

## Appendix A

# Addressing Sea Level Rise in Shoreline Master Programs

## Introduction

One widely accepted consequence of a changing climate is an increase in the rate of sea level rise (IPCC, 2007). Although there is scientific uncertainty about the precise amount of sea level rise by the end of this century, projections for Puget Sound range from 14 to 54 inches relative to year 2000 (Mauger et al, 2015). Rates could be higher or lower, depending on the rate of vertical land motion locally.

Sea level rise will have significant effects on both human and natural systems (Shipman, 2009), increasing the risk from coastal hazards and the pressure on shoreline resources. These effects present a serious challenge to shoreline planning and coastal management.



Figure A – 1: An unusually high tide in January 2010 caused water to spill over the seawall at Alki Beach in Seattle. Even modestly higher sea levels will cause the frequency of events such as this to increase, along with the potential for associated damage. (Photo by Hugh Shipman.)

The Shoreline Management Act (SMA) and the Shoreline Master Program (SMP) Guidelines contain no requirements for SMPs to address climate change or sea level rise. However, they require local jurisdictions to take into account scientific and technical information pertinent to shoreline management issues. The Guidelines require local governments use “the most current, accurate and complete scientific and technical information available” [WAC 173-26-201(2)(a)]. The Guidelines also encourage local governments to consult Ecology’s guidance for applicable new information on emerging topics such as sea level rise [WAC 173-26-090(1)].

Some local governments have already incorporated sea level rise considerations into their Comprehensive SMP updates. Ecology recommends local governments include SMPs into their broader planning framework for addressing rising seas. This SMP Handbook appendix presents background information on projected sea level rise in Washington State, potential impacts of sea level rise, and suggestions for local governments to address sea level rise in their SMP updates.

This appendix addresses only sea level rise, but climate change may also result in other environmental impacts that will affect shorelines and the ecosystems they support. Some anticipated effects of climate change include:

- Altered hydrological cycles that may affect flooding and water resources.
- Increased sediment in glacier-fed rivers that may result in increased aggradation, flooding and channel movement.
- Increased landslides, which may result in more sediment and wood inputs to streams, potentially increasing flooding, channel movement, and transport of wood to hazardous positions (Beason and Kennard, 2006).
- Changes in ocean chemistry driven by higher levels of atmospheric carbon dioxide that will impact marine ecosystems.
- The potential for invasive species to increase their ranges as the ocean warms.

More information about the anticipated effects of climate change on Washington’s coasts, as well as a number of other sectors such as water resources, endangered species, and human health, can be found at the University of Washington’s [Climate Impacts Group](#) website and Ecology’s [Climate Change](#) web pages.

## Projected sea level rise in Washington State

When planning for sea level rise, it is helpful to understand the potential extent of sea level rise and the effects this will likely have on coastal areas in Washington State. Distinct regions of the Washington coast will experience different levels of sea level rise due to vertical land movement in those regions. This movement is driven primarily by tectonic forces such as those responsible for the formation of the Olympic Mountains. Western Washington is located on the edge of the North American continental plate, and as the Juan de Fuca oceanic plate moves underneath it a gradual uplift in the northwestern part of the state is produced.

*Sea Level Rise in the Coastal Waters of Washington State*, co-authored by the University of Washington’s Climate Impacts Group and Ecology, explains these variations and provides high,

**Table A-1: Sea level rise projections**

	<b>Puget Sound</b>	<b>NW Olympic Peninsula</b>	<b>Central &amp; Southern Outer Coast</b>
<b>2050</b>	Low 3" Medium 6" High 22"	Low -5" Medium 0" High 14"	Low 1" Medium 5" High 18"
<b>2100</b>	Low 6" Medium 13" High 50"	Low -9" Medium 2" High 35"	Low 2" Medium 11" High 43"

Table A-1: Sea level change projections for 2050 and 2100 in Washington's coastal regions. Note that the low projections for the NW Olympic Peninsula are negative values due to vertical land movement. Adapted From: *Sea Level Rise in the Coastal Waters of Washington State*.

medium, and low sea level change projection scenarios for three broad regions of Washington's coasts. Table A- summarizes the report's projections.

## Environmental impacts of sea level rise

Sea level rise will have a variety of impacts on Washington state coastal areas. Increased sea level will allow high tides to reach farther into low-lying areas and higher against flood control structures such as dikes and tide gates. Coastal flooding will persist longer and will be more difficult to drain due to higher sea level. Higher water levels will result in faster rates of erosion on beaches and coastal bluffs (Shipman, 2009).

An important consequence of higher sea level will be increased frequency of high-tide flooding and the potential for storm damage. A rise in sea level of one foot might lead to as much as a ten-fold increase in the frequency of any particular flood event. This means that events that currently occur only once every decade may become annual events, increasing the severity and frequency of flood and storm-related damages to coastal development (Shipman, 2009). These events could pose an increasing threat to coastal development and infrastructure.

The prospect of more flooding, erosion, and storm damage may lead communities and property owners to seek to build seawalls, dikes, and tidal barriers. The construction and placement of these structures will have a direct and immediate impact on natural shoreline environments. These structures will also lead to the progressive loss of beach and marsh habitat as those areas are squeezed between the rising sea and a more intensively engineered shoreline. Predicted

decreases in size or transitions in tidal marshes, salt marshes, and tidal flats will affect the species these habitats support. It is predicted that while some species may be able to locate alternate habitats or food sources, others will not (Glick, 2007).

Shellfish, forage fish, shorebirds, and salmon are among those identified as examples of species at risk (Glick, 2007). Sea level rise will also lead to other changes in coastal ecosystems, such as shifting of stream mouths and tidal inlets, reconfigured estuaries and wetlands, and more frequently disturbed riparian zones.

## **Coastal landforms and impacts**

The impacts of rising sea level will differ substantially between locations, based on landform (bluff, estuary, spit), the character of development (urban, agricultural, rural), and the capacity of the shoreline to adjust to changing conditions. Below is a list of areas particularly vulnerable or resilient to the impacts of sea level rise and anticipated impacts to these areas.

- Low-lying areas – river deltas, historically filled lands, spits and barrier beaches. These areas will experience more frequent and more persistent flooding and damage to infrastructure. In developed low lying areas, there will be an increased need for more robust dikes and drainage systems if the existing uses are to continue.
- Coastal bluffs. In general, sea level rise will result in higher erosion rates and greater instability of landslide prone areas. Demand for seawalls is expected to increase, as will the adverse effects of such structures on shoreline habitat and on erosion patterns on nearby beaches.
- Spits and other barrier beaches. These low-lying features will be subject to increased flooding during storms and high tides and in many situations will experience more rapid erosion.
- Tidal environments – beaches and tide flats. These areas are expected to experience additional inundation and either be lost or undergo conversion to another habitat type.
- Marshy shorelines found in small estuaries and river deltas. These areas will be subject to increased flooding and increased erosion. Loss of salt marsh and related habitats may be significant in systems constrained by surrounding development.
- Developed shorelines – ports, marinas, roads and railroads, urban and residential shorelines. Typically, these are heavily armored with seawalls and riprap. Their level of vulnerability may be largely a function of their elevation. Developed shorelines of all types in low-lying areas will be vulnerable to losses from erosion, storms, or flooding.
- Rocky shorelines. Fairly resilient to modest increases in sea level.

## **Addressing sea level rise in SMPs**

In the absence of advance planning, human reaction to sea level rise will likely be driven by our incremental responses to damaging storms and floods, not by our desire to reduce the long-term impacts of a gradually rising sea. SMPs are among many planning measures that local governments may need to deploy to assure the wise development of coastal areas and the protection of public resources as sea level increases. Many potential problems associated with

sea level rise will intensify existing management challenges such as development in flood prone areas, construction of shoreline armoring, protection of beaches and salt marshes, and siting a variety of shoreline uses.

Local governments that are evaluating potential ways to adapt to or prepare for rising sea levels should consider how these plans may be reflected in their SMPs. The guidance below identifies different areas of SMP planning where sea level rise can be considered.

## **Shoreline jurisdiction**

As sea level rises, the ordinary high water mark (OHWM) will move inland as well, altering the line from which shoreline jurisdiction is measured. Although the SMA does not specifically mention shifts in shoreline jurisdiction due to sea level rise, it does identify that the OHWM is located “as it may naturally change” [RCW 90.58.030 (2)(c)]. The location of the OHWM often changes, even without sea level rise, due to erosion, accretion, or shoreline modification.

Local governments may respond to new sea level rise projections or local data by updating shoreline jurisdiction maps. In some cases, this may call for adjustments to environment designations, policies, or regulations.

## **Public participation**

Sea level rise has the potential to generate considerable interest among shoreline property owners and other interested citizens and organizations and can be incorporated into public participation activities. Local information could be presented to the public along with options for addressing sea level rise in the SMP update. Sea level rise adaptation should be part of most if not all public participation activities.

For example, the City of Olympia presented technical information to the public about the anticipated impacts of climate change to hydrologic regimes and area sea levels. The meeting closed with a presentation by city staff about the SMP update process and their plans to incorporate climate change adaptation into the update process. Providing this information during the early stages of the SMP allows local governments to alert interested parties about potential ways the draft SMP can address sea level rise or other climate change adaptation elements.

## **Shoreline inventory and characterization**

The inventory and characterization provides an opportunity to identify shoreline areas that will be particularly vulnerable or resilient to rising sea level. One fairly straightforward way to characterize vulnerability is to classify the shoreline according to coastal landform. Landform types include coastal bluffs, marshes, rocky shorelines, and armored shorelines. Each type of landform will experience different long-term effects of rising sea level.

Once coastal landforms have been mapped, local governments can determine the level of vulnerability to sea level rise for the extent of the shoreline. This type of characterization does not require a precise estimate of the rate of sea level rise.

Some urban jurisdictions have used high resolution coastal topographic data to develop maps of low-lying areas subject to inundation by higher water levels. Such maps can be used to illustrate the consequences of different sea level scenarios and storm and tide combinations. This type of approach can be useful for identifying coastal areas subject to increased flooding and to help direct appropriate future land use or development types to appropriate locations. These maps and projections may be particularly helpful for guiding engineering questions, such as structural elevations, drainage requirements, construction techniques, and hazard mitigation measures.

Some local governments have already prepared a detailed analysis of sea level rise predictions and potential effects. These local products have been produced by academic researchers, independent consultants, and local government public works departments or other agencies responsible for stormwater or wastewater infrastructure. For an example of a detailed local analysis, view the City of Olympia's "[Sea Level Rise](#)" web page. Olympia's vulnerability assessment illustrates why a comprehensive assessment is needed – the areas subject to flooding at all projected sea level rates extend far beyond shoreline jurisdiction.

### **Public access**

As part of the shoreline inventory and characterization, local governments identify existing physical and visual public access sites and opportunities. During this process, sites where sea level rise may pose a threat to public access can be identified. For example:

- Parks in low lying areas may be subject to increased flooding.
- Public tidelands may become inaccessible if shoreline armoring prevents the tidelands from migrating inland.
- Publicly accessible spits may be lost to erosion.
- Visual access sites along coastal bluffs may become hazardous due to landslides.

Local governments also may be able to identify opportunities to preserve or replace those sites. For example, consider expanding the upland reach of coastal parks to accommodate shifting shorelines in low lying areas, or planning for new public access sites in areas less vulnerable to flooding or erosion. Additional potential techniques for ensuring that public access is provided in the future include:

- Building public docks and piers that are more resilient to sea level rise.
- Removing shoreline armoring or moving it inland to allow the public to walk on the beach even as the sea level rises.
- Locating boardwalks or trails above the elevation of projected sea level rise.

### **Shoreline use analysis**

In conducting the shoreline use analysis, take into account the effects of rising sea levels on existing and projected development. The use analysis estimates the future demand for shoreline space and identifies projected development trends and potential use conflicts. The objective is to ensure that shorelines are available for uses that are unique to or dependent on the shoreline. The

use analysis can be helpful in identifying developed and undeveloped areas that may be vulnerable to sea level rise.

Where possible, use analyses should build upon the inventory and characterization to project areas where future infrastructure will be necessary to address sea level rise impacts. This may include corridors along developed shorelines for new or expanded flood control structures, elevation of structures, or locations for pump stations and larger storm drainage facilities. These types of efforts will require detailed planning beyond the SMP and large public and private investments.

## **Goals, policies, and regulations**

SMP goals, policies, and regulations can address sea level rise adaptation. These sea level rise provisions can help to create awareness of the impacts of sea level rise and other climate change effects among shoreline property owners and development proponents. Enhanced awareness of impacts may in turn result in project designs that incorporate measures to decrease the risk of flooding and storm damage to these developments as sea level rises.

Sea level rise adaptation can be incorporated into several different sections of the goals, policies, and regulations. Examples of goals and policies addressing sea level rise are provided below.

### **General policies**

The King County SMP contains the following explanation and policies related to climate change.

#### **F. Preparing for Climate Change**

As discussed in Chapter 4 of the King County Comprehensive Plan, climate change has the potential for significant impacts on shorelines and shoreline habitats. Sea-level rise and storm surges may place at risk infrastructure, habitat restoration projects, and other development, including residential development. New development and maintenance or replacement of existing development should take into account the potential for harm that may result from sea-level rise (VII, Environment Protection Policies).

S-650 King County shall ensure that new projects for and major maintenance or replacement of utilities, roads, and other public infrastructure consider the impacts of sea-level rise in the location, design, and operation of the projects.

S-651 Habitat protection and restoration projects in the shoreline jurisdiction shall consider implications of sea-level rise and other climate change impacts to promote resiliency of habitats and species.

## **Shoreline use policies**

Consideration of sea level rise can be incorporated into shoreline use goals and policies. Jefferson County's SMP contains the following shoreline use goal:

10. Encourage all use and development to address potential adverse effects of global climate change and sea level rise (Article 3, 7. Shoreline Use, B. Goals).

The City of Seattle's SMP call for strategies to balance shoreline uses with protection of ecological functions.

LUG52 Address and minimize the impacts of sea level rise on the shoreline environment with strategies that also protect shoreline ecological functions, allow water-dependent uses and provide public access (Shoreline protection and restoration).

Island County's SMP incorporates sea level rise in the shoreline use element.

- II.D. 6. Sea level rise and increased frequency and magnitude of extreme storm events as a result of climate change should be taken into account when considering and evaluating shoreline uses.

## **Flood hazard policies**

SMPs must address flood hazards and seek to reduce the damage caused by floods. Goals and policies addressing flood hazards are another opportunity to address sea level rise and the increased threat from flooding that will accompany it. The Jefferson County SMP provides an example of a policy designed to reduce future flooding from sea level rise:

2. Proponents of a development on no-bank or low bank marine shorelines are encouraged to locate the bottom of a structure's foundation higher than the level of expected future sea-level rise (Article 6, 4. Shoreline Setbacks and Height, A. Policies).

The City of Burien's SMP includes a sea level rise policy in the Flood Prevention element. This policy articulates the intention to incorporate updated sea level rise predictions in their future SMP updates and alter policies as needed:

Pol. FLD 4 - Monitor sea level rise and accordingly adjust development standards and building setbacks to minimize flooding potential (Chapter II, 20.20.045, Flood Prevention and Minimization Element).

Island County's flood hazard policies call for future sea level projections to be incorporated into site-specific development review to minimize flood damage.

- V.C.6. When reviewing projects that could be affected by sea level rise, adjust development standards such as building setbacks or elevation as necessary to minimize potential damage from flooding.

## **Shoreline modifications policies**

As sea level rises, some property owners may wish to install shoreline armoring. If there are particular sections of the shoreline where armoring is not appropriate and is prohibited, state this clearly in the shoreline modifications policies and regulations. Incorporate planning for sea level rise into permit conditions for shoreline modifications. Policies and regulations should recognize the role that shoreline erosion and accretion play in preserving ecological functions, and to encourage softer armoring techniques where appropriate.

King County's SMP encourages developers to consider sea level rise in projects along marine shorelines. This policy will help to prevent future unnecessary shoreline armoring.

S-778 King County should notify all prospective developers of new development along Vashon and Maury Islands that their development may be impacted by sea-level rise and should encourage all such new development to be set back a sufficient distance to avoid the need for shoreline protection during the expected life of the development (VIII, Shoreline Use and Shoreline Modification).

## **Development regulations**

Shoreline buffers and setbacks are one way to ensure that future development is not threatened by sea level rise. Buffers and setbacks along with restrictive building standards near low lying or erosion prone shorelines will help reduce flooding and the need for shoreline armoring.

In intensely developed urbanized settings, the likely policy response to sea level rise will be to defend the existing developed area. In these locations, it might be appropriate to establish a setback to accommodate a future dike or elevated sea wall. The level of investment and intended life of the improvement are important considerations in addressing long-term sea level rise issues.

## **Environment designations**

Environment designations should reflect the results of the inventory and characterization and take into account existing shoreline development. Undeveloped areas that are designated as "natural" will remain less developed and therefore less likely to contain infrastructure that may be damaged by storms or flooding exacerbated by sea level rise. These shorelines may also prove better able to shift and change in response to sea level rise than those in more highly developed areas. Environment designation regulations can also state where and what types of armoring are or are not acceptable.

## **Restoration plan**

Developing a restoration plan provides an excellent opportunity to implement sea level rise adaptation measures. Restoration plans may identify restoration actions that improve resilience to sea level rise. Projects that protect and restore natural geomorphic processes such as erosion, sediment transport, tidal flooding, and marsh accretion are likely to be more successful than



Figure A -2: A high tide event at a restored beach in the City of Seattle. Restoration projects such as this pocket beach should be selected and designed in ways that accommodate rising sea levels. Photo by Hugh Shipman.

those that target the creation of historic habitat configurations that may be inundated or sustain increased flood damage due to sea level rise.

In addition, sea level rise predictions should be factored into restoration planning, perhaps including larger inland areas in restoration or habitat protection efforts to accommodate increasing inundation and to allow the shoreline to shift farther inland.

Jefferson County recognized the potential need to alter the restoration plan as the effects of sea level rise become more evident. The “Obstacles and Challenges” section of County’s Restoration Plan includes the following text:

Climate change: Rising temperatures and sea levels have the potential to dramatically alter Jefferson County’s shoreline jurisdiction, processes, and functions over time. Depending on the scale of change and time period over which changes occur, restoration priorities could shift substantially within a relatively short period of time.

Language such as this would allow local governments to alter their restoration plan over time to address emerging impacts from climate change.

## References and resources

- Beason, S. R. and P.M. Kennard, 2006, *Environmental and Ecological Implications of Aggradation in Braided Rivers at Mount Rainier National Park*, Pages 52–53 in J. Selleck, editor. Natural Resource Year in Review—2006. Publication D-1859. National Park Service, Denver, Colorado.
- Climate Impacts Group, 2009, *The Washington Climate Change Impacts Assessment*, M. McGuire Elsner, J. Littell, and L. Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, WA.
- Glick, P., J. Clough, J., and B. Nunley (2007) *Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon*. National Wildlife Federation, Reston, VA.
- Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover. 2015. *State of Knowledge: Climate Change in Puget Sound*. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D
- IPCC, 2007: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)], Cambridge University Press, Cambridge, UK and New York, NY, USA, 996 pp.
- Mote, P., A. Petersen, S. Reeder, H. Shipman, and L. Whitely Binder, 2008, *Sea Level Rise in the Coastal Waters of Washington State*, University of Washington Climate Impacts Group and the Washington Department of Ecology, University of Washington, Seattle, WA, 11 pp.
- Shipman, H., 2009 (in press), *The Response of the Salish Sea to Rising Sea Level: A Geomorphic Perspective*, Puget Sound Georgia Basin Ecosystem Conference, February 8-11, 2009, Seattle, WA, 8pp.