding. This makes it even more difficult to address both the contamination and the flood risk. This jurisdiction suggested prioritizing remediation funding that dovetails with sea level rise planning.

4.6.5 Social Vulnerability

We also asked interview subjects about inclusion of local knowledge and environmental justice considerations in their vulnerability assessments. The degree to which each was included varied significantly, but all jurisdictions that we interviewed acknowledged to some degree the state mandate to consider overburdened communities in their Comprehensive Plans. Local knowledge can draw on deep and intergenerational experience to understand changes over time and identify existing problems. Some communities were able to harness this knowledge to understand core vulnerabilities, while others struggled to engage stakeholders, or the knowledge simply didn't exist. Environmental justice is a new term for some communities, but even if they were not able to address it directly, it is often implicitly understood. One county relied on a now unavailable federal tool[17] to identify vulnerable communities within their jurisdiction. Other jurisdictions used FEMA's flood maps or the Washington Environmental Health Disparities Map[18] to address environmental justice. Local knowledge informs environmental justice in a more meaningful way as one county pointed out. The balance between affordable housing and addressing vulnerabilities while updating development regulations highlights this challenge and provides an opportunity for vulnerability assessments to inform planning efforts.

[17] The White House Council on Environmental Quality's Justice 40 Climate and Economic Justice Screening Tool has been removed by the Trump Administration: https://eelp.law.harvard.edu/tracker/ceqs-climate-economic-justice-screening-tool-removed/

[18] https://fortress.wa.gov/doh/wtnibl/WTNIBL/

CHAPTER 5: DISCUSSION & CONCLUSION

5.1 DISCUSSION

Sea level rise vulnerability assessments have a significant amount of variation in the overall focus of the assessment, how they are conducted, and how vulnerability is measured and assessed. Assets included in assessments should be context-specific and responsive to community needs. The more comprehensively that vulnerability is assessed allows communities to protect their identified assets. We identified three primary themes in vulnerability assessments: infrastructure, social, and ecological vulnerability, often assessed individually or in combination. Our codebook included a subjective measure of each assessment's primary focus. Infrastructure and ecological vulnerability were most frequently emphasized, though nearly one-quarter of assessments placed significant focus on social vulnerability. The lack of a standardized way that vulnerability is assessed across these three categories results in assessments that vary in depth and breadth of vulnerability to infrastructure, people, and ecosystems.

Social vulnerability is an emerging concept, but it has been incorporated more often in assessments published after 2020. This could be due to the emerging environmental justice movement, or in response to an understanding of how different communities were affected by the COVID-19 pandemic.[19] Assessments conducted for tribal nations explicitly addressed environmental justice and impacts to frontline communities, reflecting their lived experience of historical and ongoing injustice. **Table 3** shows that assessments involving tribal considerations are more likely to include value-based assets. These may include assets that a jurisdiction was already considering, but it also shows that engaging with tribes can help identify assets that are important to members of the community.

Figure 8 shows that tribal assessments include more socioeconomic components in their assessments than other Washington State assessments. This likely reflects tribal priorities to assess sea level rise impacts on cultural and spiritual assets, as well as on the health and livelihoods of enrolled community members. Cities, counties, and government agencies more commonly assess impacts to infrastructure and built assets they must plan to relocate, protect, or replace (**Figure 15**). Cities considered economic impacts more often than other jurisdictions likely due to specific impacts on businesses and employment. A larger proportion of tribes considered managed retreat as an option. Washington tribes have been a leader in the relocation of critical infrastructure to adapt to rising sea levels.

In general, assessments considered the same suite of geologic and ecological hazards. Sea level rise impacts (flooding, inundation, storm surge, and wave runup), changes in precipitation, saltwater intrusion, and shoreline changes are the most common hazards assessed. Compounding effects are more commonly assessed by climate vulnerability assessments than sea level rise

[19] An EPA report published in 2021 showed evidence of environmental racism under Covid-19 response. Available from Vermont Law School.

specific assessments because they include additional hazards. Tsunami impacts are also more common among the Oregon and Canadian assessments than the Washington assessments, including tribes.

In contrast to Fu et al (2019), we found that a significant number of assessments did include implementation and mitigation or adaptation steps and strategies (**Figure 8**). Implementation steps included recommendations for additional studies or changes to future planning while mitigation or adaptation were classified as specific strategies, policy changes, or projects to mitigate risks identified by the vulnerability assessment. We found that assessments conducted by consultants were slightly more likely to include both measures of shoreline change and mitigation strategies. This potentially illustrates that vulnerability to erosion (the most commonly identified type of shoreline change by assessments) forces jurisdictions to be more proactive in their response to sea level rise.

Infrastructure, social, and ecological vulnerabilities were identified in our review of the literature and are reflected in the language used by the Washington State Legislature. The Revised Code of Washington directs Ecology to require Shoreline Master Programs to “address the impact of sea level rise on people, property, and shoreline natural resources and the environment.”[20] We consider assessments that consider vulnerability of all three to be more comprehensive assessments of the hazards that communities face from sea level rise.

Overall, we found that sea level rise vulnerability assessments vary significantly in content and focus. There is no standardized approach to modeling, projecting, or assessing sea level rise and its impacts on communities. This result echoes Hirschfeld et. al.'s (2023) finding that there is no global standard in the use of sea level rise scenarios. While it is helpful to communities to be able to tailor the vulnerability assessment to their needs, we believe that communities would benefit from a more standardized approach to measuring and assessing vulnerability while preserving discretion over the focus and scope of the assessment. Undertaking a vulnerability assessment is a big expense for local governments in terms of time, money, and staff capacity. This research helps local governments contrast the information that is included in assessments from different localities to identify gaps, best practices, and future research.

5.2 LIMITATIONS & FUTURE RESEARCH

A key challenge in our analyses was the inherent subjectivity involved in interpreting the presence or absence of SLR vulnerability assessment components in our data. Although qualitative methods often embrace interpretative flexibility, we attempted to mitigate potential bias through the development of a coding framework supplemented with intercoder reliability checks. The threshold of an acceptable intercoder agreement score is often within the range of 0 and 1. However, the recommended minimum threshold to indicate agreement has changed

[20] See RCW 90.58.630 https://app.leg.wa.gov/rcw/default.aspx?cite=90.58.630

through the past few decades. Some frameworks consider 0.4 - 0.6 an acceptable moderate score, and others argue 0.8 - 0.9 to be the minimum acceptable score (Halpin, 2024). Krippendorff suggests that an alpha score greater than or equal to 0.8 should be considered a satisfactory level of agreement (Krippendorff, 2022). According to Krippendorff, our coding agreement on average falls on the lower end of acceptability for making tentative conclusions. This could suggest our results may not be widely applicable outside of the Washington state context or perhaps our assessment coding framework was not applied consistently.

Our framework was iteratively refined as we engaged with the literature and efforts were made to discuss and resolve disagreements, but the coding definitions may have allowed for interpretive variability due to overly broad definitions. Broad definitions can lead to conceptual overlap between some themes which can force us as coders to make interpretative leaps, increasing subjectivity in our analysis and in turn lowering coding agreement. Broad definitions also make it more difficult to detect nuanced patterns that lie beneath the surface of our data. Despite this, we believe that the moderate agreement we achieved within our study is sufficient given our relatively small sample size and serves to highlight the broad trends present within currently completed Washington state assessments. It is our hope that our work provides a foundation for future research and we acknowledge that this process remains fundamentally shaped by our internal assumptions, disciplinary backgrounds, and familiarity level with sea level rise vulnerability assessments and associated science.

This analysis of sea level rise vulnerability assessments across the Pacific Northwest reveals a need for expanded research into critical physical processes such as shoreline erosion, bluff retreat, and sediment loss, despite their significant implications for land use, habitat stability, and infrastructure resilience. A state or region wide analysis of coastal erosion, informed by high-resolution geospatial data and long-term shoreline change modeling, is needed to fill this gap. Such research would support more accurate projections of morphological change and better equip local governments to plan for landward retreat and shoreline adaptation.

Another key data gap is the lack of integrated analysis of riverine flooding and sea level rise in coastal river deltas. Population centers in areas like the Skagit and Duwamish face increasing exposure to compound flood hazards, yet few assessments model the interaction of fluvial and tidal systems. Future research should prioritize coupled watershed–coastal models to identify compound flood risks and inform more robust, equitable adaptation strategies in low-lying and socially vulnerable areas.

Additionally, future research is needed to examine the degree to which sea level rise vulnerability assessments influence tangible planning and regulatory outcomes. This includes tracing how assessment findings inform shoreline master programs, zoning ordinances, infrastructure investment, and hazard mitigation strategies. Public policy students should also explore whether assessments meaningfully incorporate procedural equity (i.e. community participation and representation) and distributional equity (i.e. how adaptation benefits and burdens are shared). Further research on cross-jurisdictional learning and governance could evaluate how local governments share tools, data, and strategies, and assess the effectiveness of state-supported peer learning networks in advancing coastal resilience. Additional research should build on this study's comparative framework to deepen the analysis of how sea level rise vulnerability assessments are structured, interpreted, and applied in coastal planning contexts. Students should focus on developing more refined evaluative tools (e.g., weighted scoring indices or composite metrics) that enable systematic comparison across jurisdictions and over time. These tools can help determine whether assessments are improving in methodological rigor, inclusivity, and alignment with climate adaptation best practices.

CHAPTER 6: RECOMMENDATIONS

To strengthen the quality, accessibility, and equity of sea level rise vulnerability assessments across the state, we offer the following recommendations to the Washington State Department of Ecology. These recommendations are designed to enhance technical consistency, improve regulatory integration, expand public engagement, and ensure that under-resourced communities along Washington's coastlines are fully supported in their adaptation planning efforts.

1) Establish a Standardized Framework for Sea Level Rise Vulnerability Assessments

To support consistency, comparability, and effectiveness across local jurisdictions, Ecology should develop a standardized framework for conducting sea level rise vulnerability assessments. While recognizing the diverse goals and contexts of local governments, a standardized framework approach would provide technical guidance on baseline components such as authoritative sources for sea level rise projections (e.g., Miller et al., 2018; NOAA, 2022), a common definition of vulnerability, and structured methodologies for constructing vulnerability indices. It should also specify the minimum components to assess, including geomorphic hazards, land use differentiation, social vulnerability, and ecological assets.

The standardized framework should recommend relevant literature, modeling tools, and spatial analysis methods. Additionally, Ecology should support jurisdictions in applying the framework across diverse planning contexts, from hazard mitigation to shoreline planning. This may include promoting integrative, cross-sectoral approaches—such as those used in the Adapting to Rising Tides program and SANDAG's holistic planning framework—that connect climate adaptation to land use, infrastructure, ecosystem resilience, and equity objectives. Drawing from such models can help ensure that assessments not only generate robust data but also inform multi-benefit adaptation strategies.

By establishing a standardized yet adaptable framework, Ecology can enhance the utility of sea level rise vulnerability assessments for informing regulatory and land use decisions, reduce disparities in assessment quality across jurisdictions, and strengthen statewide coordination on climate resilience.

2) Delineate the Role of SLR Vulnerability Assessments in Shoreline Master Programs

Ecology should provide guidance on how sea level rise vulnerability assessments are to be integrated into the development and revision of local Shoreline Master Programs (SMPs) and how to align assessments with the Washington State Shoreline Management Act. This guidance should delineate how vulnerability data informs shoreline land use policies, regulatory frameworks, and adaptation strategies. It should also specify minimum requirements for incorporating sea level rise findings into SMP updates, including examples of best practices from existing assessments to support consistency and actionable implementation.

Given the variability in assessment purposes and approaches, Ecology should identify the core components most relevant to shoreline management, such as impacts to shoreline access, ecological assets, and at-risk species, which are key priorities under the Shoreline Management Act that are often underrepresented in existing assessments. The guidance should address the need for detailed spatial data and future hazard area mapping to support regulatory updates, while acknowledging disparities in mapping resolution and data formats across assessments. Ecology should also assess existing spatial data, identify gaps, and support jurisdictions in accessing and applying this information for regulatory purposes.

Finally, local governments will require support translating complex assessment findings into policy-relevant insights. Ecology should offer technical assistance to help jurisdictions distill key takeaways and draft regulatory language that addresses shoreline vulnerability. Recognizing that not all data from existing assessments will be relevant for SMP updates—and that some essential data may be absent—this process will require close coordination, capacity-building, and iterative refinement between state and local partners.

3) Develop Public Communication Tools to Support Sea Level Rise Adaptation

To strengthen public engagement and support for shoreline adaptation, Ecology should develop targeted communication tools that translate sea level rise vulnerability data into accessible, locally relevant information. While sea level rise vulnerability assessments serve as necessary and critical planning functions for technical audiences and agency staff, they are not sufficient tools for public outreach. Adaptation efforts require widespread public understanding and participation, particularly among property owners and frontline communities. Ecology should produce materials that clarify sea level rise projections, illustrate localized risks (e.g., neighborhood-scale inundation, impacts to cultural sites), and outline actionable options for property protection. These tools should frame adaptation in terms of co-benefits such as economic savings, public safety, and environmental resilience, and avoid partisan framing to reduce resistance. Localized, user-centered outreach resources are essential to complement technical assessments and foster the public buy-in necessary for equitable and effective climate adaptation planning.

4) Leverage Existing Networks to Expand Public Outreach and Resource Sharing

To strengthen sea level rise adaptation planning and public engagement, Ecology should actively leverage and contribute to existing regional networks including but not limited to the Coastal Hazards Resilience Network (CHRN) and Shoreline and Coastal Planners Group (SCPG). These networks can share outreach tools, communication strategies, and assessment resources. Through existing networks, Ecology can facilitate the dissemination of accessible, locally tailored materials that translate assessment findings into actionable information for residents, landowners, and frontline communities. These networks offer a strategic platform to coordinate messaging, highlight effective engagement practices, and align outreach efforts across jurisdictions. By strengthening collaboration through established partnerships, Ecology can help ensure that adaptation planning is informed not only by robust science, but by inclusive, community-driven communication.

5) Prioritize Funding and Technical Support for Under-Resourced Jurisdictions

To advance equitable coastal resilience across the state, Ecology should continue to fund sea level rise vulnerability assessments with an explicit focus on jurisdictions that have not yet initiated this work. Rural and tribal communities with limited internal capacity should receive additional priority. As highlighted in the report, barriers such as insufficient staffing, unclear mandates, and constrained financial resources inhibit many jurisdictions from undertaking sea level rise planning, despite facing growing coastal risks. By prioritizing grantmaking and technical assistance for under-resourced communities, Ecology can help ensure that vulnerability assessments are more widely distributed and inclusive. This support should include not only funding for assessments but also training, data access, and peer-learning opportunities. Such targeted investment will strengthen statewide resilience planning, close critical capacity gaps, and foster more coordinated responses to sea level rise across diverse coastal geographies.

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Appendix I: Codebook

Category: Background Information				
Code	**Description**	**Data Source**	**Code Options**	**Examples**
Name	Name of the local government entity that the report was conducted for.	Assessment		Burien; Puyallup Tribe of Indians; Skagit Delta; Tillamook County; Vancouver, BC; WA State Parks
Year	Year published	Assessment		2013, 2016, 2019, 2024
Author	Who wrote the report (consultant or in-house)?	Assessment		AECOM; Cascadia Consulting Group, Herrera Environmental Consultants; Geos Institute; Pierce County
Scale	Level of government	Assessment		Agency, City, County, Regional District, Tribe, Other
Income	Median household income for the community	US Census		$55,292; $74,067; $122,148
Population	Total population of the community	US Census		780; 32,977; 662, 248; 2,340,211
Data source	What is the data source for the SLR data?	Assessment		NOAA (Sweet et al. 2022); WA (Miller et al. 2018)
Timeframe	How long did the assessment take? (Add note if estimate is made based on grant date to publication date)	Assessment		2009-2013; 2015-2016; 2019-2023; 2022-2024

Category: Planning Capacity				
Code	**Description**	**Data Source**	**Code Options**	**Examples**
Funds	Total funding budgeted for the project	Assessment, Web search, Ecology grants		$52,990; $243,624; unknown
Funding Source	Source of funding for the project	Assessment		FEMA; WA Department of Commerce Early Climate Planning Grant; WA Salmon Recovery Funding Board, NOAA Pacific Coastal Salmon Recovery Fund; US EPA NODC Grant

SLR Specific	Is the assessment for sea level rise specifically or a more general climate change vulnerability assessment?	Assessment	1 (slr), 0 (general)	
Define	Does the assessment include a definition of vulnerability that includes exposure, sensitivity, and adaptive capacity? (Note how it is defined or measured)	Assessment	1 (yes), 0 (no)	Vulnerability refers to the susceptibility of a given asset, service, or group to harm arising from climate change impacts. Vulnerability is a function of two criteria: the sensitivity of the community to a given climate change impact, and its adaptive capacity (ability or access to resources to respond, recover and/or cope)
Implementation	Does the assessment include implementation steps? Implementation steps include next steps, plans for future research, road map for planning mitigation strategies.	Assessment	1 (yes), 0 (no)	Assessment outlines a clear implementation roadmap by guiding staff to integrate the Climate Impacts Tool into capital-project planning and educational outreach while informing the next Climate Action Plan update. It details a set of prioritized mitigation measures (updated stormwater standards, expanded green infrastructure incentives) and maps each high-priority strategy into the master plans to ensure systematic execution
Mitigation	Does the assessment include mitigation strategies? Mitigation strategies refer to specific policy changes, projects, and actions to mitigate risks identified by the vulnerability assessment. (These could include relocation, rezoning, shoreline armoring, nature-based solutions, etc)	Assessment	1 (yes), 0 (no)	Assessment outlines mitigation strategies (updating land-use and stormwater regulations, implementing green infrastructure projects and incentive programs, enhancing data collection and system mapping, forging public/private partnerships for habitat-supportive easements, developing regional stormwater parks) to systematically reduce identified climate risks
Retreat	Does the assessment consider managed retreat as an option?	Assessment	1 (yes), 0 (no)	Mentions potential for relocating homes due to bluff erosion, relocating RV park infrastructure to upland areas due to high vulnerability of the site, and road migration as a way to maintain access

Category: Exposure				
Code	**Description**	**Data Source**	**Code Options**	**Examples**
Index Type	Does the study include a vulnerability index? If so, which one?	Assessment		Assessment includes a custom vulnerability index in the form of a matrix developed using the EPA's Being

				Prepared for Climate Change framework. It evaluates each identified risk based on likelihood, consequence, spatial extent, time horizon, and habitat type. Risks are then rated as high, medium, or low vulnerability. This approach was used to assess 74 risks to the Tillamook Estuaries Partnership's goals, providing a structured method for prioritizing climate-related threats
Exposure	Does the assessment identify and define exposure? (Severity of adverse outcomes from a hazard event)	Assessment	1 (yes), 0 (no)	Assessment defines exposure as the degree to which a coastal facility is subject to coastal hazards (inundation and erosion) and the nature of those hazards. It is measured using a GIS-based approach that overlays facility locations with hazard polygons representing SLR scenarios and recurrence intervals. Exposure scores are assigned based on the likelihood and severity of a facility's interaction with these hazards. Higher scores given to facilities currently or frequently impacted. Exposure reflects the presence and intensity of hazard events. Severity of outcomes is addressed separately under sensitivity.
Risk	Does the assessment identify and define risk? (Probability of a hazard event in a given timeframe or spatial extent) If the assessment includes probability of exceedance estimates, this counts as a quantification of risk.	Assessment		Assessment defines and considers risk in relation to the probability of sea level rise-driven hazard events occurring within a given timeframe. It assigns higher vulnerability rankings to locations where significant infrastructure, cultural resources, or habitats will be at risk under even minor sea level rise scenarios. Built infrastructure risk is determined by evaluating whether roads, homes, or other facilities would be cut off or significantly damaged under 0.4m and 1.5m sea level rise scenarios. Cultural resource risk is considered high where shoreline erosion will likely expose archaeological remains, midden deposits, or disrupt traditional ecological knowledge practices.
FEMA Community Rating System	Does the jurisdiction participate in the FEMA community rating system?	FEMA CRS Community List 2016	1 (yes), 0 (no)	Assessment notes that the county has achieved a class 5 rating under the CRS, which provides a 25% discount on flood insurance premiums for properties within Special Flood Hazard Areas (SFHAs)
Public Perception	percentage of adults worried about climate change in the county	Yale Climate Opinion Study	Percentage	59; 63%; 71%; 77%

Scenario	How many **SLR scenarios** are included? (Note which ones and if they consider the worst case.)	Assessment		Assessment includes 3 scenarios based on the research by Miller et al., 2018 and are used to project sea level changes by specific years (2050, 2070, 2100) and to guide the planning and mitigation strategies for the City of Langley. The inclusion of the "Unlikely" scenario provides insight into potential worst-case outcomes, crucial for planning resilient infrastructure and community responses to significant sea level rise. 1) Very Likely (95% probability): high-confidence scenario. 2) Likely (50% probability): medium-confidence scenario. 3) Unlikely (1% probability): low-confidence, worst-case scenario.
Timeline	What is the **timeline of the projections** used? How far into the future are effects modeled?	Assessment		2030-2100; 2025-2140; 2050-2200
Uncertainty	Did the assessment **acknowledge** or address uncertainties?	Assessment	1 (yes), 0 (no)	Assessment openly addresses uncertainty by noting data limitations in its community-scale GHG inventory, presenting SLR projections as probability ranges rather than single forecasts, acknowledging that its risk strategy is qualitative where detailed data are lacking, and building flexibility into its emissions tracking tool by allowing staff to adjust key assumptions.

Category: Geologic and Ecological Hazards				
Code	**Description**	**Data Source**	**Code Options**	**Examples**
Shoreline Change	Does the assessment include measures of **shoreline change including erosion, accretion** or other changes to the landscape on the marine edge?	Assessment	1 (yes), 0 (no)	Assessment addresses shoreline change primarily through discussions of erosion, storm surge, and habitat loss along the marine edge. It highlights local examples of shoreline retreat and identifies climate stressors (SLR, increased wave height, coastal flooding) as key drivers of erosion and habitat inundation. It does not provide quantitative measures of shoreline change, but it emphasizes the risks these changes pose to infrastructure, estuarine habitats, and conservation efforts

Sea Level Rise	Does the assessment include measures of **sea level rise and flooding including wave height, runup, changes to tidal range, and storm surge**? (Record notes on how sea level rise is assessed? Change in water height, or are storm effects included? How many scenarios are assessed?)	Assessment	1 (yes), 0 (no)	Assessment measures SLR as increases in MHHW using 83% probability projections for 2050 and 2100, with mapped increases of +1 foot. It also includes extreme flood scenarios by layering SWL projections in sheltered areas and TWL projections (limited wave runup) for exposed coastlines. Scenarios include +4 feet (2050) and +5 feet (2100) in Willapa Bay, and +10 feet along the outer coast. However, the assessment does not model wave height, tidal range changes, or hydrodynamic processes, relying instead on a simplified bathtub approach
Saltwater Intrusion	Does the assessment include impacts of **saltwater intrusion/inflow/inundation** of freshwater surface and groundwaters? (Saltwater intrusion, also salinization, is the movement of seawater into freshwater. This can occur in rivers, estuaries, lagoons, and lakes, but is most common with coastal freshwater aquifers. Often exacerbated by sea level rise, changing water table dynamics, and excessive groundwater pumping in coastal areas. Can contaminate ecosystems, wells, and drinking water supplies.)	Assessment	1 (yes), 0 (no)	Assessment briefly acknowledges the potential for rising water tables to impair septic systems near the coast, it does not discuss or model the broader issue of saltwater moving into coastal aquifers, wells, or surface waters.
Subsidence	Does the assessment include impacts associated with anthropogenic **subsidence or subduction** due to seismic activity? (Sinking land, also known as subsidence, leads to higher sea level and increased flood risk. Subsidence can be caused by groundwater pumping, excessive soil tilling, sediment compaction, and mining.)	Assessment	1 (yes), 0 (no)	Assessment acknowledges tectonic subsidence from subduction zone earthquakes as a significant factor that could abruptly increase relative sea level rise by 2 to 6 feet. It notes that such subsidence would raise flood risk considerably but is not included in the sea level rise projections or vulnerability mapping. The report also states that areas experiencing subsidence will face increased exposure to inundation. Assessment not address or assess anthropogenic subsidence, such as that caused by groundwater extraction or soil compaction
Tsunami	Does the assessment include tsunami risks? (A tsunami occurs when a sudden displacement of water is caused by an event such as an earthquake.)	Assessment	1 (yes), 0 (no)	Assessment outlines tsunami risks from a potential Cascadia Subduction Zone earthquake. No historical tsunamis have affected the county, but modeling shows possible inundation up to 11.5 feet in low-lying areas like the Nisqually Delta. Around 161 people and $94 million in structures lie within the inundation

				zone. The overall risk is low, but Thurston County may serve as a key evacuation and recovery hub
Land Use	Does the assessment differentiate risks based on **land use type**? (e.g., residential, commercial, industrial (developed), agricultural, natural, wetlands, etc.)	Assessment	1 (yes), 0 (no)	Assessment evaluates risks associated with various land use types, including residential, commercial, industrial, agricultural, natural areas, and wetlands. The assessment's County-Wide Exposure Analysis and detailed studies of Sandy Point and Birch Bay consider how different land uses are affected by flooding and sea-level rise.Assessment discusses potential for implementing overlay zones to regulate land use in areas susceptible to coastal hazards and SLR, suggesting the development of coastal flood and erosion maps to guide land use regulations within these zones.
Precipitation	Does the assessment include risks of **changing** precipitation patterns? (e.g., atmospheric rivers, changes in snowfall, or increased runoff)	Assessment	1 (yes), 0 (no)	Assessment identifies changing precipitation patterns as a significant climate risk, including increased frequency and intensity of atmospheric rivers, a shift from snow to rain in winter, and earlier snowmelt. These changes are projected to alter hydrologic regimes by increasing winter runoff, advancing peak streamflow timing, and reducing snowpack, particularly in the Cascade Range. Such shifts are expected to exacerbate flood hazards, enhance sediment transport, and affect streamflow-dependent ecosystems and infrastructure across the Tribe's region.
Compound	Does VA include **compound risks**? (Increased danger when multiple hazards (e.g., rising sea levels & increased wildfire, coastal flooding and atmospheric rivers) coincide to cause more severe impacts than they otherwise would individually)	Assessment	1 (yes), 0 (no)	Assessment explicitly addresses compound risks, recognizing that interacting climate hazards (SLR, storm surge, atmospheric rivers) can produce more severe impacts than individual events alone. It includes a dedicated section on cascading and compounding impacts (p. 93), using case studies like the 2022 King Tide Flood and 2021 heat dome to illustrate how simultaneous hazards disrupt infrastructure, emergency response, and public health. It also acknowledges the limitations of traditional risk models that treat hazards independently and emphasizes the need to anticipate climate surprises resulting from complex system interdependencies.

Category: Socioeconomic Indicators				
Code	**Description**	**Data Source**	**Code Options**	**Examples**
Environmental Justice	Does the assessment include environmental justice?	Assessment	1 (yes), 0 (no)	Assessment integrates key principles of environmental justice by centering Indigenous sovereignty and the protection of culturally significant sites within territory. It evaluates risks to built and natural infrastructure, archaeological resources, traditional use areas, and social infrastructure critical to cultural continuity. It acknowledges the disproportionate impacts of SLR on Indigenous communities and emphasizes adaptation strategies such as shoreline monitoring, cultural site protection, and archaeological repatriation.
Frontline Communities	Does the assessment assess risks to frontline communities? (Frontline communities are those that are most affected by climate change and environmental hazards. Often communities of color, low income, or Indigenous communities.)	Assessment	1 (yes), 0 (no)	Assessment assesses risks to frontline communities by identifying Tribes, economically disadvantaged populations, and those dependent on natural resource economies as especially vulnerable to climate impacts. It includes actions to evaluate how climate change affects different neighborhoods and to incorporate equity metrics into the assessment of climate initiatives, ensuring that the needs of disproportionately affected communities are addressed in planning and implementation.
Tribal Consultation	Did assessment include tribal consultation, participation, or other tribal priorities?	Assessment	1 (yes), 0 (no)	Assessment incorporates Tribal consultation and prioritizes Indigenous perspectives by engaging Tribal representatives in its community outreach process. It acknowledges the county as the ancestral homeland of the Muckleshoot, Puyallup, Nisqually, and Squaxin Island Tribes, and emphasizes that climate change poses significant threats to treaty-protected resources and cultural practices (impacts to salmon and shellfish populations, access to cultural sites, availability of traditional plant and animal species). Assessment integrates data from Tribal sources and recognizes the importance of protecting biocultural resources and upholding treaty rights in climate resilience planning.

Social	Does the assessment include social vulnerability? (e.g., measures of race, age, income, education, housing occupancy, home values, access to the internet, access to social services, other inequities)	Assessment	1 (yes), 0 (no)	Assessment integrates a social vulnerability framework, incorporating indicators such as race, age, income, education, housing tenure, and language proficiency to identify populations with heightened sensitivity and limited adaptive capacity to climate impacts. It uses the county's equity index, the WA State Env. Health Disparities Map, and the PSRC Displacement Risk Index to spatially analyze inequities in exposure and resilience.
Infrastructure	Does the assessment include general risks to infrastructure/built environment?	Assessment	1 (yes), 0 (no)	Assessment provides a detailed analysis of risks to infrastructure. It evaluates a wide range of park facilities (buildings, roads, utilities, marine structures, shoreline protection) using a custom vulnerability index based on exposure to coastal hazards and sensitivity to impacts. Facilities are scored to prioritize adaptation needs, and findings highlight which infrastructure types are most at risk. The report also includes adaptation strategies tailored to specific asset types, such as retreat, redesign, or protection, to guide future planning and resilience efforts
Built Assets	Does the assessment list or analyze risks to specific built environment assets? (This can include roads, homes, and other infrastructure)	Assessment	1 (yes), 0 (no)	Assessment analyzes risks to specific built environment assets through detailed vulnerability tables for Sandy Point and Birch Bay, listing individual roads, stormwater systems, sewer infrastructure, buildings, and other facilities. Each asset is evaluated for exposure, sensitivity, and adaptive capacity under compound flooding scenarios. A county-wide exposure analysis also identifies broader infrastructure risks, supporting informed planning and prioritization of adaptation strategies.
Value Assets	Does the assessment list or analyze risks to specific culturally valued assets? (This can include tribal assets, community gathering places, sense of place, cultural values, etc.)	Assessment	1 (yes), 0 (no)	Assessment identifies significant risks to culturally valued assets, including traditional food sources (salmon, shellfish, cedar), community gathering spaces, and ancestral lands. It emphasizes how SLR, habitat loss, and ecological disruption threaten physical resources, cultural identity, traditional knowledge, and sense of place.
Ecological Assets	Does the assessment list or analyze risks to specific environmental or ecological	Assessment	1 (yes), 0 (no)	Assessment includes analysis of risks to env. and eco. assets, discussing how beaches and wetlands, while generally tolerant of changing water levels,

	assets? (e.g., recreation areas, habitats, and species)			may lose their ability to migrate inland in areas constrained by development or armoring. It also notes potential impacts to habitats for forage fish and juvenile salmon, particularly where shoreline roads prevent natural habitat shifts. It references the need for habitat evolution/migration modeling to better understand future impacts and guide adaptation strategies. Recreation areas, such as parks and beach access points, are also identified as potentially affected by flooding and erosion
Shoreline Access	Does the assessment specifically assess impacts to shoreline access points?	Assessment	1 (yes), 0 (no)	Assessment identifies threats to infrastructure that supports public beach access (roads, parking areas, and access paths) and notes that many of these are vulnerable to erosion, SLR, and storm surges. It highlights the potential loss of public access points due to coastal hazards.
Economic	Does the assessment include economic loss estimates? (e.g., lost tourism revenue, lost extractive industry, lost jobs, property damages)	Assessment	1 (yes), 0 (no)	Assessment identifies significant projected economic losses for Washington State under a business-as-usual emissions scenario, estimating annual costs of $6.5 billion by 2040 and $12.9 billion by 2080. Losses include damages from SLR, extreme precipitation, and wildfires; decreased agricultural output and salmon populations; and rising health costs linked to air pollution and vector-borne disease. Infrastructure impacts, such as disrupted transportation networks and compromised stormwater systems, are also expected. Inefficient energy use and continued reliance on coal-fired electricity contribute further to the economic burden, with projected costs reaching $2,750 per household annually by 2080.
Ecosystems	Does the assessment assess loss of coastal ecosystems and habitat?	Assessment	1 (yes), 0 (no)	Assessment evaluates the vulnerability of tidal marshes in the Pacific Northwest to sea level rise, emphasizing projected habitat loss due to inundation and sediment deficits. It presents scenarios showing significant reductions in tidal marsh extent by 2100 under various sea level rise projections and highlights implications for ecological functions and species reliant on these habitats.
Endangered Species	Does the assessment include risks to listed endangered or threatened species?	Assessment	1 (yes), 0 (no)	Assessment identifies climate-related risks to federally listed species, including Chinook salmon

				and steelhead, due to increasing stream temperatures, altered hydrologic regimes, declining snowpack, and heightened sedimentation. These stressors degrade critical spawning and rearing habitats, threatening species recovery efforts. Additionally, Southern Resident killer whales face indirect risks from reduced Chinook availability, underscoring the cascading ecological impacts of climate change on interconnected endangered species
Primary Focus	What is the primary focus of the assessment?	Assessment	0 (economic), 1 (social), 2 (eco)	Assessment primarily focuses on social vulnerability; it emphasizes the risks faced by low-income, elderly, and disabled populations through a Community Vulnerability Index and aligns with environmental justice principles and the HEAL Act. It also analyzes environmental risks to ecosystems like salmon habitats and urban forests, and includes an Economic Vulnerability Index, economic impacts are addressed more generally and without quantitative loss estimates

Category: Readability				
Code	**Description**	**Data Source**	**Code Options**	**Examples**
Accessibility	Is the assessment a pdf or a website?	Assessment	1 (pdf), 0 (web)	PDF or webpage storymap
Public Access	Is the assessment publicly available?	Assessment	1 (yes), 0 (no)	Yes
Length	How many pages is the assessment?	Assessment		35; 67; 132; 676
Visuals	Does the assessment use visuals such as images, graphs, or maps to convey information?	Assessment	1 (yes), 0 (no)	Assessment provides color-coded maps illustrating geographic distribution of hazards (e.g., flood-prone areas and urban heat islands), graphs and charts depicting climate projections and population vulnerabilities, and infographics that summarize key findings. The assessment also features photographs to ground the analysis in lived experience and tables to compare vulnerabilities across sectors and populations.

Public Outreach	Does the assessment describe public outreach that was conducted as part of the assessment or define ways to communicate SLR vulnerabilities to the community? Describe	Assessment		Assessment includes public outreach conducted through interviews, consultations, and a workshop with local experts, stakeholders, and estuaries partnership staff. It follows the EPA's guidance to maintain communication and consultation throughout the process. While it does not detail communication strategies for sea level rise specifically, it references a separate report by Climate Access focused on outreach and messaging for local communities and stakeholders
Science Communication	Does science inform the development of the assessment? Is the underlying science associated with causes and components of sea level rise explained? Do they help the reader understand causes or consequences of the nature of SLR, spatial extent, etc? Must go beyond an analysis of expected climate changes	Assessment		Assessment describes key drivers such as thermal expansion, melting ice sheets, and vertical land motion, and explains how these factors contribute to spatial variability in SLR across the coast. It uses probabilistic scenarios and region-specific hazard modeling to assess inundation and erosion. Scientific concepts like compound flooding, drift cells, and shoreline erosion are illustrated with diagrams and explained in accessible language.

Appendix II: Catalog of Assessments

Washington State

Type	Government / Entity	Title	Year	Author(s)
City	Bainbridge Island	City of Bainbridge Island SLR Vulnerability and Risk Assessment	2024	Environmental Science Associates (ESA)
City	Burien	Burien Climate Vulnerability Assessment, Policies, and Strategies	2023	Berk Consulting, Inc., Makers Architecture and Urban Design, Perteet Inc., Cascadia Consulting Group, Inc.
City	Coupeville	Coupeville Sea Level Rise Vulnerability Assessment	2023	Peak Sustainability Group, Coastal Geologic Services, Inc.
City	Edmonds	City of Edmonds Climate Action Plan	2023	City of Edmonds
City	Everett	City of Everett Climate Action Plan	2020	Cascadia Consulting Group
County	Island County	Sea Level Rise and Coastal Flood Risk Assessment: Island, County Washington	2016	Island County, WA Sea Grant, Adaptation International
Tribe	Jamestown S’Klallam Tribe	Jamestown S’Klallam Tribe Climate Vulnerability Assessment and Adaptation Plan	2013	Jamestown S’Klallam Tribe, Adaptation International
County	Jefferson County	Jefferson County Sea Level Rise Study	2023	Environmental Science Associates (ESA)
County	King County	Sea Level Rise Impacts on King County Assets	2021	King County Department of Natural Resources and Parks
City	Langley	City of Langley Shoreline Master Plan Sea Level Rise Assessment	2021	Langley Department of Community Planning and Building
Tribe	Lower Elwha Klallam Tribe	Lower Elwha Klallam Tribe Climate Change Vulnerability Assessment	2022	Natural Systems Design, Adaptation International, WA Sea Grant
City	Marysville	Climate Change Vulnerability Assessment City of Marysville	2023	Cascadia Consulting Group

Tribe	Nooksack Indian Tribe	Nooksack Indian Tribe Natural Resources Climate Change Vulnerability Assessment	2017	University of Washington Climate Impacts Group
City	Olympia	Olympia Sea Level Response Plan	2019	City of Olympia, LOTT Clean Water Alliance, Port of Olympia, AECOM
Region	Olympic Peninsula	Climate Change Preparedness Plan for the North Olympic Peninsula	2015	North Olympic Peninsula Resource Conservation and Development Council, Adaptation International, WA Sea Grant
County	Pacific County	Sea Level Risk Assessment Pacific County	2023	DCG Watershed, Inc.
County	Pierce County	Pierce County Climate Vulnerability Assessment	2023	Env. Science Associates (ESA), BERK Consulting
Port	Port of Bellingham	Port of Bellingham Coastal Vulnerability Assessment	2023	EA Science, Engineering, Science, and Technology, Inc.
City	Port Townsend	The City of Port Townsend Sea Level Rise and Coastal Flooding Risk Assessment	2022	Cascadia Consulting Group
Region	Puget Sound National Estuary Program	Prioritize Sea Level Rise Exposure and Habitat Sensitivity Across Puget Sound	2022	Coastal Geologic Services, Inc.
Tribe	Puyallup Tribe of Indians	Climate Change Impact Assessment and Adaptation Options	2016	Cascadia Consulting Group
Tribe	Samish Indian Nation	Samish Indian Nation Sea Level Rise Vulnerability Assessment	2020	Samish Indian Nation Department of Natural Resources
County	San Juan County	San Juan County Sea Level Rise Vulnerability and Risk Assessment	2024	Environmental Science Associates (ESA)
City	Seattle	Climate Vulnerability Assessment City of Seattle	2023	Cascadia Consulting Group
City	Shoreline	Climate Impacts & Resiliency Study, City of Shoreline	2020	Cascadia Consulting Group, Herrera Environmental Consultants

Region	Skagit Delta	Assessing Tidal Marsh Vulnerability to Sea Level Rise in the Skagit Delta	2016	Skagit River Systems Cooperative, U.S. Geological Survey
County	Snohomish County	Snohomish County Climate Change Vulnerability and Risk Assessment Report	2023	Parametrix, BERK Consulting
City	Tacoma	Tacoma Tideflats Climate Vulnerability Assessment	2021	Moffatt & Nichol
County	Thurston County	Hazards Mitigation Plan for the Thurston Region	2023	Thurston Regional Planning Council, Tetra Tech
Region	WSDOT	Climate Impacts Vulnerability Assessment	2011	Washington State Department of Transportation
Region	Washington State Parks	Coastal Facilities Vulnerability Assessment: Implications for Sea Level Rise and Coastal Hazard Planning	2023	Herrera Environmental Consultants, Inc.
City	Westport	Westport Climate Resilience Prioritization Toolkit	2022	UW Evans School Master's Students, New England Environmental Finance Center
County	Whatcom County	Whatcom County Compound Flood Vulnerability Assessment	2023	Environmental Science Associates (ESA)

Oregon

Type	Government / Entity	Title	Year	Author(s)
County	Coos County & Cities of Coos Bay & North Bend	Coos Bay Climate Hazards Adaptation Plan	2022	University of Oregon Institute for Policy Research and Engagement
County	Lane County	Climate Change Vulnerability Assessment for Lane County, Oregon	2022	Lane County Climate Equity and Resilience Taskforce, GEOS Institute
County	Tillamook County	Tillamook Estuaries and Watersheds Climate Change Vulnerability Assessment	2018	GEOS Institute

British Columbia

Type	Government / Entity	Title	Year	Author(s)
Regional District	Capital Regional District	Capital Regional District Coastal Sea Level Rise Risk Assessment	2015	AECOM
Regional District	Sunshine Coast Regional District	Sunshine Coast Regional District Climate Change Vulnerability & Risk Assessment Report	2022	Sunshine Coast Regional District
City	Vancouver	City of Vancouver Coastal Flood Risk Assessment	2014	Northwest Hydraulic Consultants, Ltd.

Appendix III: Client-Provided Background Information & Grey Literature

Organization / Author(s)	Title	Year
Adapting to Rising Tides Program	How to Design Your Project	2025
Tyndall Centre for Climate Change Research / Nick Brooks	Vulnerability, risk, and adaptation: A conceptual framework	2003
California Coastal Commission	California Coastal Commission Statewide Sea Level Rise Vulnerability Synthesis	2016
UC Santa Barbara Ocean & Coastal Policy Center	California Coastal Adaptation Planning Inventory	2022
Charlotte Dohrn, Climate Resilience Planner, WA Dept. of Ecology	Sea Level Rise Vulnerability Assessments: Overview and Discussion	2025
WA Dept. of Ecology	Interim Climate Resilience Planning Guidance for Shoreline Master Programs	2024
IPCC AR6 WG2	Summary for Policymakers	2022
Oregon Climate Change Research Institute, Adaptation International	Tribal Climate Adaptation Guidebook	
NOAA Office for Coastal Management	Coastal Adaptation Planning Guide	2023
American Society of Adaptation Professionals	ASAP Living Guide to the Principles of Climate Change Adaptation	2019
American Society of Adaptation Professionals	Knowledge and Competencies Framework for Climate Change Adaptation and Climate Resilience Professionals	2019

Appendix IV: Interview Questions

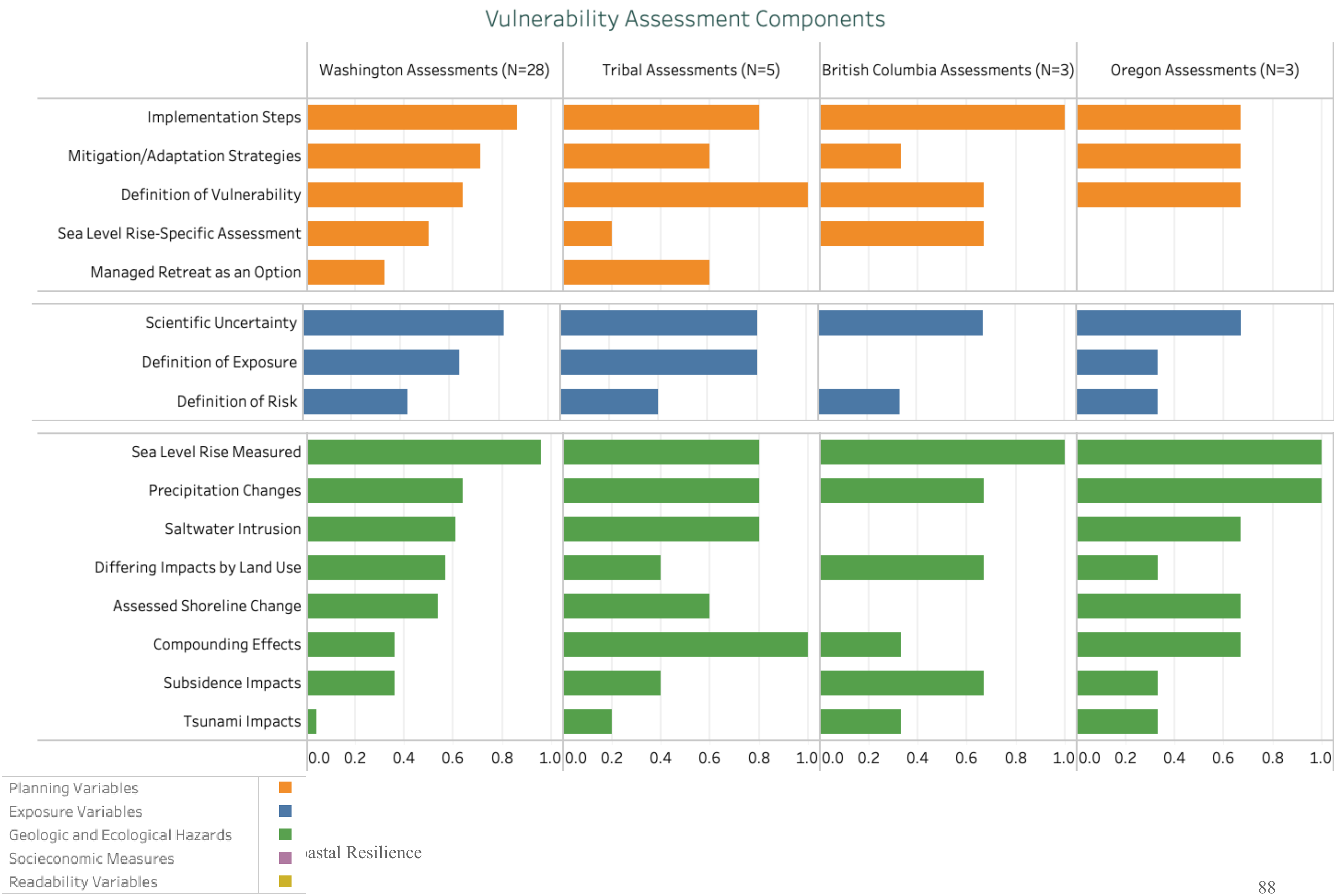
Municipality/Agency with Completed Assessments

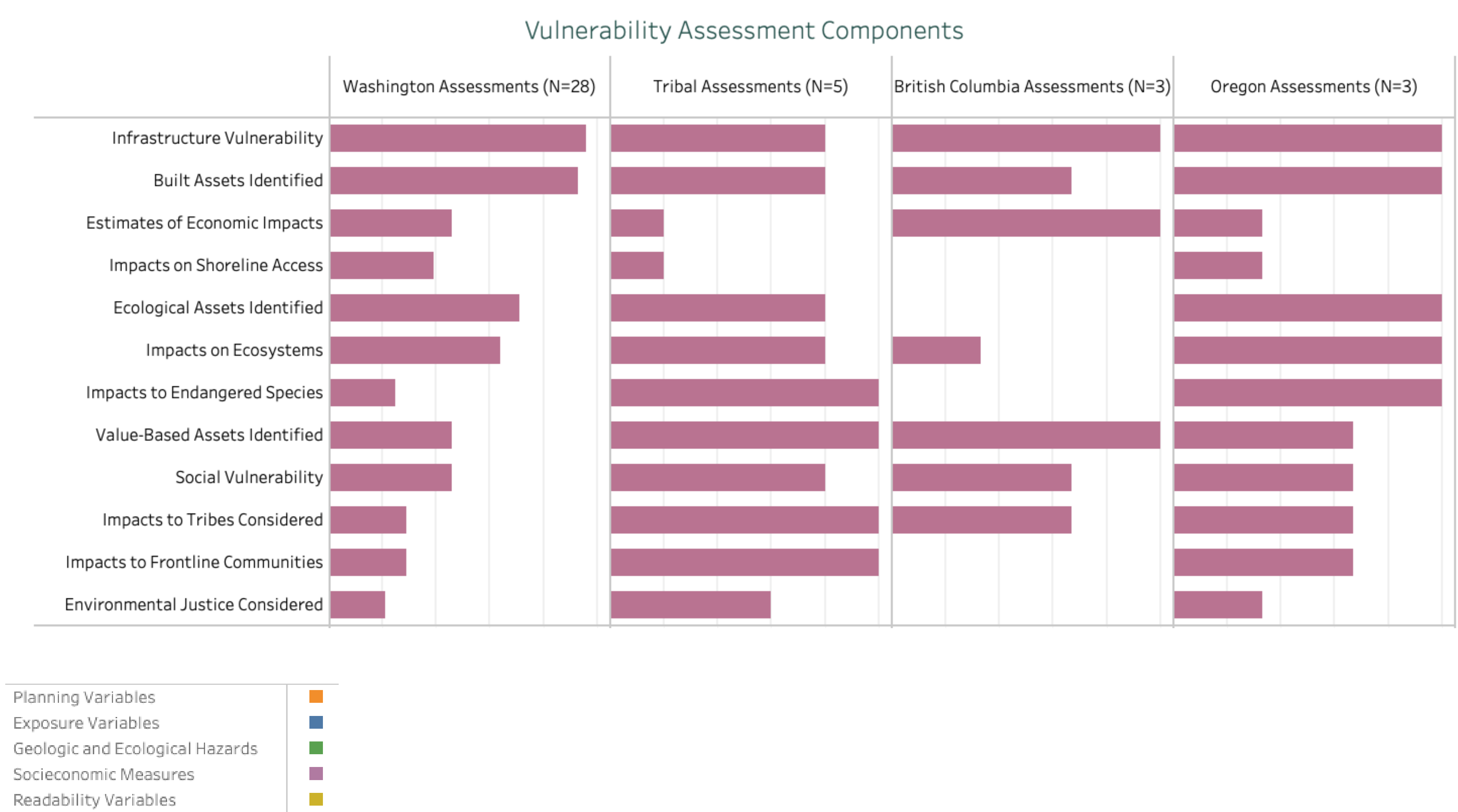
1. What is your role at [city or county]?
2. How have you been involved in developing and/or conducting vulnerability assessments?
3. Does the [city or county's] assessment include implementation steps for adaptation strategies?
4. How has the [city or county's] assessment been integrated into the Shoreline Management Program?
5. How do you incorporate local knowledge into sea level rise planning?
6. How does the [city or county's] assessment incorporate and address environmental justice? If not incorporated, please describe why.
7. How has the [city or county's] assessment been used to inform local planning practices?
8. What barriers to developing a vulnerability assessment exist for the [city or county]?
9. What barriers did the [city or county] overcome?
10. What would enable the [city or county] to begin or better plan for future vulnerabilities?
11. How was the [city or county's] assessment limited by funding restraints?
12. How was the [city or county's] assessment limited by knowledge and/or data gaps?
13. How was the [city or county's] assessment limited by staff capacity?

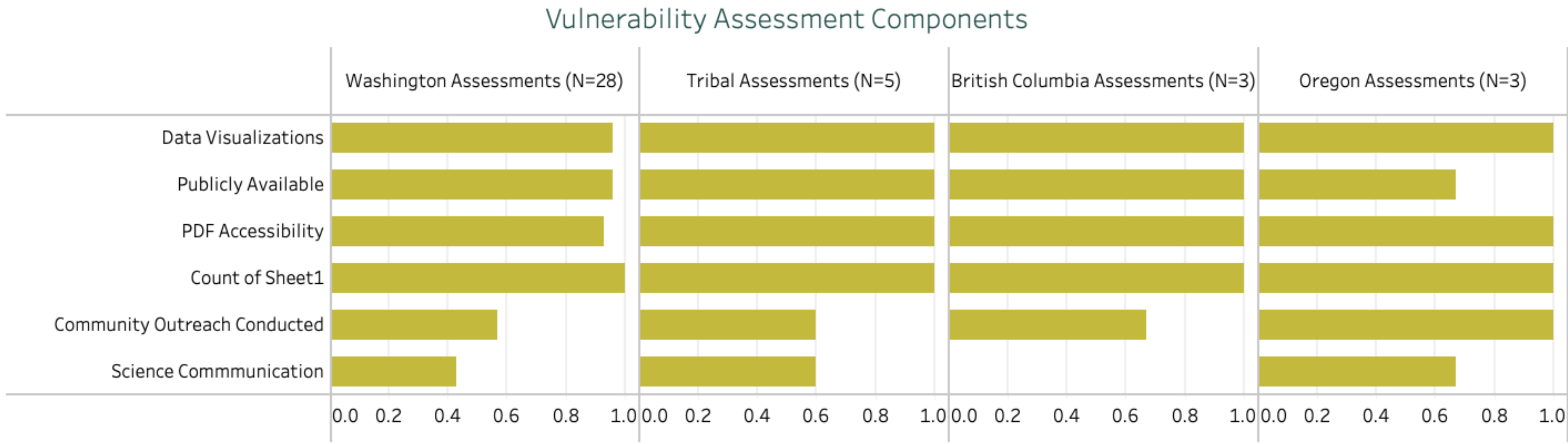
Municipality/Agency without Assessments or with Incomplete Assessments

1. What is your role at the [city or county]?
2. Has the [city or county] initiated a sea level rise vulnerability assessment? If so, describe the current status and steps taken to get started.
3. What coastal hazards related to sea level rise are most concerning for your community?
4. Does the [city or county] incorporate local knowledge into sea level rise planning?
5. Does the [city or county] incorporate and address environmental justice into sea level rise planning?
6. Are there specific populations, assets, or infrastructure you believe are especially vulnerable to sea level rise in your jurisdiction?
7. What barriers have prevented [city or county] from conducting a vulnerability assessment?
8. What kind of resources (technical assistance, funding, data tools) would make it more feasible for your jurisdiction to complete an sea level rise assessment?
9. Are there knowledge or data gaps that need to be addressed before conducting an assessment? If yes, describe.
10. How would you describe the current level of internal capacity to undertake climate resilience planning?
11. Are you aware of any best practices or examples from other communities that would be helpful to replicate or learn from?

Appendix V: All Component Comparison


Vulnerability Assessment Components
Washington Assessments (N=28)
Tribal Assessments (N=5)
British Columbia Assessments (N=3)
Oregon Assessments (N=3)
Implementation Steps
Mitigation/Adaptation Strategies
Definition of Vulnerability
Sea Level Rise-Specific Assessment
Managed Retreat as an Option
Scientific Uncertainty
Definition of Exposure
Definition of Risk
Sea Level Rise Measured
Precipitation Changes
Saltwater Intrusion
Differing Impacts by Land Use
Assessed Shoreline Change
Compounding Effects
Subsidence Impacts
Tsunami Impacts
0.0 0.2 0.4 0.6 0.8 1.0
0.0 0.2 0.4 0.6 0.8 1.0
0.0 0.2 0.4 0.6 0.8 1.0
0.0 0.2 0.4 0.6 0.8 1.0
Planning Variables
Exposure Variables
Geologic and Ecological Hazards
Socieconomic Measures
Readability Variables


Vulnerability Assessment Components
Washington Assessments (N=28)
Tribal Assessments (N=5)
British Columbia Assessments (N=3)
Oregon Assessments (N=3)
Infrastructure Vulnerability
Built Assets Identified
Estimates of Economic Impacts
Impacts on Shoreline Access
Ecological Assets Identified
Impacts on Ecosystems
Impacts to Endangered Species
Value-Based Assets Identified
Social Vulnerability
Impacts to Tribes Considered
Impacts to Frontline Communities
Environmental Justice Considered
Planning Variables
Exposure Variables
Geologic and Ecological Hazards
Socieconomic Measures
Readability Variables


Vulnerability Assessment Components
Washington Assessments (N=28)
Tribal Assessments (N=5)
British Columbia Assessments (N=3)
Oregon Assessments (N=3)
Data Visualizations
Publicly Available
PDF Accessibility
Count of Sheet1
Community Outreach Conducted
Science Commmunication
0.0
0.2
0.4
0.6
0.8
1.0