

Siuslaw Estuary Partnership

*An Integrated Multiple Objective Approach
To Watershed Protection and Restoration*

Climate Change Report



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Siuslaw Estuary Partnership
Interdisciplinary Team

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Executive Summary: Key Issues and Potential Strategies

This report identifies the following as key issues for the Siuslaw Estuary Partnership:

- Issue #1: Groundwater/Drinking Water Quality and Quantity
- Issue #2: Surface Water Quality and Quantity and
Fish and Wildlife Habitat
- Issue #3: Wetlands and Riparian Areas
- Issue #4: Public Infrastructure and Long-range Planning
- Issue #5: Research Needs and Action Planning

Each of these issues is summarized below with a list of Potential Strategies to address them. Please see Chapter III of this report for a more in-depth discussion of these issues and strategies.

The statements below and throughout this report are excerpted verbatim from the sources cited in the footnotes, except where additional text is added to provide context or further explanation; this explanatory text is shown in [brackets]. Please take note of the applicable geographic references in the findings. Only findings that are relevant to the Florence area are presented, whether the statements apply worldwide, to the U.S., the Northwest Coast, the Pacific Northwest, Oregon, or to the Florence area. Likewise, references to events and conditions that are not relevant to the Florence area, for example trends in snowpack levels in the Cascades and trends in the Great Lakes, are omitted from the report. Findings for the geographic area closest to Florence are provided whenever possible. Please see Appendix C for Common Acronyms.

Issue #1: Groundwater/Drinking Water Quality and Quantity

- Sea-level rise resulting from climate change could affect groundwater in coastal regions in Oregon. Sea level is an important boundary condition affecting water levels in the extensive sand-dune aquifers along the coast such as found near Coos Bay, Reedsport, Florence, and in Clatsop County (Rinella et al., 1980; Brown and Newcomb, 1963; Hampton, 1963; Frank, 1970). A rise in mean sea level will result in a comparable rise in water-table elevations in sand dune aquifers as well as alluvial aquifers hydraulically connected to tidally influenced estuaries. This could result in water-level rises and expansion of groundwater-fed lakes and wetlands in sand dune areas and other low-lying coastal settings. Sea level rise will exacerbate any existing saltwater intrusion problems, as will warming-related increases in groundwater pumping in coastal areas [warmer temperatures lead to increased municipal and irrigation pumping and thus lower groundwater levels, and may increase risk of saltwater intrusion.]¹

¹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 104.

- The North Florence Dunal Aquifer is an EPA-designated sole source aquifer. “Possible sources of aquifer contamination include fuel storage tank failure, accidental spills of hazardous material, septic tank effluent, storm runoff, pesticides, and chemical fertilizers.”²
- [In Oregon,] changes in the seasonal distribution of precipitation will affect seasonal water table fluctuations and groundwater discharge to springs and streams... Increased winter precipitation, therefore, may not result in increased groundwater recharge.³
- [In Oregon,] aquifer systems in alluvial deposits that are in direct hydraulic connection to streams can be affected by the lowering of stream and lake stages resulting from diminished flows. Lower stream and lake stages can result in lower water levels in adjacent aquifers.⁴
- Shallow groundwater aquifers that exchange water with streams are likely to be the most sensitive part of the groundwater system to climate change.⁵
- [In the U.S.,] sea-level rise is expected to increase saltwater intrusion into coastal freshwater aquifers, making some unusable without desalination. Increased evaporation or reduced recharge into coastal aquifers exacerbates saltwater intrusion.⁶
- The recent work of Weiss and Overpeck, University of Arizona, has centered on the analysis of digital elevation models (DEMs) to help delineate low-elevation coastal areas. The mapping tool they developed allows for estimation of inundation areas resulting from one, two, and three meters [about three feet to ten feet] of sea level rise. The abstract cited in Chapter IV of this report explains in detail the limitations of the tool, particularly as it applies to the Pacific coast. The tool shows areas of potential inundation from about a three foot rise in sea level in the Florence area to be estimated to occur around the estuary, the North Fork, and northern portions of the Dunal Aquifer.⁷

² See, *U.S. Environmental Protection Agency Resource Document: For Consideration of the North Florence Dunal Aquifer as a Sole Source Aquifer*, August 1987; EPA 910/9-87-167.

³ *Ibid.*, p. 102-103.

⁴ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 103.

⁵ *Ibid.*

⁶ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; *Regional Climate Change Impacts: Northwest*, p. 135-138 and *Coasts*, p. 47.

⁷ Weiss, J.L., J.T. Overpeck, and B. Strauss. 2011. Implications of Recent Sea Level Rise Science for Low-elevation Areas in Coastal Cities of the Conterminous U.S.A. Climatic Change DOI 10.1007/s10584-011-0024-x.

Potential Strategies:

1. Continue to Monitor Groundwater Quality and Quantity.
2. Conduct a study to evaluate sustainable wellfield production rates from current and future wells that can be achieved without degrading water quality as a result of sea water intrusion from the ocean or the Siuslaw estuary.
3. Develop a sustainable source of drinking water.
4. Prepare an Aquifer Protection Plan that meets State requirements for a Source Water Protection Plan.

Issue #2: Surface Water Quality and Quantity and Fish and Wildlife Habitat

- [The] interface between streams and groundwater is an important site for pollution removal by microorganisms. Their activity will change in response to increased temperature and increased or decreased streamflow as climate changes, and this will affect water quality.⁸
- [In Oregon,] water quality is also likely to be impacted with rising air temperature and seasonal shifts in flow availability... There is little research on long term trends in water temperature in undisturbed watersheds; sites with long term data are rare. Sediment and phosphorus loads, which are a detriment to water quality, are expected to increase in winter as winter flow is projected to rise. It will be important for water resource managers statewide to include considerations for climate change in future planning.⁹
- [In the lower Siuslaw River Watershed,] the lack of snowpack, steep terrain, low gradient streams, shallow soils, relative dryness in the east, and absence of a true "headwaters" combine to create a naturally "flashy" stream system, with unpredictable and highly variable flows. The first heavy rains of autumn are only partly absorbed into the dry, porous sandstone soils. Streams rise quickly once the rains return, then dry to a trickle by mid summer. The land has limited ability to store water, and what natural ability it does have has been compromised by logging, road construction, valley clearing, wetland draining, removal of logjams and resulting stream downcutting. This has important effects on the aquatic system.¹⁰

⁸ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; Regional Climate Change Impacts: Northwest, p. 135-138 and Coasts, p. 47.

⁹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, *Executive Summary*.

¹⁰ The discussion of the Siuslaw Basin was excerpted from: "A Watershed Assessment for the Siuslaw Basin, Executive Summary," Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

- Portions of the Siuslaw River are classified as "Water Quality Limited," under the Clean Water Act, for temperature, dissolved oxygen, fecal coliform, and sediment; and the Oregon Department of Environmental Quality has included the Siuslaw on the State's 303(d) list of Impaired Water Bodies.¹¹
- Early cannery records indicate that the Siuslaw was second only to the Columbia River in numbers of coho. The average coho numbers from 1889–1896 were 209,000 fish (Booker). This compares to an average of just over 3,000 in the years 1990–1995.¹²
- [In Oregon,] climate change has the potential to influence water quality conditions in estuaries primarily through changes in precipitation in the watersheds, land cover in the watersheds, temperature (atmospheric, riverine, and oceanic), coastal upwelling, wind stress, and RSL [relative sea level] rise.¹³
- The Siuslaw is a “drowned river mouth estuary.” Drowned river mouth estuaries formed as ancient river valleys were flooded by the rising sea at the end of the last ice age. Today, these estuaries have relatively large coastal watersheds. They are freshwater (river) dominated during winter, when runoff is high, but saltwater dominated in the dry summer and fall.¹⁴
- Through various mechanisms, climate change has the potential to influence dissolved oxygen levels in estuaries; although to what extent this may happen is unknown at this time.¹⁵
- Since present water temperatures in the upriver portions of estuaries often exceed temperature criterion for protection of salmon and trout, there is the potential for climate change to result in an increase in temperature impairments, and thus to potentially affect the distribution and survival of cold water species.¹⁶
- Susceptibility of estuarine wetlands to SLR [sea level rise] will vary among estuaries due to difference in RSL [relative sea level] rise rate along the coast as well as due

¹¹ Oregon Department of Environmental Quality.

¹² The discussion of the Siuslaw Basin was excerpted from: “A Watershed Assessment for the Siuslaw Basin, Executive Summary,” Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

¹³ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 239.

¹⁴ *Watershed Stewardship: A Learning Guide, Supplement, Chapter 10: Estuarine Science, Management, and Restoration*, Oregon State University Extension Service, Revised 2003, p. II-10.11.

¹⁵ *Ibid.*

¹⁶ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 245.

to differences in the extent and type of wetlands within in each estuary (Lee and Brown, 2009).¹⁷

- The recent work of Weiss and Overpeck, University of Arizona, has centered on the analysis of digital elevation models (DEMs) to help delineate low-elevation coastal areas. The mapping tool they developed allows for estimation of inundation areas resulting from one, two, and three meters [about three feet to ten feet] of sea level rise. The abstract cited in Chapter IV of this report explains in detail the limitations of the tool, particularly as it applies to the Pacific Northwest. The tool shows areas of potential inundation from about a three foot rise in sea level in the Florence area to be estimated to occur around the estuary, the North Fork, and northern portions of the Dunal Aquifer.¹⁸
- [In the Siuslaw estuary,] as a result of filling and diking between 1870 and 1970, there was a loss of an estimated 29% of total intertidal wetland area (from 4,316 acres in 1870 to 3,060 acres in 1970) and an estimated 63% loss of vegetated intertidal wetland area (from 2,002 acres in 1870 to 746 acres in 1970).¹⁹
- Sea level rise (SLR) [in Oregon] will result in additional wetland loss with a concomitant loss of associated ecosystem services, such as habitat for juvenile salmon and waterfowl, flood control, maintenance of estuarine water quality, and carbon sequestration (Zedler and Kercher, 2005).²⁰

Potential Strategies:

1. Continue to Monitor Surface Water Quality and Quantity (Munsel Creek, Ackerley Creek, Clear Lake, and the Siuslaw estuary) and retain gauging stations in the creeks for monitoring flow.
2. Prepare an Aquifer Protection Plan that includes strategies to protect and improve surface water quality and fish and wildlife habitat.
3. Maintain forest buffers for shade along banks and change operations on managed rivers to reduce present warming.

¹⁷ *Oregon Climate Change Assessment Report*, Oregon Climate Change Research Institute, December 2010; Chapter 6 - Impacts of climate change on Oregon's coasts and estuaries, p. 214

¹⁸ Weiss, J.L., J.T. Overpeck, and B. Strauss. 2011. Implications of Recent Sea Level Rise Science for Low-elevation Areas in Coastal Cities of the Conterminous U.S.A. Climatic Change DOI 10.1007/s10584-011-0024-x.

¹⁹ *Watershed Stewardship: A Learning Guide, Supplement, Chapter 10: Estuarine Science, Management, and Restoration*, Oregon State University Extension Service, Revised 2003, p. II-10.11.

²⁰ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p.236.

4. Continue to actively seek ways to partner with federal, state, and local agencies and non-profits to achieve the water quality and quantity and fish and wildlife habitat protections and improvements articulated in the Guiding Principles.

Issue #3: Wetlands and Riparian Areas

- [In the U.S.,] in general, rising sea levels will inundate coastal wetlands and other low-lying lands and intensify erosion and flooding as new areas are exposed to storm surges, waves, currents, and tides. Inundation, erosion, and flooding will threaten human health, coastal property, and infrastructure as well as coastal ecosystems, especially those that cannot migrate inland or are sediment-starved. Any changes to these ecosystems will, in turn, affect the biological, ecological, and physical services they provide.²¹
- [In Oregon,] a rise in mean sea level will result in a comparable rise in water-table elevations in sand dune aquifers as well as alluvial aquifers hydraulically connected to tidally influenced estuaries. This could result in water-level rises and expansion of groundwater-fed lakes and wetlands in sand dune areas and other low-lying coastal settings.²²

Potential Strategies:

1. Plan and implement wetland and riparian area protection measures that incorporate possible climate change impacts.
2. Build ecological resilience into a local wetland and riparian protection program.
3. Link wetland protection to drinking water and storm water management.

Issue #4: Public Infrastructure and Long-range Planning

- [In Oregon,] coastal infrastructure will come under increased risk to damage and inundation under a changing climate with impacted sectors including transportation and navigation, coastal engineering structures (seawalls, riprap, jetties etc.) and flood control and prevention structures, water supply and waste/storm water systems, and recreation, travel and hospitality.²³
- [In Oregon,] increasing sea levels, wave heights and storm surges will increase coastal erosion and likely increase damage to private property and infrastructure

²¹ *National Oceanic and Atmospheric Administration (NOAA). 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers.* NOAA Office of Ocean and Coastal Resource Management, p. 12.

²² *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 104

²³ *Ibid*, p. 210.

situated on coastal shorelands. Coastal erosion, and the common response to reduce shoreland erosion, can lead to long-term loss of natural buffering functions of beaches and dunes.²⁴

- Municipal wastewater systems are also threatened by sea level rise and storm surges associated with climate change. As in most communities, the Florence wastewater plant is located in a low lying area, which poses an increased risk in the event of storm surges. Adaption planning can provide the basis for scenario planning to help the City and its partners minimize risks to these critical drinking water sources.
- The potential exists for the Pacific Northwest to experience an influx of “climate refugees,” i.e., people relocating here from regions disproportionately affected by global climate change. This could increase the demands on social services, public municipalities, and local infrastructure and services.

Potential Strategies:

1. Integrate consideration of potential Climate Change impacts into infrastructure planning, including evaluation of possible scenarios.

Issue #5: Research Needs and Action Planning

- Uncertainty is still high in projecting future changes in runoff, water quality, and urban water demand in Oregon.²⁵
- [In Oregon,] there is little research on long term trends in water temperature in undisturbed watersheds; sites with long term data are rare... It will be important for water resource managers statewide to include considerations for climate change in future planning.²⁶
- More research is needed to determine to what extent climate change may influence estuarine water temperatures [in Oregon]. Since estuarine water temperatures are closely coupled to upwelling dynamics, improvement is needed in models which are used to predict changes in upwelling.²⁷
- Like water quality, research on the impacts of climate change on groundwater has been minimal.²⁸

²⁴ *Oregon Climate Change Adaptation Framework*, State of Oregon, December 2010; p. ix.

²⁵ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 70.

²⁶ *Ibid*, *Executive Summary*.

²⁷ *Ibid*, p. 245.

²⁸ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; *Regional Climate Change Impacts: Northwest*, p. 135-138 and *Coasts*, p. 47.

- Through various mechanisms, climate change has the potential to influence dissolved oxygen levels in estuaries; although to what extent this may happen is unknown at this time.²⁹
- The National Oceanic and Atmospheric Administration (NOAA) has a presence in many communities along the Oregon coast, although it is not currently active in studying climate change impacts on the Florence area or the Siuslaw estuary. The Oregon Coastal Atlas, Oregon State University, recognizes that all estuaries in Oregon are unique: "Each of Oregon's estuaries is a unique ecosystem influenced by many variables - watershed size, geology, and land use; river gradient; the estuary's shape and size; and annual patterns of precipitation, river runoff, solar heat input, ocean tides, and fresh water-salt water mixing."

Potential Strategies:

1. Partner with DEQ, NFS, USGS, BLM, and NOAA to seek funding for and install weather stations from the crest to the beach.
2. Conduct modeling to track historic patterns and predict future conditions.
3. Based on the results of the above research projects, prioritize actions to monitor indicators of climate change, to respond to consequences of climate change (or even abnormal weather patterns and events), and implement "Potential Strategies."
4. Encourage state and federal agencies to focus research efforts on areas where there are currently large data gaps in OWEB Restoration Priorities for the Siuslaw.
5. The partners will work together to encourage NOAA to play an active role in studying the effects of climate change on the Florence area and the Siuslaw Estuary.

²⁹ Ibid.

I. Introduction

Do we know enough today about climate change and its impacts to develop adaptation strategies? All of the references cited in this report agree that long-term climate change impacts should be taken into consideration in shorter-term planning efforts and that adaptation strategies should be developed in the present to address the impacts. Leading scientists and policy makers in the U.S. and the world agree on this:

“Our understanding of the effects of climate change on the United States is still evolving. According to the U.S. Global Change Research Program, future changes in some phenomena are more difficult to project than others (e.g., changes in precipitation are more difficult to project than changes in temperature) (Karl et al. 2009). A lot remains uncertain and depends on the success of our efforts to mitigate climate change. Nevertheless, despite the uncertainties, current climate change projections are considered reliable enough to warrant and support adaptation planning (Karl et al. 2009).”³⁰

“The scientific literature provides strong evidence that global climate change is affecting the world’s water resources (USGCRP, 2009; UNEP, 2009; IPCC, 2007), including ocean acidification, global temperature rise, receding ice caps, melting glaciers, changing precipitation patterns, and sea level rise (IARU, 2009; USGCRP, 2009; USEPA, 2008; IPCC, 2007). These effects may result in more severe drought or flooding, varying stream flow patterns, rising sea levels along the coasts, and contamination of freshwater aquifers and coastal water bodies (IPCC, 2007)...Eleven of the 12 years between 1995 and 2006 rank among the warmest in the instrumental record of global temperature data (i.e., since 1850; IPCC, 2007).”³¹

Purpose of This Report

This report acknowledges that a great deal is yet to be discerned about the short term and long term effects of climate change and that there is on-going public debate as to the nature and causes of climate change. However, regardless of the nature and causes of climate change, the sources cited in this report contend that it is worthwhile to monitor our environment and strategize how best to adapt to the potential impacts of climate change. Furthermore, the potential strategies identified are relevant approaches to long-term livability and the resilience of our community.

³⁰ *National Oceanic and Atmospheric Administration (NOAA). 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers.* NOAA Office of Ocean and Coastal Resource Management, p. 7

³¹ *Emerging Issues: Improving Resilience Against the Effects of Climate Change,* Journal AWWA, November 2010, American Water Works Association.

The purpose of this report is to synthesize the most recent, reliable information on climate change, focusing on coastal areas and the Pacific Northwest, in order that this information can be factored into local strategies to meet the project goals to protect and improve water quality and fish and wildlife habitat.

Based on the sources cited throughout this report, there is ample evidence to support the conclusion that climate change is occurring. Throughout the world, air temperatures are changing, extreme weather patterns are observed, precipitation patterns are changing, and there are important changes in the oceans. In terms of mitigating climate change, reducing greenhouse gas emissions is the most common strategy. "Because of the influence of greenhouse gas emissions on climate change, humans may be able to reduce the rate and severity of climate change by reducing the rate at which carbon and other heat-trapping gases are added to the atmosphere."³²

However, this report is not about ways to mitigate, i.e., to slow or reduce the degree of, climate change. Climate change is expected to occur regardless of human efforts to reduce it. For this reason, federal and state government agencies are developing methods and approaches for adapting to the effects of climate change. This report attempts to capture the relevant highlights of these efforts; it cites the sources relied upon in order to allow the readers to avail themselves of a more in-depth examination of the subject. This report is not a scientific study; it does not contain original data. It is an attempt to locate, in one place, information on climate change relevant to the Siuslaw Estuary Partnership objectives. It may also serve to inform local leaders and staff in the Florence, Oregon area about potential considerations for operations under their control; and it provides suggestions for actions the City and its partners can take to prepare for the effects of climate change.

The Siuslaw Estuary Partnership and the Interdisciplinary Team³³

This "Climate Change Report" was prepared by the Siuslaw Estuary Partnership Interdisciplinary Team (see back of front cover for members who contributed to this report). The Siuslaw Estuary Partnership is a collaborative effort by the City of Florence and its federal, state, and local partners to protect and improve water quality and fish and wildlife habitat in the lower Siuslaw River Watershed. This three-year project is funded by project partners and the US Environmental Protection Agency.

Study Area boundaries include:

- Siuslaw River Estuary
- North Fork Siuslaw River

³² *National Oceanic and Atmospheric Administration (NOAA), 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers.* NOAA Office of Ocean and Coastal Resource Management, p. 1

³³ For detailed information about the Siuslaw Estuary Partnership and Project Partners, visit the web site: www.siuslawwaters.com.

- North Florence Sole Source Dunal Aquifer boundary, which includes Clear Lake, Munsel Creek, all wetlands, upland and riparian areas, and 100 acres adjacent to and outside the Urban Growth Boundary (UGB) that is trust land of the Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians

The land use measures in the project will focus on the portion of the Siuslaw River basin within the Florence city limits and Florence Urban Growth Boundary.

Guiding Principles

The Guiding Principles in Appendix A are the shared values, beliefs, and philosophy that will guide the environmental policies and practices of those government and non-government entities that choose to endorse them. The Principles are far-reaching and broad because they are intended to inspire rather than dictate and to guide specific policies and practices today and into the future. The Guiding Principles have been endorsed by the City of Florence and its partners as a means of facilitating agreement among them on future environmental policies and programs. Measurable Outcomes have been developed at the staff level as a tool to measure progress in meeting the goals reflected in the Guiding Principles.

Project Need

Florence is the watershed's only major urban center and its entire urban growth boundary (UGB) drains primarily to the Siuslaw estuary or the Pacific Ocean. Rapid infiltration rates into the sand cover, combined with a shallow water table, make the North Florence Sole Source Dunal Aquifer, and the hydrologically-connected wetlands, riparian, and estuarine system, highly susceptible to contamination from surface activity. These conditions, combined with the high habitat value of the area, and projected growth, make this "Integrated, Multiple Objective Approach to Watershed Protection and Restoration Project" a high priority project for the watershed.

Objectives, Phases and Products

Multiple objectives of the project are:

1. Use Collaboration and Scientific Investigation
2. Foster Public Education and Stewardship
3. Protect Water Quality and Quantity
4. Protect and Restore Wetlands and Riparian Areas
5. Protect and Restore Key Estuary Wetlands
6. Plan for Ecological Growth

The Project is being conducted in three Phases:

Phase I: October 1, 2009-September 30, 2010

Phase II: October 1, 2010-September 30, 2011

Phase III: October 1, 2011-September 30, 2012

Products are being prepared to meet each of the six objectives, above. Draft products are developed by the staff Teams and submitted for public and stakeholder review and comment.

Scientific Investigation and the Interdisciplinary Team

The Siuslaw Estuary Partnership is staffed by an Interdisciplinary Team representing 19 local, state, and federal agencies, including: the City of Florence; Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians; Lane County; Heceta Water District; Siuslaw Soil and Water Conservation District; Siuslaw Watershed Council; Oregon Department of Environmental Quality; Oregon Department of Fish and Wildlife; Oregon Department of Human Services, Drinking Water Program; Oregon Department of Land Conservation and Development; Oregon Department of State Lands; Oregon Department of Transportation; Oregon Department of Water Resources; National Oceanic and Atmospheric Administration, National Marine Fisheries Service; US Army Corps of Engineers; US Bureau of Land Management; US Geological Survey; USFS Siuslaw National Forest; and the US Environmental Protection Agency.

Team members work with consultant experts in fields of hydrogeology, chemical and biological analyses, wetlands, and stormwater systems. The Team meets frequently to provide technical and policy guidance on the specific Project Elements, processes, and products. The Interdisciplinary Team serves the project objective: Collaboration and Scientific Investigation because of the significant scientific background and expertise the Team brings to the Project.

Siuslaw Estuary

The Siuslaw Estuary, and the area surrounding it, is a place of transition from land to sea, and freshwater to saltwater. Home to 23 species of fish, almost 200 species of birds, and numerous species of marine mammals, this watershed is a significant natural area. It provides habitat to several endangered and threatened species and supports spawning runs of fall chinook, winter steelhead, chum, coho, and sea-run cutthroat trout.

“Early cannery records indicate that the Siuslaw was second only to the Columbia River in numbers of coho. The average coho numbers from 1889–1896 were 209,000 fish (Booker). This compares to an average of just over 3,000 in the years 1990–1995. Most of those who have followed the issue of salmon in the Siuslaw Basin over the years now agree that the combination of over-fishing, loss of habitat [due to logging, road building, and other activities], and poor ocean conditions in the 1980s and 1990s finally brought the entire situation to a head. The listing of coho as a threatened species in 1996 forced policy makers, resource managers, and local communities to try new approaches to aquatic conservation. The question now is not how many fish we can catch, but whether the aquatic ecosystem can recover to a point where salmon can again be a sustainable resource.”³⁴

³⁴ The discussion of the Siuslaw Basin was excerpted from: “A Watershed Assessment for the Siuslaw Basin, Executive Summary,” Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

“The essentials are clear. The basin ecosystem (including changes in the ocean) may have been changed to the point where it likely can no longer support historic, or even reasonably high numbers of most salmonid species. One exception appears to be the chinook, which has recovered to nearly historic levels. There are two likely explanations for this. First, the chinook may have a greater reliance on the estuary, rather than the river system, as essential rearing habitat. Second, chinook juveniles rely on stream reaches only during late winter and spring seasons, when there is plenty of cool water. Their life history demands may be met during this period.”³⁵

Portions of the Siuslaw are classified as "Water Quality Limited," under the Clean Water Act, for temperature, dissolved oxygen, fecal coliform, and sediment; and the Oregon Department of Environmental Quality has included the Siuslaw on the State's 303(d) list of Impaired Water Bodies.³⁶

North Florence Sole Source Aquifer and Clear Lake

The North Florence Dunal Aquifer is an EPA-designated sole source aquifer. This means that there is no other source of drinking water that can serve the existing population. This is the only EPA-designated sole source aquifer in the State of Oregon.³⁷

Groundwater in the aquifer was of good quality when the last comprehensive testing was done 23 years ago. The 1987 EPA Sole Source Aquifer Resource Document states, "Possible sources of aquifer contamination include fuel storage tank failure, accidental spills of hazardous material, septic tank effluent, storm runoff, pesticides, and chemical fertilizers." Today, pharmaceutical by-products are also an environmental threat. Clear Lake is a remarkably unpolluted, clean source of drinking water. On December 2, 1998, Heceta Water District, Lane County and the Oregon Environmental Quality Commission created the Clear Lake Watershed Protection Zone to protect the Clear Lake drinking water source well into the future.³⁸

³⁵ The discussion of the Siuslaw Basin was excerpted from: "A Watershed Assessment for the Siuslaw Basin, Executive Summary," Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

³⁶ Oregon Department of Environmental Quality.

³⁷ See, *U.S. Environmental Protection Agency Resource Document: For Consideration of the North Florence Dunal Aquifer as a Sole Source Aquifer*, August 1987; EPA 910/9-87-167.

³⁸ Heceta Water District staff.

II. What is Climate Change and How Will It Affect Us?

Climate change and its impacts have been studied at global, national, and state and regional levels and for both coastal and non-coastal environments. This Chapter summarizes available information on climate change from current, reliable sources; and focuses on climate change impacts on the Pacific Northwest coast, Oregon coast, and, to the extent possible, the Siuslaw Estuary.

What is Climate Change?

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as follows.

“Climate change is any change in climate over time, whether due to natural variability or as result of human activity.”³⁹

This definition is used in this report as well as in the reports referenced herein. Climate change is occurring. Most of the global warming in this century can be attributed to human activities. There are serious efforts underway across the globe to mitigate it. In addition to mitigation efforts, there are ways local governments can adapt to climate change in the interest of protecting human health and safety, water quality and quantity, and fish and wildlife habitat. Adaptation strategies are the focus of this report.

Trends and Projections

“Since 1900, the global average surface temperature of the Earth has risen by about 1.5°F (Karl et al. 2009). And, the 2000s decade (2000-09) was the warmest on record, with 9 of its 10 years (2001- 09) ranking among the top 10 warmest years on record (NOAA 2010a). Significantly, it was the global warming that occurred over the last 50 years that accounts for the majority of the increase, which is largely attributable to human activities (i.e., greenhouse gas emissions). In the United States, the average temperature has risen more than 2°F over the last 50 years (Karl et al. 2009).”⁴⁰

The following specific changes in climatic and related conditions [relevant to the Florence area] have been observed in the Northwest [Coast]:⁴¹

- The region experienced an average temperature increase of 1.5°F over the last century, with some areas having an average increase of up to 4°F.

³⁹ *National Oceanic and Atmospheric Administration (NOAA), 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers.* NOAA Office of Ocean and Coastal Resource Management, p. 6.

⁴⁰ *Ibid*, p. 7.

⁴¹ *Ibid*, p. 122.

- Higher cool season temperatures have resulted in more precipitation falling as rain rather than snow.
- A low oxygen [hypoxic or] dead zone [found increasingly closer to shore] off the coast of Washington and Oregon is believed to be driven by climate change.
- Ocean acidification is occurring along the Northwest coast.

The following climate-related changes [relevant to the Florence area] are projected for the Northwest [Coast]:⁴²

- Temperatures are projected to increase another 3 to 10°F by 2100.
- Increases in winter precipitation and decreases in summer precipitation are projected, though these projections are less certain than those for temperature.
- Heavier winter rainfall suggests an increase in saturated soils and, therefore, an increased number of landslides on coastal bluffs, which will be especially problematic in areas where there has been intensive development on unstable slopes. Sea level rise will exacerbate these conditions.
- Extreme high and low streamflows are also projected to change. Increased winter rainfall is expected to lead to more flooding in some areas, and low flows in the late summer are projected to decrease further.
- Sea level rise along vulnerable coastlines will result in increased erosion and the loss of land. Some areas in the Northwest are experiencing falling sea levels due to uplift.
- Salmon and other coldwater species will experience additional stresses as a result of rising water temperatures and declining summer streamflows.

Climate Change Impacts

The topic of climate change has been studied extensively by numerous agencies and organizations, including government, educational, and private research organizations; and at the global, national, regional, and state levels. There is very little climate change research specifically applicable to the Florence area or to the Siuslaw Estuary. For this reason, this report synthesizes available information that is relevant to the Florence area, and, where a specific connection can be made, it is included in this report.

The following are statements of interest to the Siuslaw Estuary Partnership. The detailed references and citations from the sources described in Chapter IV of this report provide guidance on interpreting these statements. This report is not a definitive authority on climate change impacts. It provides key findings from the most up-to-date sources available at the time it was prepared. The topic of climate change is highly complex and evolving; and some of the findings in this report are more certain than others, as noted in the wording of the findings. For an in-depth understanding, the reader is encouraged to read beyond this summary, starting with the recent report: *Oregon Climate Change*

⁴² *National Oceanic and Atmospheric Administration (NOAA), 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers.* NOAA Office of Ocean and Coastal Resource Management, p. 122.

Assessment Report, Oregon Climate Change Research Institute, December 2010, and particularly *Chapter 6: Impacts of climate change on Oregon's coasts and estuaries*.

A Note on Methodology

The statements below and throughout this report are excerpted verbatim from the sources cited in the footnotes, except where additional text is added to provide context or further explanation; this explanatory text is shown in [brackets]. Please take note of the applicable geographic references in the findings. Only findings that are relevant to the Florence area are presented, whether the statements apply worldwide, to the U.S., the Northwest Coast, the Pacific Northwest, Oregon, or to the Florence area. Likewise, references to events and conditions that are not relevant to the Florence area, for example trends in snowpack levels in the Cascades and trends in the Great Lakes, are omitted from the report. Findings for the geographic area closest to Florence are provided whenever possible.

Key Findings for the Siuslaw Estuary Partnership

Impacts of climate change [applicable to the Florence area] will result from:

- Increasing Air Temperature
- Rising Sea Levels
- Increasing Storm Intensity and Frequency [and Wave Heights]
- Changing Precipitation Patterns
- Increasing Water Temperature
- Ocean Acidification⁴³

Impacts from these phenomena are discussed below, followed by the sections, *Impacts of Climate Change on Oregon Estuaries*, and *Impacts of Climate Change on Human Health and the Economy*.

Increasing Air Temperature

- With the exception of ocean acidification, all of the impacts [above] can be attributed to increasing air temperature.⁴⁴
- Regionally averaged temperature [in the Northwest Coast] rose about 1.5°F over the past century (with some areas experiencing increases up to 4°F) and is projected to increase another 3 to 10°F during this century. Higher emissions scenarios would

⁴³ *National Oceanic and Atmospheric Administration (NOAA), 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA Office of Ocean and Coastal Resource Management, p. 7.

⁴⁴ *Ibid*, p. 12.

result in warming in the upper end of the projected range.⁴⁵ Future regional climate changes in Oregon include increases in temperature around 0.2-1 °F per decade.⁴⁶

Rising Sea Levels

- It is near certain that global mean sea level will increase, possibly by 2-4 feet by 2100. By the mid 21st century, the rate of sea level rise will exceed vertical land movement on the Oregon Coast. Submerged areas will experience erosion and flooding impacts.⁴⁷
- Evaluating the consequences to enhanced erosion and flooding is complicated by Oregon's tectonic setting, with there being significantly different rates of uplift along the coast. The prospects are that with the expected accelerated rates of sea level rise (SLR), the entire coast will at some point be submerging and experience significantly greater erosion and flooding impacts than at present day.⁴⁸
- During the period 1930–1995, land on the southern Oregon coast between Florence and Coos Bay has generally risen faster than worldwide changes in sea level by about 1 mm [.039 inches] per year (Abbott 2004). However, the same data, which are based on geodetic leveling and tide-gauge records, indicate that land on the central and northern coast of Oregon (from Florence to Astoria) is being submerged by rising sea level at a rate of 1.5–2 mm [.06 -.08 inches] per year.⁴⁹
- Globally averaged sea level has risen through the 20th century, coincident with warming. In the Pacific Northwest, actual sea level rise varies along the coast, as a result of geologic uplift (or vertical land movement). In some spots along the coast, the upward movement of land is exceeding actual sea level rise and have been relatively immune to sea level rise impacts thus far. It is nearly certain that global mean sea level will increase, by 2-4 feet (1 meter) by 2100. Coastal areas that are uplifting geologically have been relatively immune to sea level rise impacts thus far. However, by the mid 21st century, the rate of sea level rise will probably exceed vertical land movement on all stretches of the Oregon Coast. Submerged areas will experience significant erosion and flooding impacts.⁵⁰

⁴⁵ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program (formerly the U.S. Climate Change Science Program), Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; Regional Climate Change Impacts: Northwest, p. 135.

⁴⁶ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute (OCCRI), *Legislative Summary*.

⁴⁷ *Ibid*, *Legislative Summary*.

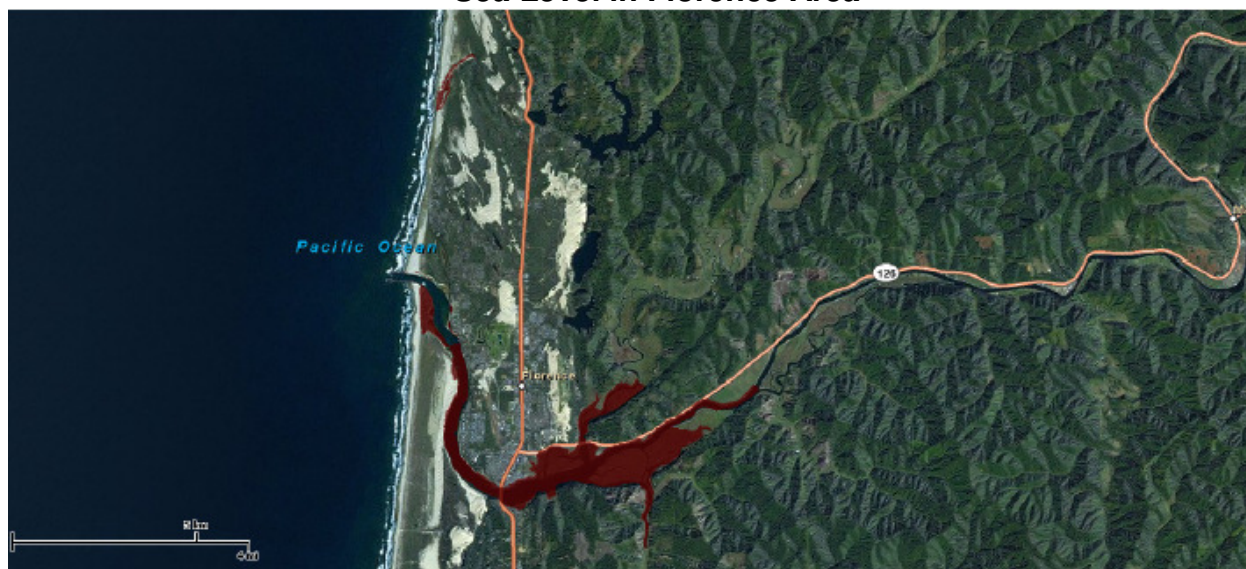
⁴⁸ *Ibid*, p. 227.

⁴⁹ *Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest*, Product of the Impacts of Climate Change on the Pacific Northwest Scientific Meeting, June 2004; p. 4.

⁵⁰ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, *Legislative Summary*.

- Analysis of elevation data in the context of projected sea level rise serves as one of the fundamental components needed to fully identify low-lying coastal areas that may confront impacts such as accretion and erosion, temporary flooding, and permanent inundation.⁵¹ [The recent work of Weiss and Overpeck, University of Arizona,] has centered on the analysis of digital elevation models (DEMs) to help delineate low-elevation coastal areas. [The abstract cited in Chapter IV of this report explains in detail the limitations of the tool, particularly as it applies to the Pacific coast. The mapping tool they developed allows for estimation of potential inundation areas resulting from one, two, and three meters, about three feet to ten feet, of sea level rise. The areas of potential inundation from about a three foot rise in sea level in the Florence area are estimated to occur around the estuary, the North Fork, and northern portions of the Dunal Aquifer, as shown in the Map below.]

Potential Areas of Inundation from a Three-Foot Rise in Sea Level in Florence Area



Areas potentially impacted by sea level rise: Weiss JL, Overpeck JT, Strauss B (2011) Implications of recent sea level rise science for low-elevation areas in coastal cities of the conterminous U.S.A. Climatic Change DOI 10.1007/s10584-011-0024-x. Esri provided basemaps. Tue Mar 15 2011 02:28:20 PM.

Source: Weiss and Overpeck, University of Arizona

⁵¹ Weiss, J.L., J.T. Overpeck, and B. Strauss. 2011. Implications of Recent Sea Level Rise Science for Low-elevation Areas in Coastal Cities of the Conterminous U.S.A. Climatic Change DOI 10.1007/s10584-011-0024-x. http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/mapping_slr/mapping_slr.htm

- [In the U.S.,] human and ecosystem populations will also suffer from a loss in quantity and quality of freshwater as saltwater inundates estuaries, marshes, rivers, and aquifer recharge areas; water tables rise; and inundated lands and infrastructure introduce more nonpoint source pollutants and toxic substances into the rising seas.⁵²
- [In Oregon,] higher sea levels could eventually result in saltwater intrusion into coastal aquifers used to supply domestic and agriculture uses.⁵³ Municipalities drawing on water supplies vulnerable to drought, pollution, and saltwater intrusion may need to consider new protection programs and supplemental water sources.⁵⁴
- Sea-level rise resulting from climate change also could affect groundwater in coastal regions in Oregon. Sea level is an important boundary condition affecting water levels in the extensive sand-dune aquifers along the coast such as found near Coos Bay, Reedsport, Florence, and in Clatsop County (Rinella et al., 1980; Brown and Newcomb, 1963; Hampton, 1963; Frank, 1970). A rise in mean sea level will result in a comparable rise in water-table elevations in sand dune aquifers as well as alluvial aquifers hydraulically connected to tidally influenced estuaries. This could result in water-level rises and expansion of groundwater-fed lakes and wetlands in sand dune areas and other low-lying coastal settings. Sea level rise will exacerbate any existing saltwater intrusion problems, as will warming-related increases in groundwater pumping in coastal areas [warmer temperatures lead to increased municipal and irrigation pumping and thus lower groundwater levels, and may increase risk of saltwater intrusion.]⁵⁵
- [In Oregon,] in addition to changes in recharge, other factors will influence the way in which groundwater systems respond to climate change. Aquifer systems in alluvial deposits that are in direct hydraulic connection to streams can be affected by the lowering of stream and lake stages resulting from diminished flows. Lower stream and lake stages can result in lower water levels in adjacent aquifers.⁵⁶
- [In the U.S.,] sea-level rise is expected to increase saltwater intrusion into coastal freshwater aquifers, making some unusable without desalination. Increased evaporation or reduced recharge into coastal aquifers exacerbates saltwater intrusion. Shallow groundwater aquifers that exchange water with streams are likely to be the most sensitive part of the groundwater system to climate change. Small reductions in groundwater levels can lead to large reductions in streamflow and increases in groundwater levels can increase streamflow. Further, the interface between streams

⁵² *National Oceanic and Atmospheric Administration (NOAA). 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers.* NOAA Office of Ocean and Coastal Resource Management, p. 12.

⁵³ *The Oregon Climate Change Adaptation Framework*, State of Oregon, December 2010; p. 45.

⁵⁴ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 375.

⁵⁵ *Ibid*, p. 104.

⁵⁶ *Ibid*, p. 103.

and groundwater is an important site for pollution removal by microorganisms. Their activity will change in response to increased temperature and increased or decreased streamflow as climate changes, and this will affect water quality. Like water quality, research on the impacts of climate change on groundwater has been minimal.⁵⁷

Increasing Storm Intensity and Frequency and Wave Heights

- [In the U.S.,] in general, rising sea levels will inundate coastal wetlands and other low-lying lands and intensify erosion and flooding as new areas are exposed to storm surges, waves, currents, and tides. Inundation, erosion, and flooding will threaten human health, coastal property, and infrastructure as well as coastal ecosystems, especially those that cannot migrate inland or are sediment-starved. Any changes to these ecosystems will, in turn, affect the biological, ecological, and physical services they provide.⁵⁸
- [In Oregon,] increasing sea levels, wave heights and storm surges will increase coastal erosion and likely increase damage to private property and infrastructure situated on coastal shorelands. Coastal erosion, and the common response to reduce shoreland erosion, can lead to long-term loss of natural buffering functions of beaches and dunes.⁵⁹
- [In Oregon,] coastal infrastructure will come under increased risk to damage and inundation under a changing climate with impacted sectors including transportation and navigation, coastal engineering structures (seawalls, riprap, jetties etc.) and flood control and prevention structures, water supply and waste/storm water systems, and recreation, travel and hospitality.⁶⁰
- The Oregon coast is well known for the severity of its winter storms and the heights of the waves they generate. The most extreme storm in recent years in terms of the heights of the waves measured by offshore buoys occurred in early March 1999, when the significant wave heights reached 14 to 15 meters [45 -49 feet] (Allan and Komar, 2002). With that 1.7 factor [maximum wave heights are estimated to be 1.7 times higher],⁶¹ the highest individual waves during that storm would have been ~25

⁵⁷ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; *Regional Climate Change Impacts: Northwest*, p. 135-138 and *Coasts*, p. 47.

⁵⁸ *National Oceanic and Atmospheric Administration (NOAA). 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA Office of Ocean and Coastal Resource Management, p. 12.

⁵⁹ *Oregon Climate Change Adaptation Framework*, State of Oregon, December 2010; p. ix.

⁶⁰ *Ibid*, p. 210.

⁶¹ During storms, the deep-water significant wave heights are regularly greater than 10 meters (about 1 storm of this size per year), the “significant wave height” being defined as the average of the highest one-third of the measured wave heights within a (typically) 20-minute period. Being something of an average, there are larger individual waves generated by the

meters [82 feet], the height of an [eight]-story building. Being capable of generating such extreme waves, Oregon's winter storms have been the dominant factor responsible for episodes of erosion and flooding along this coast (Ruggiero, 2008).⁶²

- Of particular significance to Oregon's coastal hazards is that the more extreme waves generated by the strongest storms are increasing at appreciably higher rates than are the "winter" averages (Allan and Komar, 2006; Ruggiero et al., 2010). There is also a suggestion that the lowest measured significant wave heights, those that occur during the summer, have also experienced an increase over the decades.⁶³
- On the Pacific Northwest (PNW) coast, the highest monthly-mean (ocean) [sea] water levels always occur during the winter months of December through February, the lowest being in the summer, with the normal difference between the two seasons being on the order of 9.8 inches. This occurrence of the highest water levels during the winter is unusual in that on most coasts the highest levels occur in the summer when the water is warmest, resulting from solar radiation and the heating and thermal expansion of the water. However, along the coast of the PNW the development of upwelling during the summer brings cold dense water up to the surface; the water is therefore coldest in the summer and warmest during the winter.⁶⁴
- This unusual cycle of water temperatures along the PNW coast, together with the changing directions and magnitudes of the ocean's currents, produce the seasonal changes in monthly-mean water levels. This represents an important factor in occurrences of coastal erosion and flooding since the highest water levels occur at the same time as the strongest storms and their extreme waves.⁶⁵ As rates of global sea level rise accelerate during the 21st century, it can be expected that the "winter" average water levels together with El Niño induced extremes will progressively shift to higher elevations. This pattern of increasing sea level extremes will result in greater impacts from erosion and flooding along the Oregon coast.⁶⁶ [Please note: a detailed explanation of the dynamics of climate variability in the Pacific Ocean and the relationship between climate change, El Niño/Southern Oscillation (ENSO), and Pacific Decadal Oscillation (PDO) is included in Chapter IV in the description of the *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute.]

storm, with the maximum height being approximately a factor 1.7 greater than the significant wave height; therefore, for a storm with a 10-meter [32-foot] significant wave height, individual waves having heights up to ~17 meters [55 feet] can be expected. *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 223.

⁶² *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 223.

⁶³ *Ibid*, p. 224.

⁶⁴ *Ibid*, p. 220.

⁶⁵ *Ibid*, p. 220.

⁶⁶ *Ibid*, p. 222.

Changing Precipitation Patterns

- [In the lower Siuslaw River Watershed,] the lack of snowpack, steep terrain, low gradient streams, shallow soils, relative dryness in the east, and absence of a true "headwaters" combine to create a naturally "flashy" stream system, with unpredictable and highly variable flows. The first heavy rains of autumn are only partly absorbed into the dry, porous sandstone soils. Streams rise quickly once the rains return, then dry to a trickle by mid summer. The land has limited ability to store water, and what natural ability it does have has been compromised by logging, road construction, valley clearing, wetland draining, removal of logjams and resulting stream downcutting. This has important effects on the aquatic system.⁶⁷
- Rainfall is much higher in the western part of the Siuslaw basin than in the eastern part. This, combined with the pattern of seasonal rain, also limits the amount of water available to streams in the summer. Relatively very little is generated or stored in the upper watershed (Armantrout).⁶⁸
- The Siuslaw River and its major tributary, Lake Creek, drain 780 square miles primarily in the Oregon Coast Range (Siuslaw Watershed Council 2002). The precipitation pattern in the Siuslaw Basin is unusual in that the headwaters of the mainstem Siuslaw River receive approximately one half the rain (50 inches) that the headwater tributaries on the west side of the Oregon Coast Range receive (100+ inches). The area with the highest precipitation, over 100 inches annually, is the summit of the Coast Range in the western half of the basin. Rain-on-snow events occur and sometimes are factors in large floods.⁶⁹
- [On Northwest coast,] increases in winter precipitation and decreases in summer precipitation are projected by many climate models, though these projections are less certain than those for temperature.⁷⁰
- Uncertainty is still high in projecting future changes in runoff, water quality, and urban water demand in Oregon.⁷¹ The most consistent changes in global climate models show a regional warming and drying in the summer. The multi-model average decrease for summer precipitation is 14% by the 2080s. There is some evidence that extreme precipitation will increase in the future. Though trends in extreme daily

⁶⁷ The discussion of the Siuslaw Basin was excerpted from: "A Watershed Assessment for the Siuslaw Basin, Executive Summary," Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

⁶⁸ Ibid.

⁶⁹ Pacific Coast Watershed Partnership Web Site.

⁷⁰ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program (formerly the U.S. Climate Change Science Program), Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; Regional Climate Change Impacts: Northwest, p. 135.

⁷¹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 70.

precipitation over the 20th century have been ambiguous in Oregon, there is some indication that such events will increase in the 21st century.⁷²

- [In Oregon,] changes in the seasonal distribution of precipitation will affect seasonal water table fluctuations and of groundwater discharge to springs and streams. If seasonal shifts are sufficiently large and total annual precipitation remains constant, the result could be less annual recharge in some areas. This is because some shallow aquifer systems ... fill to capacity and recharge during the winter is already “rejected” and shunted off to streams (Conlon et al., 2005). Increased winter precipitation, therefore, may not result in increased groundwater recharge.⁷³
- [In Oregon,] in addition to changes in recharge, other factors will influence the way in which groundwater systems respond to climate change. Aquifer systems in alluvial deposits that are in direct hydraulic connection to streams can be affected by the lowering of stream and lake stages resulting from diminished flows. Lower stream and lake stages can result in lower water levels in adjacent aquifers.⁷⁴
- [In Oregon,] groundwater systems are also susceptible to the effects of increased water demand resulting from climate change. Warmer temperatures typically result in increased groundwater pumping by both municipalities and irrigators. Diminished late season streamflow predicted by most analyses will reduce the surface water available for irrigation which will also increase demand for groundwater. The very small increase in precipitation projected by the ensemble average of climate models for Oregon is unlikely to offset increased pumping due to warmer temperatures and diminished late-season streamflow.⁷⁵

Increasing Water Temperature

- [In Oregon,] water quality is also likely to be impacted with rising air temperature and seasonal shifts in flow availability... There is little research on long term trends in water temperature in undisturbed watersheds; sites with long term data are rare. Sediment and phosphorus loads, which are a detriment to water quality, are expected to increase in winter as winter flow is projected to rise. It will be important for water resource managers statewide to include considerations for climate change in future planning.⁷⁶
- Models predict Pacific Northwest coastal sea surface temperatures to increase by 1.2°C [1.8°F] by the 2030-2059 period (Mote and Salathé, 2010). However, coastal upwelling dramatically affects Oregon’s nearshore ocean temperatures as cold, nutrient rich subsurface waters rise to the surface in spring and summer. Average sea

⁷² *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, Legislative Summary.

⁷³ *Ibid*, p. 102-103.

⁷⁴ *Ibid*, p. 103.

⁷⁵ *Ibid*.

⁷⁶ *Ibid*, *Executive Summary*.

surface temperature in near-coastal environments varies by about 8°C [46°F] seasonally (Mote and Salathé, 2010). If changes in climate alter the frequency, duration, or intensity of upwelling, there could be decreases in average nearshore temperatures during upwelling events and more dramatic temperature swings in the transitions between upwelling events and seasons. Higher ocean temperatures overall will result in species range shifts to the north.⁷⁷ There is already some evidence of northward shift in distribution of some marine species such as Pacific hake (Phillips et al., 2007), pink shrimp (Hannah, in press), northern and flat abalone (Rogers-Bennett, 2007), and jumbo squid (Field et al., 2007).⁷⁸

- In particular, changes in the hydrology of streams important for coho salmon may reduce the viability of some coho populations [in Oregon].⁷⁹

Ocean Acidification

- Ocean acidification is the result of an increase in carbon dioxide absorption by ocean water, [formation of carbonic acid,] and the corresponding decrease in pH. As seawater becomes less alkaline (more acidic), less calcium carbonate is available for corals, shellfish, and other sea life to build their shells and skeletons. Threats to these ecosystems and species will be wide-ranging across the marine food web and associated coastal communities.⁸⁰
- Long-term observational records and empirical studies provide strong evidence that global increases in atmospheric carbon dioxide (CO₂) concentrations have contributed to widespread changes in the carbonate chemistry of ocean waters (Feely et al., 2004; Fabry et al., 2008; Dore et al., 2009). Elevated atmospheric CO₂ values are directly coupled with increased pCO₂⁸¹ values in the ocean, and the shift in equilibrium results in increased carbonic acid (H₂CO₃) and decreased pH values. Long-term decreases in pH values (ocean acidification) have the potential to pose a major environmental problem, and ocean acidification has emerged as a pressing regional, national, and international issue that has important physiological and ecological implications for marine organisms throughout the world. The biochemical process that contributes to ocean acidification is driven by availability of hydrogen ions (H⁺), and shifts in pH values are of particular concern for species such as coral reefs, pteropods, coccolithophores, echinoderms, mollusks, and the larval stages of marine in-

⁷⁷ *Oregon Climate Change Adaptation Framework*, State of Oregon, Dec. 2010; p. 32.

⁷⁸ *Ibid*; p. 33-34.

⁷⁹ *Ibid*; p. 21.

⁸⁰ *Ibid*.

⁸¹ PCO₂ is the partial pressure of CO₂ in the atmosphere and the ocean. In the atmosphere, the partial pressure of CO₂ is defined as the pressure the CO₂ would exert if all other gases were removed. The sum of the partial pressure of all the atmospheric gases will equal the atmospheric pressure.

vertebrates that have calcium carbonate skeletons (i.e., calcite, aragonite; Orr et al., 2005; Kurihara, 2008).⁸²

Impacts of Climate Change on Oregon Estuaries

- The Siuslaw estuary's intertidal area habitats include large areas of salt marsh (746 acres), eelgrass (338 acres), and tidal flat habitat (541 acres); and no areas of fresh marsh or forested/scrub shrub habitat. The head of tide extends far upriver, 22.8 miles. As a result of filling and diking between 1870 and 1970, there was a loss of an estimated 29% of total intertidal wetland area (from 4,316 acres in 1870 to 3,060 acres in 1970) and an estimated 63% loss of vegetated intertidal wetland area (from 2,002 acres in 1870 to 746 acres in 1970).⁸³
- Added to these historical impacts, sea level rise (SLR) [in Oregon] will result in additional wetland loss with a concomitant loss of associated ecosystem services, such as habitat for juvenile salmon and waterfowl, flood control, maintenance of estuarine water quality, and carbon sequestration (Zedler and Kercher, 2005).⁸⁴
- [In Oregon,] climate change has the potential to influence water quality conditions in estuaries primarily through changes in precipitation in the watersheds, land cover in the watersheds, temperature (atmospheric, riverine, and oceanic), coastal upwelling, wind stress, and RSL [relative sea level] rise.⁸⁵
- Water quality conditions in [Pacific Northwest] PNW estuaries are strongly influenced by both freshwater inflow and ocean conditions (Roegner and Shanks, 2001; Brown and Ozretich, 2009; Lee and Brown, 2009; Roegner, et al., 2010). As a result, there is the potential for climate change to influence estuarine water quality. During the wet season (November to April), water quality conditions in estuaries are dominated by freshwater inflows, while during the dry season (May to October), freshwater inflows to the estuaries decline and the estuaries become more marine-dominated. The dry season also roughly coincides with the upwelling season on the Oregon shelf. Previous studies have demonstrated that water quality conditions within PNW estuaries during the summer are influenced by intrusions of oceanic water into the estuaries, affecting nutrients (Haertel et al., 1969; de Angelis and Gordon, 1985; Brown and Ozretich, 2009; Lee and Brown, 2009), phytoplankton (Roegner and Shanks, 2001; Roegner et al., 2002; Brown and Ozretich, 2009; Lee and Brown, 2009; Roegner et al., 2010), and dissolved oxygen levels (Pearson and Holt, 1960; Haertel et al., 1969; Brown and Power, in review). Water quality condi-

⁸² *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute (OCCRI), p. 250.

⁸³ *Watershed Stewardship: A Learning Guide, Supplement, Chapter 10: Estuarine Science, Management, and Restoration*, Oregon State University Extension Service, Revised 2003, p. II-10.11.

⁸⁴ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p.236.

⁸⁵ *Ibid*, p. 239.

tions in Oregon estuaries are also influenced by land use/cover and human activities in the watersheds.⁸⁶

- Different types of estuaries will have differing responses to climate change drivers (Table 6.1).⁸⁷
- The Siuslaw is a “drowned river mouth estuary.” Drowned river mouth estuaries formed as ancient river valleys were flooded by the rising sea at the end of the last ice age. Today, these estuaries have relatively large coastal watersheds. They are freshwater (river) dominated during winter, when runoff is high, but saltwater dominated in the dry summer and fall.⁸⁸
- More research is needed to determine to what extent climate change may influence estuarine water temperatures [in Oregon]. Since estuarine water temperatures are closely coupled to upwelling dynamics, improvement is needed in models which are used to predict changes in upwelling. Since present water temperatures in the up-river portions of estuaries often exceed temperature criterion for protection of salmon and trout, there is the potential for climate change to result in an increase in temperature impairments, and thus to potentially affect the distribution and survival of cold water species.⁸⁹
- [In Oregon,] it is likely that regional coastal climate change will result in changes in the intensity and timing of coastal upwelling, shifts in temperatures and dissolved oxygen concentrations, and alteration of the carbonate chemistry (ocean acidification) of nearshore waters. The combination of these meteorological and nearshore ocean changes will exert stress on the communities of near-coastal and estuarine organisms. The range of community responses to the climate change stressors may include elevational shifts in the distribution of submerged aquatic vegetation, disruption of shell formation for calcifying organisms, alteration of the phenology of phytoplankton blooms, shoreward migration of tidal marshes, and increased colonization by non-indigenous aquatic species.⁹⁰
- In Oregon estuaries, typically low dissolved oxygen conditions have been observed near the upper end of salt water intrusion (DEQ, 1995), such as in the sloughs of Tillamook Estuary. In the Yaquina Estuary, there has been a shift in the location of low dissolved oxygen conditions. Historically, low dissolved oxygen levels occurred in the upper portion of the Yaquina Estuary (20 km from the mouth; Brown et al.,

⁸⁶ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 239.

⁸⁷ *Ibid.*

⁸⁸ *Watershed Stewardship: A Learning Guide, Supplement, Chapter 10: Estuarine Science, Management, and Restoration*, Oregon State University Extension Service, Revised 2003, p. II-10.11.

⁸⁹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 245.

⁹⁰ *Ibid.*, p. 210.

2007), which coincided with the location of the point source discharges and a region of extensive log rafting. Recently, there have been occurrences of severe hypoxia on the inner continental shelf of Oregon (Chapter 1; Grantham et al., 2004; Chan et al., 2008), which influence dissolved oxygen levels in Oregon estuaries. For example, low dissolved oxygen conditions have been periodically imported from the inner shelf into the Yaquina Estuary (Brown et al., 2007), as well as into Umpqua, Tillamook, Coos, and Siletz estuaries (Brown and Power, in review). This low dissolved oxygen water has a distinctive thermal signature and dissolved oxygen levels in the Yaquina Estuary are correlated with alongshore wind stress. Recent time-series data (2001-2007) demonstrate that the water advected into the Yaquina Estuary from the coastal ocean has dissolved oxygen levels <5 and <6.5 mg l⁻¹ [mg per liter] about 13% and 38% of the time, respectively (Brown and Power, in review). Research has also demonstrated that dissolved oxygen levels in South Slough Estuary are related to ocean conditions. O'Higgins and Rumrill (2007) found a negative correlation between dissolved oxygen levels inside the South Slough and the PDO (O'Higgins and Rumrill, 2007).⁹¹

- Any changes in frequency or intensity of upwelling may cause changes in the occurrence of low oxygen conditions in the marine-dominated portion of estuaries, particularly for tide-dominated estuaries. A rise in sea level may cause oceanic low dissolved oxygen water to penetrate further into the estuaries. In the more upriver parts of the estuaries, dissolved oxygen levels may also be influenced by climate change through increased stratification, reduced flushing, as well as temperature effects. In estuaries, dissolved oxygen levels typically decrease with increasing temperature due to both reduced solubility of oxygen in water and to increased respiration and decomposition rates. In a comparison of water quality conditions in four west coast estuaries (including Coos Estuary), the number of hours of oxygen stress (dissolved oxygen levels < 5 mg l⁻¹) [mg per liter] per day increased linearly with mean annual water temperature (O'Higgins and Rumrill, 2007). Through various mechanisms, climate change has the potential to influence dissolved oxygen levels in estuaries; although to what extent this may happen is unknown at this time.⁹²
- Oregon estuaries receive nutrients from watershed point and non-point sources as well as from the coastal ocean (Haertel et al., 1969; de Angelis and Gordon, 1985; Sigleo et al., 2005; Sigleo and Frick, 2007; O'Higgins and Rumrill, 2007; Brown and Ozretich, 2009; Lee and Brown, 2009). There is considerable interannual variability in coastal upwelling and in nutrient concentrations on the shelf (Corwith and Wheeler, 2002; Wheeler et al., 2003), as well as in the input of oceanic nutrients to coastal estuaries (Brown and Ozretich, 2009). In addition, previous studies have suggested that the presence of red alder trees in the watersheds is a significant source of nitrogen to many Oregon estuaries (Wigington et al., 1998; Compton et al., 2003; Naymik et al., 2005; Brown and Ozretich, 2009; Lee and Brown, 2009). Cli-

⁹¹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 248 (see Chapter IV of this Siuslaw Estuary Partnership Report for a discussion of PDO, Pacific Decadal Oscillation).

⁹² *Ibid.*

mate change has the potential to influence nutrient levels in Oregon estuaries through various mechanisms.⁹³

- [Chlorophyll a is used to measure phytoplankton levels in water bodies; and high levels of chlorophyll a indicate high phytoplankton blooms in the estuary.] Newton and Horner (2003) demonstrated that high productivity phytoplankton blooms were imported from the coastal ocean and that these blooms consisted of species of oceanic origin, while moderate blooms which included species of oceanic and estuarine origin also occurred within the estuary. Previous studies have demonstrated that chlorophyll a is advected into estuaries along the Oregon and Washington coasts from the coastal ocean during the dry season (Roegner and Shanks, 2001; Roegner et al., 2002; Brown and Ozretich, 2009; Roegner et al., 2010). Although the import of chlorophyll a from the coastal ocean to estuaries is related to coastal upwelling, there is a lag between upwelling on the coast and import of phytoplankton to estuaries (Brown and Ozretich, 2009)... A rise in sea level may result in chlorophyll a of oceanic origin reaching further into Oregon estuaries, particularly for tide-dominated systems... Chlorophyll a levels in estuaries will be more sensitive to changes in river inflow during the dry season. Reductions in river discharge during the dry season may result in an increase in chlorophyll a levels in the estuary due to increased residence time of nutrients in the estuary.⁹⁴
- Recent oceanographic measurements demonstrate that acidified seawater is currently upwelling close to the Pacific continental shelf of Oregon and northern California (Feely et al., 2008). The acidified waters are presumed to move by advective transport directly into Oregon estuaries... The presumption that ocean acidification and intensified upwelling is uniformly problematic for shellfish populations in all Oregon estuaries may not be valid, however, because it is not clear how the pH and total alkalinity of estuarine waters are related or influenced by the carbonate chemistry of nearshore ocean waters. ..The carbonate chemistry of Oregon's estuarine waters will be modified on a site-specific basis depending on the extent of watershed influence and biochemical processes that occur within each individual estuary. Furthermore, it is also likely that pH variability differs even more substantially from the ocean waters within the mesohaline and polyhaline regions of the estuary which are influenced by the watershed drainage basin and are critical for larval settlement, recruitment, and early growth of native oysters and other shellfish.⁹⁵
- [PCO₂ is the partial pressure of CO₂ in the atmosphere and the ocean; in the atmosphere, the partial pressure of CO₂ is defined as the pressure the CO₂ would exert if all other gases were removed. The sum of the partial pressure of all the atmospheric gases will equal the atmospheric pressure.] Very little is known about the inherent variability in pCO₂ concentrations in the near shore marine waters of the Pacific northwest coast (Wootton et al., 2008), and the relationships between ocean

⁹³ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 248-249.

⁹⁴ *Ibid*, p.249-250.

⁹⁵ *Ibid*, p. 251-252.

acidification and pH values are poorly understood for the different types of Oregon estuaries. Long-term datasets that span periods of multiple decades are required to fully analyze inherent temporal and spatial variability in Oregon's estuarine water parameters, and to identify possible directional changes in pH values as a prospective response variable that can contribute to increased understanding of climate-induced changes in ocean carbonate chemistry.⁹⁶

Impacts of Climate Change on Human Health and the Economy

- Projected climate changes in precipitation rates and temperatures are likely to threaten the integrity of the built environment, including buildings, roads, highways and railroads, water and sewage systems, and energy facilities throughout Oregon (CLI 2008, 2010). Direct costs will result from flood events and anticipated increases in wildfire intensity and frequency due to climate change, while indirect costs are likely to be many times larger and will result from more rapid depreciation of property from higher temperatures, more intense storms and other climate stressors (CLI and NCCSP 2008). The full extent of impacts on cultural and built environments remains to be assessed in Oregon.⁹⁷
- Finally, climate change is likely to have an impact on public health issues in Oregon including the spread of communicable diseases as well as an increase in water-, food-, and air-borne infections. Predicted average increases in summer temperatures will make heat waves a greater likelihood, causing heat-related morbidity and mortality, especially among vulnerable populations, such as the elderly, low income populations, pregnant women and those who work in outdoor occupations. Indeed, an increase in injuries and cases of carbon monoxide poisoning (from using gas-powered generators) has been reported as a result of the recent winter storms and subsequent flooding in Oregon. Increasing temperatures in Oregon could raise the threat of vector-borne diseases and emerging infections. Respiratory insults, especially among persons with pre-existing lung health problems would be exacerbated by exposure to smoke from forest fires, as well as from the projected increases in air pollution levels in our region. Air pollution and increases in pollen counts (and a prolonged pollen producing season) may increase cases of allergies, asthma, and other respiratory conditions among susceptible populations.⁹⁸

⁹⁶ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 248-249

⁹⁷ *Ibid*, p. 395

⁹⁸ *Ibid*, p. 395.

Table 6.1. Hypothesized effects of climate alterations on estuaries.

Climate Alteration	Potential Effects
Sea level rise and extreme water levels.	Increased inundation of estuarine habitats including tidal flats, marshes, and SAV. Increased intrusion of oceanic water into estuaries. Extent of effect will vary with relative river flow, location in the estuary, and RSL rise rates in the vicinity of the estuary.
Increased winter precipitation and decreased summer precipitation	Increased winter–early spring flow of coastal rivers and creeks and reduced flow during summer. Extent of effect related to relative river flow, with a greater impact on river-dominated estuaries (e.g., Umpqua) and tidal coastal creeks (e.g., Yachats) than on tide-dominated estuaries (e.g., Yaquina, Coos), with smallest effect on bar-built estuaries (e.g., Netarts).
Increased snow melt	Change in seasonal pattern of river flow into the Columbia River; minor changes in other coastal estuaries and creeks.
Increased air temperature	Potentially high vulnerability of intertidal organisms because of the high proportion of intertidal area in Oregon estuaries that may be exposed to elevated temperatures. Air temperature also has the potential to influence water temperatures particularly in the upriver portions of estuaries.
Increased upwelling	Increased advection of high nutrient ocean water into the lower estuary during summer. Possible increase in the advection of low dissolved oxygen and low pH water into the lower estuary during the summer. Changes associated with upwelling may be more important in tide- versus river- dominated estuaries.
Increased storm activity	Potential breaching of barrier dunes at mouth of estuaries without jetties (e.g., Alsea, Siletz) and episodic input of sediment to estuaries. Estuaries with jetties may be less impacted (e.g., Yaquina, Coos, and Rogue).
Ocean acidification	Unknown effect on estuaries or how alterations may vary across estuary classes.

SAV: Submerged aquatic vegetation. RSL: Relative sea-level.

Source: *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 242.

III. Climate Change Considerations for the Siuslaw Estuary Partnership

“Improved confidence in regional forecasts of climate change impacts is, however, of primary importance in helping managers understand risk levels, identify management priorities, and define realistic adaptations.” *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 375

Issue#1: Groundwater/Drinking Water Quality and Quantity

- Sea-level rise resulting from climate change could affect groundwater in coastal regions in Oregon. Sea level is an important boundary condition affecting water levels in the extensive sand-dune aquifers along the coast such as found near Coos Bay, Reedsport, Florence, and in Clatsop County (Rinella et al., 1980; Brown and Newcomb, 1963; Hampton, 1963; Frank, 1970). A rise in mean sea level will result in a comparable rise in water-table elevations in sand dune aquifers as well as alluvial aquifers hydraulically connected to tidally influenced estuaries. This could result in water-level rises and expansion of groundwater-fed lakes and wetlands in sand dune areas and other low-lying coastal settings. Sea level rise will exacerbate any existing saltwater intrusion problems, as will warming-related increases in groundwater pumping in coastal areas [warmer temperatures lead to increased municipal and irrigation pumping and thus lower groundwater levels, and may increase risk of saltwater intrusion.]⁹⁹
- The North Florence Dunal Aquifer is an EPA-designated sole source aquifer. This means that there is no other source of drinking water that can serve the existing population. This is the only EPA-designated sole source aquifer in the State of Oregon. “Possible sources of aquifer contamination include fuel storage tank failure, accidental spills of hazardous material, septic tank effluent, storm runoff, pesticides, and chemical fertilizers.”¹⁰⁰
- [In Oregon,] changes in the seasonal distribution of precipitation will affect seasonal water table fluctuations and of groundwater discharge to springs and streams. If seasonal shifts are sufficiently large and total annual precipitation remains constant, the result could be less annual recharge in some areas. This is because some shallow aquifer systems ... fill to capacity and recharge during the winter is already “rejected” and shunted off to streams (Conlon et al., 2005). Increased winter precipitation, therefore, may not result in increased groundwater recharge.¹⁰¹

⁹⁹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 104.

¹⁰⁰ See, *U.S. Environmental Protection Agency Resource Document: For Consideration of the North Florence Dunal Aquifer as a Sole Source Aquifer*, August 1987; EPA 910/9-87-167.

¹⁰¹ *Ibid*, p. 102-103.

- [In Oregon,] in addition to changes in recharge, other factors will influence the way in which groundwater systems respond to climate change. Aquifer systems in alluvial deposits that are in direct hydraulic connection to streams can be affected by the lowering of stream and lake stages resulting from diminished flows. Lower stream and lake stages can result in lower water levels in adjacent aquifers.¹⁰²
- Shallow groundwater aquifers that exchange water with streams are likely to be the most sensitive part of the groundwater system to climate change. Small reductions in groundwater levels can lead to large reductions in streamflow and increases in groundwater levels can increase streamflow.¹⁰³
- [In the U.S.,] sea-level rise is expected to increase saltwater intrusion into coastal freshwater aquifers, making some unusable without desalination. Increased evaporation or reduced recharge into coastal aquifers exacerbates saltwater intrusion.¹⁰⁴
- The recent work of Weiss and Overpeck, University of Arizona, has centered on the analysis of digital elevation models (DEMs) to help delineate low-elevation coastal areas. The mapping tool they developed allows for estimation of inundation areas resulting from one, two, and three meters [about three feet to ten feet] of sea level rise. The abstract cited in Chapter IV of this report explains in detail the limitations of the tool, particularly as it applies to the Pacific coast. The tool shows areas of potential inundation from about a three foot rise in sea level in the Florence area to be estimated to occur around the estuary, the North Fork, and northern portions of the Dunal Aquifer.¹⁰⁵

Potential Strategies:

1. Continue to Monitor Groundwater Quality and Quantity.

The Florence Groundwater Monitoring Program, established through the Siuslaw Estuary Partnership, is funded in part by the US Environmental Protection Agency (EPA). At the outset, the program will provide baseline data. Over the long term, the program will enable the City and its partners to track variability and long term changes; and will position the City and its partners to respond to changes detected that pose a threat to the City's current and future drinking water sources. For the complete list of short, medium, and long term outcomes of

¹⁰² *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 103.

¹⁰³ *Ibid.*

¹⁰⁴ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; *Regional Climate Change Impacts: Northwest*, p. 135-138 and *Coasts*, p. 47.

¹⁰⁵ Weiss, J.L., J.T. Overpeck, and B. Strauss. 2011. Implications of Recent Sea Level Rise Science for Low-elevation Areas in Coastal Cities of the Conterminous U.S.A. Climatic Change DOI 10.1007/s10584-011-0024-x.

the monitoring program and other Project Elements in the Siuslaw Estuary Partnership Program, see the *Guiding Principles and Outcomes* in Appendix A.

Continuation of this program as an integral function of the Florence Public Works Department will provide the City and its partners with ready access to real time data on the status of groundwater. To the extent that the City is able to continue this monitoring and to track the changes over time, the City will have a better handle on how climate change is affecting this critical resource. Federal and State funding may be available to support this effort, especially as it contributes to the broader goals of understanding and responding to climate change.

2. Conduct a study to evaluate sustainable wellfield production rates from current and future wells that can be achieved without degrading water quality as a result of sea water intrusion from the ocean or the Siuslaw estuary.

The City of Florence relies on the North Florence EPA-designated Sole Source Dunal Aquifer for its drinking water source. As in most coastal areas, it is likely that a portion of the aquifer lies on top of a layer of seawater. If seawater invades the aquifer, the resulting higher salinity in the groundwater may render some of the City's wells unusable without the application of a high cost treatment system. This issue is further compounded with the anticipated rise in sea levels that are projected with climate change. In Florence, pumping levels from City wells will need to ensure that infiltration of seawater is prevented. On-going study and monitoring of seawater levels that pose a potential threat to drinking water will be necessary for this to occur.

As part of the Florence Surface and Groundwater Monitoring Program, GSI Water Solutions, Inc. will do some initial investigation into the extent that the City's water source is threatened or vulnerable to this type of contamination. The two parameters that will provide baseline data on salinity are conductivity and common ions (e.g., Na, Ca, Cl, and SO₄) as part of the monitoring for Munsel and Ackerley Creeks and in at least one deep groundwater test well. GSI is now exploring the options for using an existing deep groundwater well and a pressure transducer to obtain baseline data on conditions at deeper reaches of the aquifer.

As part of a future effort, the City will want to consider modeling to predict the interface of seawater and the aquifer and to determine appropriate pumping levels to prevent possible contamination from seawater.

3. Develop a sustainable source of drinking water.

The City of Florence's current wellfield is nearing its capacity with respect to supplying the City's needs. An additional wellfield is being contemplated and the City is preparing a Source Water Protection Plan that will identify strategies to reduce the risk to their current and future wellfields. With a finite source of groundwater, which likely will be reduced with anticipated sea level rise, it is es-

pecially important that current and future resources are protected from contamination. Loss of an existing drinking water resource as a result of contamination, when coupled with a resource loss due to salt water intrusion, will severely impact the City's sustainability.

4. Prepare an Aquifer Protection Plan that meets State requirements for a Source Water Protection Plan.

One of the products from the Siuslaw Estuary Partnership Project is an "Aquifer Protection Plan." This plan will contain the elements required by the State for a Source Water Protection Plan, plus additional strategies to protect the aquifer, outside of the existing and future wellfields, and surface waters in the aquifer boundary, north of the River, to meet project objectives to protect and improve surface water quality and fish and wildlife habitat.

Issue #2: Surface Water Quality and Quantity and Fish and Wildlife Habitat

- [The] interface between streams and groundwater is an important site for pollution removal by microorganisms. Their activity will change in response to increased temperature and increased or decreased streamflow as climate changes, and this will affect water quality.¹⁰⁶
- [In Oregon,] water quality is also likely to be impacted with rising air temperature and seasonal shifts in flow availability... There is little research on long term trends in water temperature in undisturbed watersheds; sites with long term data are rare. Sediment and phosphorus loads, which are a detriment to water quality, are expected to increase in winter as winter flow is projected to rise. It will be important for water resource managers statewide to include considerations for climate change in future planning.¹⁰⁷
- [In the lower Siuslaw River Watershed,] the lack of snowpack, steep terrain, low gradient streams, shallow soils, relative dryness in the east, and absence of a true "headwaters" combine to create a naturally "flashy" stream system, with unpredictable and highly variable flows. The first heavy rains of autumn are only partly absorbed into the dry, porous sandstone soils. Streams rise quickly once the rains return, then dry to a trickle by mid summer. The land has limited ability to store water, and what natural ability it does have has been compromised by logging, road con-

¹⁰⁶ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; Regional Climate Change Impacts: Northwest, p. 135-138 and Coasts, p. 47.

¹⁰⁷ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, *Executive Summary*.

struction, valley clearing, wetland draining, removal of logjams and resulting stream downcutting. This has important effects on the aquatic system.¹⁰⁸

- Portions of the Siuslaw River are classified as "Water Quality Limited," under the Clean Water Act, for temperature, dissolved oxygen, fecal coliform, and sediment; and the Oregon Department of Environmental Quality has included the Siuslaw on the State's 303(d) list of Impaired Water Bodies.¹⁰⁹
- Early cannery records indicate that the Siuslaw was second only to the Columbia River in numbers of coho. The average coho numbers from 1889–1896 were 209,000 fish (Booker). This compares to an average of just over 3,000 in the years 1990–1995.¹¹⁰
- [In Oregon,] climate change has the potential to influence water quality conditions in estuaries primarily through changes in precipitation in the watersheds, land cover in the watersheds, temperature (atmospheric, riverine, and oceanic), coastal upwelling, wind stress, and RSL [relative sea level] rise.¹¹¹
- The Siuslaw is a “drowned river mouth estuary.” Drowned river mouth estuaries formed as ancient river valleys were flooded by the rising sea at the end of the last ice age. Today, these estuaries have relatively large coastal watersheds. They are freshwater (river) dominated during winter, when runoff is high, but saltwater dominated in the dry summer and fall.¹¹²
- Through various mechanisms, climate change has the potential to influence dissolved oxygen levels in estuaries; although to what extent this may happen is unknown at this time.¹¹³
- Present water temperatures in the upriver portions of estuaries often exceed temperature criterion for protection of salmon and trout. There is the potential for climate change to result in an increase in temperature impairments, and thus to potentially affect the distribution and survival of cold water species.¹¹⁴

¹⁰⁸ The discussion of the Siuslaw Basin was excerpted from: “A Watershed Assessment for the Siuslaw Basin, Executive Summary,” Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

¹⁰⁹ Oregon Department of Environmental Quality.

¹¹⁰ The discussion of the Siuslaw Basin was excerpted from: “A Watershed Assessment for the Siuslaw Basin, Executive Summary,” Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

¹¹¹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 239.

¹¹² *Watershed Stewardship: A Learning Guide, Supplement, Chapter 10: Estuarine Science, Management, and Restoration*, Oregon State University Extension Service, Revised 2003, p. II-10.11.

¹¹³ *Ibid.*

¹¹⁴ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 245.

- Susceptibility of estuarine wetlands to SLR [sea level rise] will vary among estuaries due to difference in RSL [relative sea level] rise rate along the coast as well as due to differences in the extent and type of wetlands within in each estuary (Lee and Brown, 2009).¹¹⁵
- The recent work of Weiss and Overpeck, University of Arizona, has centered on the analysis of digital elevation models (DEMs) to help delineate low-elevation coastal areas. The mapping tool they developed allows for estimation of inundation areas resulting from one, two, and three meters [about three feet to ten feet] of sea level rise. The abstract cited in Chapter IV of this report explains in detail the limitations of the tool, particularly as it applies to the Pacific Northwest. The tool shows areas of potential inundation from about a three foot rise in sea level in the Florence area to be estimated to occur around the estuary, the North Fork, and northern portions of the Dunal Aquifer.¹¹⁶
- [In the Siuslaw estuary,] as a result of filling and diking between 1870 and 1970, there was a loss of an estimated 29% of total intertidal wetland area (from 4,316 acres in 1870 to 3,060 acres in 1970) and an estimated 63% loss of vegetated intertidal wetland area (from 2,002 acres in 1870 to 746 acres in 1970).¹¹⁷
- Sea level rise (SLR) [in Oregon] will result in additional wetland loss with a concomitant loss of associated ecosystem services, such as habitat for juvenile salmon and waterfowl, flood control, maintenance of estuarine water quality, and carbon sequestration (Zedler and Kercher, 2005).¹¹⁸

Potential Strategies:

1. **Continue to Monitor Surface Water Quality and Quantity (Munsel Creek, Ackerley Creek, Clear Lake, and the Siuslaw estuary) and retain gauging stations in the creeks for monitoring flow.**

The Florence Surface Water Monitoring Program, established through the Siuslaw Estuary Partnership, is funded in part by the EPA. At the outset, the program will provide baseline data on water quality and flow conditions in Acker-

¹¹⁵ *Oregon Climate Change Assessment Report*, Oregon Climate Change Research Institute, December 2010; Chapter 6 - Impacts of climate change on Oregon's coasts and estuaries, p. 214

¹¹⁶ Weiss, J.L., J.T. Overpeck, and B. Strauss. 2011. Implications of Recent Sea Level Rise Science for Low-elevation Areas in Coastal Cities of the Conterminous U.S.A. Climatic Change DOI 10.1007/s10584-011-0024-x.

¹¹⁷ *Watershed Stewardship: A Learning Guide, Supplement, Chapter 10: Estuarine Science, Management, and Restoration*, Oregon State University Extension Service, Revised 2003, p. II-10.11.

¹¹⁸ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p.236.

ley and Munsel Creeks; monitor Clear Lake for pharmaceuticals; and, through partnership with the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians, monitor water quality (including urban impacts) in the Siuslaw estuary.

Over the long term, the program will enable the City and its partners to track variability and long term changes; and will position the City and its partners to respond to changes detected that pose a threat to fish and wildlife habitat in the creeks, wetlands, and estuary. For the complete list of short, medium, and long term outcomes of the monitoring program and other Project Elements in the Siuslaw Estuary Partnership Program, see the *Guiding Principles and Outcomes* in Appendix A.

Continuation of this program as an integral function of the Florence Public Works Department would provide the City and its partners with ready access to real time data on the status of surface water in Ackerley and Munsel Creeks; and these data will help inform the monitoring of the estuary by the Tribes. To the extent that the City is able to continue this monitoring and to track the changes over time, the City will have a better handle on how climate change is affecting this critical resource. Federal and State funding may be available to support this effort, especially as it contributes to the broader goals of understanding and responding to climate change.

In addition, the City will likely be identified as a Designated Management Agency (DMA) by DEQ during the Total Maximum Daily Load (TMDL) process for the Siuslaw subbasin (i.e., as part of the Mid-coast Basin TMDL), although no specific allocations or requirements have been established for the City at this time. DMAs are typically required to develop a TMDL implementation plan to assess and address the water quality impacts of activities within their regulatory or land use jurisdiction, particularly those affecting impaired waterbodies. The City may also receive pollutant load allocations that affect wastewater treatment plant effluent limits, stormwater management, riparian management requirements and possibly other activities. DEQ and other partners work together with DMAs to prioritize those activities and actively seek resources and funding to support water quality protection planning, improvements and on-the-ground restoration work. Thus, each of these three Potential Strategies will be addressed, to some degree, during the TMDL process. The City's current efforts combined with the Siuslaw Estuary Partnership products provide a solid foundation for a TMDL Implementation Plan.

2. Prepare an Aquifer Protection Plan that includes strategies to protect and improve surface water quality and fish and wildlife habitat.

One of the products from the Siuslaw Estuary Partnership Project is an "Aquifer Protection Plan." This plan will contain the elements required by the State for a Source Water Protection Plan, plus additional strategies to protect the aquifer,

outside of the existing and future wellfields, and surface waters in the aquifer boundary, north of the River, to meet project objectives to protect and improve surface water quality and fish and wildlife habitat.

3. Maintain forest buffers for shade along banks and change operations on managed rivers to reduce present warming.

“Ecological Growth Planning” is one of the Project Elements of the Siuslaw Estuary Partnership Project. This Project Element will result in policy approaches to improve and protect surface water quality and fish and wildlife habitat. The Study Area for any land use measures resulting from the various Project Elements is the Florence Urban Growth Boundary.

This Project Element integrates needed policy and code changes resulting from the other project elements and will result in proposed revised regulatory and land use policies and measures, including: changes to the Comprehensive Plan and other applicable Plans and Codes; to include policies and measures to protect surface water and groundwater quality and quantity and fish and wildlife habitat and to explore incentive based strategies, such as transfer of development rights.

Protection measures may include such tools as: low impact development requirements; revised stormwater management BMPs; planning and regulatory requirements to protect unique wetland features, such as flooded forests and blueberry bogs; incentives; and other tools to address environmental impacts of growth.

4. Continue to actively seek ways to partner with federal, state, and local agencies and non-profits to achieve the water quality and quantity and fish and wildlife habitat protections and improvements articulated in the Guiding Principles.

Continued partnership with federal, state and local agencies such as that initiated with the Siuslaw Estuary Partnership has potentially long lasting benefits for protecting and improving water quality and quantity and fish and wildlife habitat in the lower Siuslaw River Watershed. For example, the City is in the process of becoming part of the Oregon Department of Environmental Quality’s Volunteer Monitoring Program. This Program will enable the City to be part of a statewide water quality monitoring effort and will avail the City of valuable technical assistance in these efforts.

Issue #3: Wetlands and Riparian Areas

- [In the U.S.,] in general, rising sea levels will inundate coastal wetlands and other low-lying lands and intensify erosion and flooding as new areas are exposed to storm surges, waves, currents, and tides. Inundation, erosion, and flooding will threaten human health, coastal property, and infrastructure as well as coastal eco-

systems, especially those that cannot migrate inland or are sediment-starved. Any changes to these ecosystems will, in turn, affect the biological, ecological, and physical services they provide.¹¹⁹

- [In Oregon,] a rise in mean sea level will result in a comparable rise in water-table elevations in sand dune aquifers as well as alluvial aquifers hydraulically connected to tidally influenced estuaries. This could result in water-level rises and expansion of groundwater-fed lakes and wetlands in sand dune areas and other low-lying coastal settings.¹²⁰

Potential Strategies:

1. **Plan and implement wetland and riparian area protection measures that incorporate possible climate change impacts.**

The “Wetland and Riparian Area Protection Plan” is one of the products of the Siuslaw Estuary Partnership. This plan will include an updated inventory of fresh water wetlands and riparian areas and protection measures; it also will include measures to restore wetlands on City owned property. This plan should address the possible impacts of climate change so that, as more is known about the potential impacts, adjustments to the policies and implementing measures can be made to protect these areas for their key functions and values, particularly flood control and wildlife habitat. In addition, the Surface and Groundwater Monitoring Program modeling performed as part of the Siuslaw Estuary Partnership, will take into account the role of wetlands in the overall system of stormwater retention and groundwater recharge. This modeling can be expanded in the future to incorporate climate change impact scenarios.

2. **Build ecological resilience into a local wetland and riparian protection program.**

- a. Prioritize the protection of wetland ecosystem services that minimize the impacts of the likely effects of climate change - increased flooding, reduced water quality, and increased sea level rise.
- b. Protect locally significant wetlands and riparian areas that fit into a broader, landscape level conservation strategy that will allow species to migrate northward (ie. Wildlife corridors, connectivity of all conservation areas, etc.).
- c. Require any mitigation actions that offset impacts to wetland and riparian areas (or voluntary restoration projects) to meet larger landscape level conservation goals as set by the watershed council, ODFW conservation strategy, and/or other conservation plans.

¹¹⁹ *National Oceanic and Atmospheric Administration (NOAA). 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers.* NOAA Office of Ocean and Coastal Resource Management, p. 12.

¹²⁰ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 104

- d. Periodically, update the mapping and assessment of the Local Wetland Inventory to account for any changes, climate-related or not, in the location, extent and quality of wetlands.
- e. Set restoration goals on city-owned property that are focused on restoring ecosystem function (e.g. water quality) rather than single species management goals (e.g. coho salmon)
- f. Work across jurisdictional boundaries (with Lane County and BLM and USFS) with riparian and wetland protections to support landscape level conservation goals and to build ecological resilience.
- g. Avoid fragmentation of wetland complexes by incorporating the local wetland inventory into other planning efforts.
- h. Encourage connectivity of locally significant wetlands to adjacent conservation areas.
- i. Provide incentives to landowners for restoring and expanding protected riparian and wetland areas.
- j. Adopt local protections wetland buffers to reduce non climate stressors (land use) on wetlands and allow for changes in wetland area due to changes in hydroperiod (increased precipitation/sea level rise, etc.)
- k. Adopt an "early detection rapid response program" to keep invasive plant species populations under control or eradicate them in wetland and riparian areas on public and private property.
- l. Work with landowners to use native plants in their landscaping rather than potentially invasive exotic species.
- m. Incentivize through building permit fees low impact development practices (smaller building envelope footprints and alternative transportation infrastructure) to lessen encroachment into wetland and riparian areas.

3. Link wetland protection to drinking water and storm water management.

- a. Fund research on the influence of Florence's wetlands and riparian areas on protecting the EPA-designated sole source aquifer.
- b. Include a discussion on how to incorporate existing natural wetlands and drainage systems into stormwater planning.

Issue #4: Public Infrastructure and Long-range Planning

- [In Oregon,] coastal infrastructure will come under increased risk to damage and inundation under a changing climate with impacted sectors including transportation and navigation, coastal engineering structures (seawalls, riprap, jetties etc.) and flood control and prevention structures, water supply and waste/storm water systems, and recreation, travel and hospitality.¹²¹

¹²¹ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 210.

- [In Oregon,] increasing sea levels, wave heights and storm surges will increase coastal erosion and likely increase damage to private property and infrastructure situated on coastal shorelands. Coastal erosion, and the common response to reduce shoreland erosion, can lead to long-term loss of natural buffering functions of beaches and dunes.¹²²
- The potential exists for the Pacific Northwest to experience an influx of “climate refugees,” i.e., people relocating here from regions disproportionately affected by global climate change. This could increase the demands on social services, public municipalities, and local infrastructure and services.

Potential Strategies:

1. **Integrate consideration of potential climate change impacts into infrastructure planning, including evaluation of possible scenarios.**

Infrastructure planning now underway as part of the Siuslaw Estuary Partnership addresses drinking water and stormwater systems. In terms of drinking water, the project includes the examination of threats to the City’s and Heceta Water District’s drinking water sources, including potential threats from concentrated development dependent on septic systems. Municipal wastewater systems are also threatened by sea level rise and storm surges associated with climate change. As in most communities, the Florence wastewater plant is located in a low lying area, which poses an increased risk in the event of storm surges. Adaption planning can provide the basis for scenario planning to help the City and its partners minimize risks to these critical drinking water sources.

The inter-connectedness of groundwater and surface water in the Florence area will also be studied as part of the Siuslaw Estuary Partnership Project. A Stormwater Design Manual has been prepared to improve the design of stormwater systems that cause infiltration of stormwater into the ground, thus reducing overland flow and helping to reduce the impacts from flooding. On-going evaluation of these systems will help ensure they continue to function as intended and, as more is known about climate change impacts over time, this will enable the City to adapt these systems to anticipated increase in the frequency and intensity of storm events.

Similar steps can be taken to protect other critical infrastructure in and around Florence, including docks, the airport, and transportation facilities. Funding and inter-governmental cooperation, such as the team effort involved in the Siuslaw Estuary Partnership, could be pursued to ensure that climate change is factored into infrastructure planning at the local level.

¹²² *Oregon Climate Change Adaptation Framework*, State of Oregon, December 2010; p. ix.

Issue #5: Research Needs and Action Planning

- Uncertainty is still high in projecting future changes in runoff, water quality, and urban water demand in Oregon.¹²³
- [In Oregon,] there is little research on long term trends in water temperature in undisturbed watersheds; sites with long term data are rare. Sediment and phosphorus loads, which are a detriment to water quality, are expected to increase in winter as winter flow is projected to rise. It will be important for water resource managers statewide to include considerations for climate change in future planning.¹²⁴
- Like water quality, research on the impacts of climate change on groundwater has been minimal.¹²⁵
- More research is needed to determine to what extent climate change may influence estuarine water temperatures [in Oregon]. Since estuarine water temperatures are closely coupled to upwelling dynamics, improvement is needed in models which are used to predict changes in upwelling.¹²⁶
- Through various mechanisms, climate change has the potential to influence dissolved oxygen levels in estuaries; although to what extent this may happen is unknown at this time.¹²⁷

Potential Strategies:

1. Partner with DEQ, NFS, USGS, BLM, and NOAA to seek funding for and install weather stations from the crest to the beach.

Funding for the installation of these weather stations can be sought by the project partners; and the sooner they are installed, the better the information base that will be available to decision-makers in this area.

2. Conduct modeling to track historic patterns and predict future conditions.

As noted in this report, climate change impacts on several areas of the Oregon coast are currently being studied by federal and state agencies; the project partners could become actively engaged in pursuing similar studies, including model-

¹²³ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 70.

¹²⁴ *Ibid*, *Executive Summary*.

¹²⁵ *Global Climate Change Impacts in the United States*, U.S. Global Change Research Program, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; *Regional Climate Change Impacts: Northwest*, p. 135-138 and *Coasts*, p. 47.

¹²⁶ *Oregon Climate Change Assessment Report*, Dec. 2010, Oregon Climate Change Research Institute, p. 245.

¹²⁷ *Ibid*.

ing of historic and future conditions, for the lower Siuslaw watershed. This strategy could include the use of tools that are being developed to assess impacts of land cover changes and land use decisions on stormwater volume and quality, including one at Oregon State University. For Oregon's coastal zone, the SWAMP tool (stormwater assessment and management decision support process) is under development:

http://ciceet.unh.edu/living_coasts/projects/swamps.html

(Derek Godwin, principal investigator): <http://water.oregonstate.edu/staff>

Tools to evaluate nonpoint source pollution and run-off from different land use scenarios have been developed by NOAA, including NSPECT:

<http://www.csc.noaa.gov/digitalcoast/index.html>

Application of certain modeling or analytical tools can assist with planning decisions at a variety of spatial scales. For instance, several of the tools can be used to improve estimates of the effects of land use and development on changes in amount of impervious surfaces on stormwater quantity and quality. These pollutant estimates could subsequently be used in models to protect either surface or groundwater quality. Also, a number of hazard analysis tools have been developed. Building local and state capacity to apply those tools, or actively participate in multi-agency assessments that utilize the tools, should be a priority for the City and State and is consistent with Oregon's Coastal Management Program as well as the Coastal Nonpoint Pollution Control Program (CNPCP).

Tools are being/have been developed to assist with planning for both routine and extreme conditions for coastal environments. It is important to identify these and develop a plan for applying some of those resources. Depending on the specific application, an increasing amount of data and sophistication in analyses and forecasting (modeling) is needed. It has long been recognized that additional tools are needed for improving protection of infrastructure and natural habitats, requiring coordinated efforts among multiple government agencies. A primary resource for coastal managers is the NOAA Coastal Services Center:

<http://www.csc.noaa.gov/> and associated "Digital Coast":

<http://www.csc.noaa.gov/digitalcoast/index.html>

One strategy developed for a multi-purpose coastal observational network is: [A Strategic Plan for an Enhanced Coastal Observational System and Predictive Hydrodynamics Model for Improved Management of the Coos Bay Estuary, Oregon](#) (NOAA, August 2005). This plan (not yet funded or implemented) provides a template for the design of an observational system for the Siuslaw estuary and Port of Florence. Although not focused specifically on identifying climate change indicators or a response to climate change, the Strategy identifies many of the factors that need to be addressed by a monitoring network to identify changes that may be in response to larger scale climatic conditions, including: (a) provide the information needed to protect infrastructure, (b) prepare for, and respond to, situations affecting public safety, (c) perform environmental monitoring of estuaries and tidal wetlands, and others. The implementation of such monitoring net-

works is within the scope of what can be accomplished through coordinated local-state-federal partnerships, and represents an investment that can assist with many of the challenges facing coastal communities, including those that may be associated with impacts of climate change.

3. Based on the results of the above research projects, prioritize actions to monitor indicators of climate change, to respond to consequences of climate change (or even abnormal weather patterns and events), and implement “Potential Strategies.”

One strategy with watershed plans, and similar assessment and action plans, is to capture the specific high priority actions or strategies that the staff team, stakeholders, and public identified in the process, and frame them in a way that can be used to set strategic directions and pursue funding opportunities.

The Table below, *Climate Change Adaptation Measures* is a good example of the type of action plan that could be prepared to address the climate change impacts identified in this report. This table was excerpted from the report, *National Oceanic and Atmospheric Administration (NOAA), 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers*. The impacts and measures presented apply to coastal areas across the United States. The task here would be to prepare a similar action plan that applies specifically to the lower Siuslaw River Watershed. For example, for “Increasing Air Temperature” and several other “Climate Change Phenomenon,” a priority action might be to establish a more robust system of weather monitoring stations from “Crest to Coast,” maintained by a coordinated effort, to collect data to be used to assess trends in regional-landscape-local scale climate conditions. Such data would be extremely valuable for such groups as natural resource managers, planners, agriculture, forestry, fisheries, and others, irrespective of the degree to which global climate change is affecting local weather/climate patterns. Similarly, for “Increasing Water Temperature,” a priority action could be to propose establishing a more robust regional-landscape-local scale monitoring network.

The City, through the Siuslaw Estuary Partnership, has taken important steps with the current Surface and Groundwater Monitoring Program, which could serve as a template for an expanded network in the lower Siuslaw to match up with monitoring efforts in other areas of the watershed. Integration of such efforts would clearly be needed in order to assess overall watershed patterns and trends. The Siuslaw Watershed Council’s *Tidal Wetland prioritization* and the Inforain/Ecotrust’s *A Watershed Assessment for the Siuslaw Basin* (January 2002) are some examples of this approach. Another is the *Oregon Climate Change Adaptation Framework* which identifies likely risks associated with future climate conditions; assesses the capabilities of state agencies to address those future conditions; and identifies priority short-term actions to reduce the potential for costly consequences for life, property, resources, and infrastructure from the effects of climate change.

4. Encourage state and federal agencies to focus research efforts on areas where there are currently large data gaps in OWEB Restoration Priorities for the Siuslaw.

Oregon Watershed Enhancement Board (OWEB) Partnerships developed “Limiting Factors” analyses for salmonid populations and other sensitive fisheries throughout Oregon (Summary of the Watershed Health Indicators for the Oregon Coast Coho ESU 2007 (Watershed Professionals Network, LLC, January 2009, 2008). These analyses provide valuable information regarding conditions currently affecting salmonid populations of concern, and in some cases, rank them according to relative risk. Gaps in the information for assessing Limiting Factors are often associated with other gaps in our knowledge of conditions that affect these populations and provide a roadmap to future data collection and assessment priorities that would seem to be closely linked to the types of information needed to monitor many environmental conditions, including those that may be associated with climate change. OWEB Restoration Priorities for the Siuslaw strategies are needed for those areas where there are large data gaps (i.e., Page 32, Table 22):

http://www.oregon.gov/OWEB/docs/pubs/Rest_Priorities/OR_CoastCohoESU_Priorities.pdf

Climate Change Adaptation Measures

Measure	Phenomenon								Environment	
	Increased Air Temperature	Rising Sea Levels	Declining Lake Levels	Increased Storm Intensity/Frequency	Increased Precipitation	Decreased Precipitation	Increased Water Temperature*	Ocean Acidification*	Natural Environment	Built Environment
Impact Identification and Assessment										
Research and Data Collection	x	x	x	x	x	x	x	x	x	x
Monitoring	x	x	x	x	x	x	x	x	x	x
Modeling and Mapping	x	x	x	x	x	x	x	x	x	x
Awareness and Assistance										
Outreach and Education	x	x	x	x	x	x	x	x	x	x
Real Estate Disclosure		x	x	x	x				x	x
Financial and Technical Assistance	x	x	x	x	x	x	x	x	x	x
Growth and Development Management										
Zoning		x		x	x	x			x	x
Redevelopment Restrictions		x		x	x				x	x
Conservation Easements		x	x	x	x				x	x
Compact Community Design		x		x	x				x	x
Loss Reduction										
Acquisition, Demolition, and Relocation		x		x	x				x	x
Setbacks		x		x	x				x	x
Building Codes	x	x		x	x	x			x	x
Retrofitting	x	x	x	x	x	x			x	x
Infrastructure Protection	x	x	x	x	x	x			x	x
Shore Protection Structures		x		x	x				x	x
Shoreline Management										
Regulation and Removal of Shore Protection Structures		x		x	x				x	x
Rolling Easements		x		x	x				x	x
Living Shorelines		x		x	x				x	x
Beach Nourishment		x		x	x				x	x
Dune Management		x		x	x				x	x
Sediment Management		x	x	x	x				x	x
Coastal and Marine Ecosystem Management										
Ecological Buffer Zones	x	x	x	x	x				x	x
Open Space Preservation and Conservation	x	x	x	x	x	x			x	x
Ecosystem Protection and Maintenance	x	x	x	x	x	x	x	x	x	x
Ecosystem Restoration, Creation, and Enhancement	x	x	x	x	x	x	x	x	x	x
Aquatic Invasive Species Management	x						x		x	
Water Resource Management and Protection										
Stormwater Management		x	x	x	x			x	x	x
Green Infrastructure		x	x	x	x	x		x	x	x
Water Supply Management		x	x	x	x	x			x	x

* The impacts of increased water temperature and ocean acidification are best managed by reducing the impacts of existing stressors and supporting healthy ecosystems.

Source: National Oceanic and Atmospheric Administration (NOAA), 2010. *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA Office of Ocean and Coastal Resource Management, p. 51.

IV. Resources

Global Research and International Programs

Intergovernmental Panel on Climate Change (IPCC): www.ipcc.ch/

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization and the United Nations Environment Program. The IPCC was established to provide an objective source of information about climate change. In the last twenty years, the IPCC has produced four assessment reports, which are probably the most comprehensive global-scale assessments of the science of climate change. The IPCC's work provides the foundation for international discussions and agreements to address the causes of climate change. Virtually any effort to understand climate change in any of its dimensions is likely to end up relying on IPCC publications.

ICLEI-Local Governments for Sustainability: <http://www.icleiusa.org/about-iclei>

ICLEI is an international membership association of local governments, started in 1995, dedicated to climate protection and sustainable development. The organization was initiated in 1990 when more than 200 local governments from 43 countries convened at the World Congress of Local Governments for a Sustainable Future, at the United Nations in New York. Established as the International Council for Local Environmental Initiatives, the official name is now ICLEI-Local Governments for Sustainability.

The most common reason local governments join ICLEI is for assistance with their climate mitigation work: reducing greenhouse gas emissions. Part of their climate mitigation work is the Five Milestones to assist US local governments in developing and implementing harmonized local approaches for reducing global warming and air pollution emissions, with the additional benefit of improving community livability. The Five Milestones are: 1. Conduct a baseline emissions inventory and forecast; 2. Adopt an emissions reduction target; 3. Develop a Local Climate Action Plan; 4. Implement policies and measures; and 5. Monitor and verify results.

United States Research and Case Studies

U.S. Environmental Protection Agency State and Local Climate and Energy Program, <http://www.epa.gov/statelocalclimate/index.html>

EPA's State and Local Climate and Energy Program provides technical assistance, analytical tools, and outreach support to [state](#), [local](#), and [tribal](#) governments. Specific assistance includes:

- Identifying and documenting cost-effective policies and initiatives that address climate change, including those that promote renewable energy, energy efficiency, and related clean technologies.
- Measuring and evaluating the environmental, economic, and public health benefits of climate change and clean energy initiatives.
- Offering tools, guidance, and outreach support for assessing the options and benefits of actions to reduce greenhouse gas emissions.
- Fostering peer exchange opportunities for state and local officials to share information on best practices and lessons learned about innovative policies and programs.

This Climate Change Report for the Siuslaw Estuary Partnership project focuses on the Local Climate and Energy Program: <http://www.epa.gov/statelocalclimate/local/index.html>; This Program helps local governments meet multiple sustainability goals with cost-effective climate change mitigation and clean energy strategies. EPA provides local governments with peer exchange training opportunities and competitive grant funding along with planning, policy, technical, and analytical information that support reduction of greenhouse gas emissions and advance their climate change mitigation and clean energy goals.

Climate Ready Water Utilities Toolbox: U.S. Environmental Protection Agency Web Site, <http://www.epa.gov/safewater/watersecurity/climate/toolbox.html>

The Climate Ready Water Utilities (CRWU) Toolbox provides access to resources containing climate-related information relevant to the Water Sector. These resources include several categories of information and can be searched by geographic region, water utility type and size, water resources, climate change impact, and climate change response strategies. These resources will be updated frequently to provide the most current Water Sector climate change information.

National Oceanic and Atmospheric Administration (NOAA). 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers. NOAA Office of Ocean and Coastal Resource Management

This guide was prepared in 2010 by the National Oceanic and Atmospheric Administration (NOAA) in order to give state coastal managers a guide to follow in developing and implementing strategies to adapt to climate change. This guide is an excellent resource for Florence City leaders and managers to learn about the possible local effects of climate change and to gain insights into planning and response strategies pertaining to coastal erosion, stormwater management, drinking water quality and quantity, and habitat protection. Key Resources are noted at the end of each chapter. Additional resources can be found on the NOAA Coastal Services Center Coastal Climate Adaptation web site: <http://collaborate.csc.noaa.gov/climateadaptation/> and on NOAA's Climate Portal at www.climate.gov/. Key resources used in preparing this Guide are:

- *Global Climate Change Impacts in the U.S.* (2009) (and associated reports, 2006-2009)—U.S. Global Change Research Program (formerly the U.S. Climate Change Science Program)¹²⁸
- *Intergovernmental Panel on Climate Change Fourth Assessment Report* (2007)
- The Federal Emergency Management Agency’s Mitigation Planning “How-To” Guides (2001-2008)
- *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (2007)—ICLEI—Local Governments for Sustainability
- *Synthesis of Adaptation Options for Coastal Areas* (2008)—U.S. Environmental Protection Agency, Climate Ready Estuaries Program
- *Coastal No Adverse Impact Handbook* (2007)—Association of State Floodplain Managers and the NOAA Coastal Services Center
- *Adapting to Coastal Climate Change: A Guidebook for Development Planners* (2009)—U.S. Agency for International Development

Global Climate Change Impacts in the United States, U.S. Global Change Research Program (formerly the U.S. Climate Change Science Program), Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009; esp., *Regional Climate Change Impacts, Northwest*, pp. 135-138; and *Coasts*, pp. 149-152. <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>

The U.S. Global Change Research Program (USGCRP) supports research on the interactions of natural and human-induced changes in the global environment and their implications for society. The USGCRP began as a presidential initiative in 1989 and was codified by Congress in the [Global Change Research Act of 1990](#) (P.L. 101-606), which mandates development of a coordinated interagency research program. Participants in the USGCRP include:

- [Agency for International Development](#)
- [Dept. of Agriculture](#)
- [Dept. of Commerce, Natl. Oceanic & Atmospheric Admin.](#)
- [Dept. of Defense](#)
- [Dept. of Energy](#)
- [Dept. of Health and Human Services, National Institutes of Health](#)
- [Dept. of State](#)
- [Dept. of Transportation](#)
- [Dept. of the Interior, US Geological Survey](#)
- [Environmental Protection Agency](#)
- [National Aeronautics & Space Administration](#)
- [National Science Foundation](#)
- [Smithsonian Institution](#)

¹²⁸ “*Global Climate Change Impacts in the United States* is the most comprehensive and authoritative report on the current and future impacts of climate change on the United States.” *Adapting to Climate Change*, NOAA, 2010, p. 4.

The Office of Science and Technology Policy, the Office of Management and Budget, and the Council on Environmental Quality provide oversight on behalf of the Executive Office of the President.

Since its inception, USGCRP-supported research and observational activities, in collaboration with several other national and international science programs, have documented and characterized important aspects of the sources, abundances, and lifetimes of greenhouse gases; mounted extensive space-based systems for global monitoring of climate and ecosystem parameters; begun to address the complex issues of various aerosol species that may significantly influence climate parameters; advanced understanding of the global water and carbon cycles; and taken major strides in computer modeling of the global climate. For greater detail, see the [Overview of U.S. Research on Climate and Global Change](#) on the site of the Climate Change Science Program. See also [Participating US Agencies and their Programs](#).

Emerging Issues: Improving Resilience Against the Effects of Climate Change, by Frederick Bloetscher, Journal AWWA, American Water Works Association, November 2010.

This article reports the results of a case study conducted by Florida Atlantic University on the City of Pompano Beach, Florida. The case study was funded by the National Commission on Energy Policy to assess vulnerable infrastructure and present strategies that could address the effects of climate change/sea level rise on that infrastructure. Pompano Beach was selected because it is a coastal water and sewer utility; it applies state-of-the-art treatment processes; and because of its: population size and area served; access to reclaimed water; vulnerability to saltwater intrusion; technical capabilities of staff; experience addressing water, wastewater, and stormwater issues and challenges; and interest in participating. The complexities of the surface water/groundwater interface in the face of sea level rise, which is the predominant issue for Pompano Beach, were evaluated. The case study provides valuable insights into potential adaptation strategies for the City of Florence, as reported in Chapter III of this report.

Oregon and the Pacific Northwest Research

Oregon Climate Change Assessment Report, Oregon Climate Change Research Institute, December 2010, K.D. Dello and P.W. Mote (eds). College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR; www.occri.net/OCAR; and Chapter 6. Impacts of climate change on Oregon's coasts and estuaries Peter Ruggiero, Cheryl A. Brown, Paul D. Komar, Jonathan C. Allan, Deborah A. Reusser, and Henry Lee, II

The Oregon Climate Change Research Institute (OCCRI) is a network of over 100 researchers across the Oregon University System and affiliated state and federal labs. OCCRI was established in 2007 by the Oregon State Legislature to

foster climate change research across the Oregon University System. OCCRI is housed in the College of Oceanic and Atmospheric Science at Oregon State University.

Most of the information in this Siuslaw Estuary Partnership Climate Change Report that is specifically relevant to the Oregon coast and estuaries was excerpted from the Oregon Climate Change Assessment Report. The report contains detailed scientific data, analyses, and findings that provide a more comprehensive picture of climate change impacts than is feasible with this Siuslaw Estuary Partnership Climate Change Report. Of particular interest and relevance is the following text pertaining to the relationship between climate change, El Niño/Southern Oscillation (ENSO), and Pacific Decadal Oscillation (PDO) on pages 18 and 19 of the Oregon Climate Change Assessment Report.

“Temporal patterns [variations in time] of climate variability in the Northwest are strongly influenced by variations over the Pacific Ocean, chiefly El Niño/Southern Oscillation (ENSO). ENSO involves linked variations in the tropical Pacific Ocean and overlying atmosphere. Most of the time, the warmest water lies north of Australia and the presence of the warm water draws warm moist air, which forms thunderstorms. Hence, the warmest water coincides with heavy precipitation. The air rising in thunderstorms is part of an equator-to-subtropics circulation called the Hadley Circulation, which is part of the global energy cycle and affects atmospheric circulation throughout the globe.

Before an El Niño event, something happens to disrupt the normal distribution of sea surface temperature, winds, and precipitation. Both the warm water and the heavy precipitation move eastward, with warm water anomalies appearing along the equator as far as the South American coast. (In fact, the name El Niño, for “the [Christ] child” was given centuries ago by fishermen who noticed the periodic disruption of the productive fisheries by warm water near Christmas). A typical El Niño event begins during northern hemisphere summer or fall, peaks around late December with warm water anomalies of 1 °C or more along the equator, and then fades during northern hemisphere spring, often followed by an accentuated return to normal conditions, called La Niña as an antonym of El Niño. On average, El Niño events occur once per four years, but they have occurred in successive years.

During the El Niño phase of ENSO, the wintertime jet stream tends to split, with warmer air flowing into the Northwest and Alaska, and a southern branch of the jet stream directing unusually frequent and heavy storms toward southern California. During El Niño winter and spring, Oregon’s climate is slightly more likely than usual to be warm and dry. The effect is more pronounced farther north into British Columbia.

One manifestation of ENSO in the North Pacific has been termed the Pacific Decadal Oscillation (PDO), so named because in 20th century records, variations in north Pacific sea surface temperature (SST) patterns appear to have phases lasting 20 - 30 years (Mantua et al., 1997). However, paleo reconstructions of the PDO using tree rings (e.g., Gedalof et al., 2002) indicate a similar behavior of the PDO from the mid-18th to early 19th century, then very different behavior in the succeeding 100 years. Also, after 1998 the PDO index has shown no evidence of decadal persistence. In addition, Newman et al., (2003) show that the best statistical model of the PDO treats it not as a distinct pattern of variation independent of ENSO, but simply a slow North Pacific response to ENSO forcing. Furthermore, linear trends over periods of a few decades can be affected by the phases of ENSO and PDO.”

Oregon Department of Energy Web Site:

<http://www.oregon.gov/ENERGY/GBLWRM/Portal.shtml>

This site provides up-to-date information on Climate Change Reports prepared relevant to the State of Oregon.

Oregon Climate Change Adaptation Framework Report, State of Oregon, December, 2010. <http://www.oregon.gov/ENERGY/GBLWRM/Portal.shtml>

This report was prepared by a work group of State agencies and groups to complement the Oregon Climate Change Assessment Report. Work Group participants represented the following: Department of Agriculture, Department of Energy, Department of Environmental Quality, Department of Fish and Wildlife, Department of Forestry, Department of Geology and Mineral Industries, Department of Human Services, Public Health Division, Department of Land Conservation and Development, Parks and Recreation Department, Department of State Lands, Department of Transportation, Water Resources Department, Oregon Watershed Enhancement Board, Oregon Climate Change Research Institute, Climate Leadership Initiative, Oregon Sea Grant, Oregon State University Extension Service, Oregon State University Institute for Natural Resources, Global Warming Commission, Office of the Governor, Business Oregon.

A Framework for Addressing Rapid Climate Change, State of Oregon, January 2008, The Governor’s Climate Change Integration Group, Final Report to the Governor.

In 2007, the Oregon Legislative Assembly enacted House Bill 3543, Section 15, which created the Oregon Climate Change Research Institute (OCCRI). “OCCRI will engage faculty from throughout the Oregon University System. The OCCRI is directed to:

- (a) Facilitate research by Oregon University System (OUS) faculty on climate change and its effects on natural and human systems in Oregon;
- (b) Serve as a clearinghouse for climate change information;

- (c) Provide climate change information to the public in integrated and accessible formats;
- (d) Support the Oregon Global Warming Commission in developing strategies to prepare for and to mitigate the effects of climate change on natural and human systems; and
- (e) Provide technical assistance to local governments to assist them in developing climate change policies, practices and programs.

In addition, OCCRI is directed to assess, at least once each biennium, the state of climate change science, including biological, physical and social science, as it relates to Oregon, and the likely effects of climate change on the state and submit the assessment to the Legislative Assembly and to the Governor.”¹²⁹

Oregon Watershed Enhancement Board (OWEB) and The Climate Leadership Initiative (CLI) <http://www.oregon.gov/OWEB/index.shtml>

In 2008, OWEB established plans to engage in climate change preparedness and adaptation. Then in the summer of 2008, the Board contracted with Oregon State University to study the impact of the severe 2007-2008 winter rain and wind storm to gather early indications about restoration project performance information in light of a changing climate. Next, the Board established a theme and focused a large section of the 2008 Biennial Conference on climate change learning and exploration. Finally, in March of 2009, a narrower set of research priority focus areas were adopted by the Board, including focus areas on climate change through the evaluation of water availability under a changing climate, establishment of forums for understanding and planning for local watershed impacts, the compilation and analysis of projected sea level rise impacts on coastal communities, and the terrestrial considerations of invasive species and wildfires.

The Climate Leadership Initiative (CLI) was established in 2005 under The Resource Innovation Group, a 501(c)(3) organization, with the specific mission of fostering the development and application of innovative thinking and approaches to the complex causes and solutions to climate change. In 2008 and 2009, the CLI established their first locally-based “Climate Future Forums” in both the Rogue River and Upper Willamette River basins to begin a discussion about climate change adaptation with local planners and key decision makers. In June of 2009, the Board provided funding to expand this effort to other basins including the Klamath River, in both Oregon and California, and the lower Willamette River and tributaries.

Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest, Product of the Impacts of Climate Change on the Pacific Northwest

¹²⁹ *A Framework for Addressing Rapid Climate Change, State of Oregon*, January 2008, The Governor’s Climate Change Integration Group, Final Report to the Governor; p. 63.

Scientific Meeting, June 2004.

http://inr.oregonstate.edu/download/climate_change_consensus_statement_final.pdf

In 2004 a group of scientists from the Pacific Northwest convened at Oregon State University to review evidence for climate changes in our region and to evaluate the likely impacts of further changes. They shared their findings through a “Scientific Consensus Statement on the Likely Impacts of Climate Change on the Pacific Northwest.”

Siuslaw Watershed

A Watershed Assessment for the Siuslaw Basin, Executive Summary, Inforain, Ecotrust, January 2002: www.inforain.org/siuslaw/.

Inforain is a project of Ecotrust, a conservation organization based in Portland, Oregon. Dedicated to knowledge integration, Ecotrust brings together expertise in areas that include: spatial analysis, web-based applications development and socio-economic assessment. Offering data for download, utilizing open-source technologies and publishing under Creative Commons licenses, this website embodies Ecotrust’s commitment to open, adaptive and collaborative learning.

Since 1996, Inforain has presented an online atlas for the temperate rain forest / Pacific salmon region of North America. Collected there are the results of their ongoing project to describe and model land- and sea-scape productivity across the region, and to quantify and assess the social, ecological and economic benefits of alternative resource management systems.

Pacific Coast Watershed Partnership Web Site: The Siuslaw Basin

<http://www.pacificwatersheds.net/coastalnetwork/siuslaw.htm>

The Pacific Coast Watershed Partnership is one of fifteen Large Scale Watershed Restoration Demonstration Projects sponsored by the Forest Service throughout the United States. Since September of 1999, individuals from many state and federal agencies along with private and volunteer groups have been working together to shape the concept of the Pacific Coast Watershed Partnership. In 2003, Ecotrust was awarded a grant to coordinate the PCWP and to help the partnership accomplish its goals.

Salmon and Steelhead Recovery Tracker Web Site, Oregon Department of Fish and Wildlife and Ecotrust, launched September 10, 2010. <http://odfwrecoverytracker.org/>

Web site for Siuslaw River is: http://odfwrecoverytracker.org/species/coho/ind_pop/11/

The State of Oregon maintains conservation and recovery plans for populations of salmon and steelhead listed as threatened or endangered under the Endangered Species Act (ESA). These conservation and recovery plans set goals for measurable viability criteria. Analyses of these criteria are reported on this web

site. Additional data are also available for download. Updates since the beta release include a more streamlined site design, improved metadata delivery, and new datasets including site-specific abundance and site descriptions. The site is currently focused on coastal coho salmon, though there are some additional datasets available for download. Future versions of the site will include data on other species and in other regions.

Implications of Recent Sea Level Rise Science for Low-elevation Areas in Coastal Cities of the Conterminous U.S.A. Climatic Change DOI 10.1007/s10584-011-0024-

x. Weiss, J.L., J.T. Overpeck, and B. Strauss. 2011.

http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/mapping_slr/mapping_slr.htm

This recent work of Weiss and Overpeck, University of Arizona, has centered on the analysis of digital elevation models (DEMs) to help delineate low-elevation coastal areas. The mapping tool they developed allows for estimation of inundation areas resulting from one, two, and three meters [about three feet to ten feet] of sea level rise. The abstract available through the link explains in detail the limitations of the tool, particularly as it applies to the Pacific coast. They provide results from their elevation data analyses through the Web map visualization tools on the web page above. Analyses based on DEMs with a horizontal resolution of 1 km give an overview of low-lying coastal areas at regional scales. Analyses stemming from DEMs with a horizontal resolution of 30 m allow for viewing at more local scales.

Appendix A

Guiding Principles and Measurable Outcomes For the Siuslaw Estuary Partnership

Endorsed by Florence City Council September 21, 2010

Also Endorsed by the Siuslaw Watershed Council, Siuslaw Soil and Water Conservation District, Heceta Water District, Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians, and the Lane County Board of Commissioners

1. Public Education and Stewardship

Guiding Principles

1. Promote public education and stewardship activities that increase public awareness of water quality and fish and wildlife facts and issues within the lower Siuslaw River Watershed and North Florence Dunal Aquifer.
2. Work toward common knowledge of water quantity and quality conditions and threats, including the environmental impacts of development, and decision-making reliant on facts based on field data.
3. Cooperate and coordinate among local governments and non-profits, service clubs, the travel industry, and the media to foster and promote public education and stewardship programs to protect water quality and fish and wildlife habitat.
4. Cooperate and coordinate among federal-state-local inter-agency staff, including emergency responders, in the development and implementation of water quality and fish and wildlife protection policies and programs.
5. Involve all citizens, and especially local retired citizens and youth, as stewards of wetland and riparian area resources, and seek their active participation in maintenance and restoration activities.
6. Work with the development community to increase their awareness of, and concern for, water quality and fish and wildlife habitat; and encourage them to actively seek new and innovative ways to design stormwater systems in a manner that best achieves water quality and quantity objectives.
7. Promote good stewardship of water resources in public education and communication programs as a way to foster livability and help protect surface and groundwater resources from cumulative impacts.
8. Provide public information on how personal choices and actions affect watershed health.

Measurable Outcomes

Please note: These are provided for illustrative purposes only. Endorsement of Outcomes is not requested or required.

Short Term Outcomes

1. Target population groups with internet access have the opportunity to obtain up-to-date information about the project.
2. 9,000 households and businesses have received information about water quality and fish and wildlife facts, issues, and projects in the watershed.
3. Two newspaper articles published or radio reports per year and one TV exposure during project.
4. All who live around or visit Clear Lake are informed of the importance of protecting the lake as a drinking water source through signage around the lake.
5. Over 200 people have signed up on the interested parties list to learn more about the project.
6. Targeted outreach is provided to three groups per year .
7. Five interest groups participate in the planning process, for example as stakeholders.
8. Project discussions that occur at City Planning Commission and City Council meetings are televised and shown repeatedly during the week on TV.
9. Participation of study area population in Siuslaw Watershed Council native plant distribution increases;
10. Ten volunteers help on the project, for example on the wetlands inventory and water quality testing and stewardship projects.
11. There is increased involvement in one or more activities hosted by Stakeholder Groups.
12. There is increased use of stormwater BMPs as noted in planning approval process.
13. The Stormwater Demonstration Project is completed and includes interpretation of the estuary and innovative stormwater management techniques.
14. Ten public agencies or community organizations put links to project on agency web site and four put information on their web site about the project.
15. Twenty referrals to agency web sites are made through the project web site.
16. Ten Stakeholder Groups and seven Elected Official Stakeholder Groups appoint a member.
17. Forty people attend open houses and they are geographically distributed in study area, based on “where do you live map.”
18. Twenty people are knowledgeable about the project and they in turn share this knowledge with their group’s members, spreading the word to over

- 200 people.
19. Preliminary assessment for Estuary Interpretive Trail is completed, setting the stage for future planning of the trail as an environmental interpretation tool.

Medium Term Outcomes

1. 50% of the population in the urban growth boundary become aware of issues pertaining to water quality and quantity in the study area (i.e., the aquifer, the estuary, Clear Lake, Munsel and Ackerley Creeks, and the ocean/beach area).
2. 20% of the population is aware of climate change and its potential effect on water quality and quantity in the Florence area.
3. News stories continue to be written tracing the progress of City programs to protect water quality and quantity.
4. Clear Lake is protected from contamination threats, due to increased education about the lake as a drinking water source.
5. Interested parties continue to be informed of and participate in environmental protection efforts in the community.
6. Key interest groups participate in future planning processes to protect the environment.
7. Local community leaders from the City, the Water District, etc. place an emphasis on local programs and plans to protect surface and groundwater quality in the Florence UGB.
8. Volunteers sign up to be involved in on-going stewardship programs, such as invasive plant abatement and monitoring vegetation along stream banks.
9. Inter-governmental cooperation and coordination focuses on programs that will achieve mutual environmental goals and objectives.
10. Federal-State-local inter-agency coordination promotes the exchange of ideas, information, and programs to ensure on-going protection of the resources.

Long Term Outcomes

1. Heightened awareness of the vulnerability of habitat and drinking water sources leads to permanent protection of the aquifer, Clear Lake, other area lakes, high priority tidal and fresh water wetlands, creeks, and the beach.
2. Local retired citizens and school children are actively involved in wetland and riparian area maintenance and restoration activities.
3. Developers and builders actively seek new and innovative ways to design stormwater systems in a manner that best achieves water quality and quantity objectives.
4. Public education and communication programs promote good stewardship of water resources as a way to foster livability and help protect surface

and groundwater resources from cumulative impacts.

2. Water Quality and Quantity

Guiding Principles

1. Protect water quality for human consumption in the North Florence Sole Source Dunal Aquifer and Clear Lake from known contamination threats; and adopt plans and strategies to respond to potential threats.
2. Protect the quality of water in surface waters, i.e., the estuary, creeks, lakes, wetlands, and ocean/beach, from contamination threats that could impair the quality of the water for fish and wildlife habitat and human recreation.
3. Protect water quality in ground and surface waters from the effects of urbanization through land use and development policies and procedures.
4. Understand the natural state of water quantity and quality through the establishment of base line data and a surface and groundwater assessment and monitoring program and through research and monitoring of climate change.
5. Protect the water storage function of wetlands and water flow in creeks and the estuary through water management planning and practices that maintain groundwater levels and surface water flows so that they do not impair water quality or impact fish and wildlife habitat.
6. Prevent adverse flooding conditions through natural storage and slow release of surface water and runoff.
7. Locate, design, and operate production wells so that they do not reduce groundwater at levels below that necessary to support fish and wildlife habitat.
8. Foster and support the design and use of innovative stormwater management practices, including the incorporation of properly-designed constructed wetlands into public and private stormwater systems.
9. Tailor stormwater management plans and practices for new development and re-development to the Oregon coastal environment in a manner that can adapt to changes in temperature and precipitation, and other notable climate change impacts.
10. Promote water conservation through efficient landscape and irrigation, including water reuse and recycling, and other strategies to reduce water

consumption, to reduce the need for new drinking water sources and/or expanded water storage.

Measurable Outcomes

Please note: These are provided for illustrative purposes only. Endorsement of Outcomes is not requested or required.

Short Term Outcomes

Water Quantity

1. Existing conditions (base line data) are known for aquifer flow patterns (volume, direction, and speed) and water table levels and seasonal variability
2. Model and data capacity exist to evaluate how future production well sites might affect groundwater flow, wetlands, and overall aquifer production.
3. Storage capacity of aquifer and wetlands is known; information is used to inform City Stormwater System Plans and projects (*note: this needs to be combined with wetlands outcomes worksheet*).
4. Baseline data are better understood on the impact of groundwater flow (water quantity) into Munsel and Ackerley Creeks, the estuary, the ocean/beach, Clear Lake, and wetlands.
5. Existing hydrograph conditions (baseline data) for Munsel and Ackerley Creeks will be established.
6. Impacts of fluctuation in rainfall (short term) are known, to the extent a transient model or another measuring tool is available to the Project.
7. Impacts of land use on the water table are better understood.
8. Sites for new city production wells are identified.
9. Risk (e.g., overloading) to groundwater of artificial infiltration of stormwater is reduced through modeling results and analyses.
10. Flood storage is improved through the protection of natural areas with flood storage capacity, thus, preventing further impacts to the hydrograph of the aquifer and surface waters.

Water Quality

1. Existing conditions of water quality in aquifer (background levels for each constituent included in the Quality Assurance Project Plan) are established.
2. Impacts of land uses on surface water and groundwater quality are better understood.
3. Appropriate trigger levels are set for groundwater contaminant concentration.
4. Variability of contaminant concentrations in the area is established.
5. Variability of contaminant concentrations as a function of season is determined.

6. Existing aquifer contamination is identified, assessed, and corrected, as feasible.
7. Contamination threats are identified, assessed, and prioritized for strategies in the Source Water Protection Plan.
8. Potential threats to drinking water from contaminated storm runoff and surface contaminants being carried into the aquifer via percolation are better understood and addressed or prioritized for future actions
9. Preliminary baseline data are established for existing conditions of water quality in Munsel and Ackerley Creek and estuary and marine as specified in the Quality Assurance Project Plan.
10. Impacts of Stormwater Demonstration Project on estuary water quality, as specified in the Quality Assurance Project Plan, are known and any modifications to BMPs that are indicated are made.
11. Goals and strategies for protecting water quality in the aquifer are agreed upon and submitted for local adoption and State approval.
12. Risk to groundwater quality of artificial infiltration of stormwater is reduced.
13. Impacts of stormwater runoff to water quality in estuary are evaluated and reduced as data become available.
14. The impacts from septic systems, if any, to the water quality of the aquifer are better understood, and if necessary management actions can be developed and implemented.

Fish and Wildlife Habitat

1. Human-induced and naturally occurring changes in water levels in wetlands and area lakes from water table fluctuations are understood, and the effects on fish and wildlife habitat are better understood, through the data collection, analysis, and modeling described in the Quality Assurance Project Plan.
2. Impacts of stormwater outfalls on the hydrograph of Munsel Creek are known, and the effects on fish habitat are better understood.
3. Preliminary threshold level, i.e., allowable drop in water table, is set that does not have a significant impact on lakes, streams and wetlands, as determined through data collection, analysis, and response.
4. Preliminary threshold level, above, is considered in location of new production wells.
5. If a transient model is available, recharge capacity can be gauged and different impervious surface scenarios can be evaluated. As a result, the potential threats to fish and wildlife from water quantity impacts of runoff and groundwater flowing into surface waters will be better understood and addressed or prioritized for future actions.
6. Effect of land uses on surface water quantity, and thus fish and wildlife habitat and human contact recreation, is better understood.
7. Runoff and groundwater contaminants flowing into Clear Lake, Munsel and Ackerley Creeks, wetlands, estuary, and ocean/beach are better understood. As a result, water quality data will provide a basis for better un-

- derstanding the effects on fish and wildlife habitat.
8. Potential threats (e.g., pharmaceuticals) to fish and wildlife from runoff and groundwater contaminants flowing into surface waters are better understood and addressed or prioritized for future actions.
 9. Effect of land uses on surface water quality, and thus fish and wildlife habitat, is better understood.
 10. Source Water Protection Plan is aligned with Goals and Strategies for protecting fish and wildlife habitat.
 11. Production well sites selected do not cause water levels in creeks and wetlands to go below threshold levels set above.
 12. New stormwater practices reduce impacts to fish and wildlife habitat by reducing pollutants entering surface waters through groundwater seepage and by reducing stormwater discharge impacts to wetlands and the hydrograph of Munsel Creek.
 13. Stormwater Demonstration showcases state-of-the-art Best Management Practices in established commercial area adjacent to an estuary with high habitat values.

Medium Term Outcomes

Water Quantity

1. Aquifer flow patterns (volume, direction, and speed) and water table levels and seasonal variability are monitored and better understood.
2. Future production well sites are evaluated for their potential effect on groundwater flow, wetlands, and overall aquifer production.
3. City Stormwater System Plans and projects take into account the storage capacity of aquifer and wetlands.
4. The impact of groundwater flow (water quantity) into Munsel and Ackerley Creeks, the estuary, the ocean/beach, Clear Lake, and wetlands is monitored and better understood.
5. Hydrograph conditions for Munsel and Ackerley Creeks are better understood.
6. Stormwater policy and practices incorporate knowledge about the impacts of fluctuation in rainfall (short term) (requires transient model).
7. Known impacts of land use on the water table are addressed in modifications to land use and development policies and practices.
8. New city production wells are planned.
9. Risk (e.g., overloading) to groundwater of artificial infiltration of stormwater is reduced through modeling results and analyses.
10. Flood storage is improved through the protection of natural areas with flood storage capacity, reducing reliance on culverts for stormwater discharge and, thus, preventing further impacts to the hydrograph of the aquifer and surface waters.
11. Water quantity in Munsel Creek is monitored.

Water Quality

1. Water quality in aquifer is monitored.
2. Impacts of land uses on surface water and groundwater quality are monitored.
3. Groundwater contaminant concentration and variability are monitored and maintained below trigger levels in all seasons.
4. Aquifer contamination is identified, assessed, and corrected, as feasible.
5. Strategies in the Source Water Protection Plan are adopted and implemented to protect water quality.
6. Water quality in Munsel and Ackerley Creek , the estuary, and marine area is monitored.
7. Modifications to BMPs are made, as indicated by the impacts of Stormwater Demonstration Project on estuary water quality, as described in the Quality Assurance Project Plan.
8. Goals and strategies for protecting water quality in the aquifer are adopted by the City and approved by the appropriate State agencies.
9. Groundwater quality is protected from artificial infiltration of stormwater.
10. Impacts of stormwater runoff to water quality in estuary are monitored and continue to be reduced.
11. Water quality in Munsel Creek is monitored.

Fish and Wildlife Habitat

1. The threat to water levels in wetlands and area lakes from water table fluctuations, and the effects on fish habitat, are reduced.
2. Impacts of stormwater outfalls on the hydrograph of Munsel Creek, and the effects on fish habitat, are reduced.
3. Drop in water table is monitored and significant impact on lakes and wetlands, and thus fish and wildlife habitat, from drop is reduced.
4. New production wells are planned that will not allow water table to go below threshold levels and thus, significant impact on lakes and wetlands, and thus fish and wildlife habitat, from drop is reduced, as described in the Quality Assurance Project Plan.
5. Plans and strategies are in place to prevent threats to fish and wildlife and human contact recreation from runoff and groundwater seeping into surface waters (assumes transient model is available.)
6. Land use and development policies are pursued to reduce impacts to surface water quantity and quality, and thus fish and wildlife habitat.
7. Runoff and groundwater contaminants seeping into Clear Lake, Munsel and Ackerley Creeks, wetlands, estuary, and ocean/beach are reduced, improving conditions for fish and wildlife habitat and human contact recreation.
8. Source Water Protection Plan and City Comprehensive Plan amendments are adopted, and contain strategies to protect drinking water and fish and wildlife habitat.

9. Production well sites are planned in a manner that will not negatively affect fish and wildlife habitat.
10. New stormwater practices are monitored for continued reduction of impacts to fish and wildlife habitat and human contact recreation by reducing pollutants entering surface waters through groundwater seepage and by reducing stormwater discharge impacts to wetlands and the hydrograph of Munsel Creek.
11. Stormwater Demonstration showcases state-of-the-art Best Management Practices in established commercial area adjacent to an estuary with high habitat values.

Long Term Outcomes

1. The quality of water for human consumption in the North Florence Sole Source Dunal Aquifer and Clear Lake is protected from known contamination threats; and plans and strategies are adopted to respond to any unforeseen threats.
2. The quality of water in surface waters, i.e., the estuary, creeks, lakes, wetlands, and ocean/beach is protected from contamination threats that could impair the quality of the water for fish and wildlife habitat or human contact recreation.
3. Water quality in ground and surface waters is protected from the effects of urbanization through adopted land use and development policies and procedures.
4. Groundwater levels and fluctuations, and runoff volumes and velocity, are maintained at levels and flow patterns that do not impair the function of wetlands, creeks, and the estuary for fish and wildlife habitat.
5. Stormwater management plans and practices for new development and re-development are tailored to the Oregon coastal environment; and can adapt to changes in temperature and precipitation, and other notable climate change impacts.

3. Wetlands and Riparian Area Protection

Guiding Principles

1. Protect the functions and values of significant¹³⁰ wetlands for water quality, water storage, fish and wildlife habitat, public recreation and use, and education.
2. Protect the functions and values of significant riparian areas¹³¹ for water quality, flood management, thermal regulation, and fish and wildlife habitat.

¹³⁰ “Significant” means wetlands that meet the definition of significant in Statewide Planning Goal 5.

¹³¹ Id.

3. Restore and protect publicly-owned wetlands and riparian areas.
4. Encourage restoration and protection of privately-owned wetlands and riparian areas through education and incentives.
5. Retain and restore native shoreline and riparian vegetation cover, manage invasive plants, monitor significant streamsides, and protect streamsides from erosion.

Measurable Outcomes

Please note: These are provided for illustrative purposes only. Endorsement of Outcomes is not requested or required.

Short Term Outcomes

Wetland / Riparian Function

1. The functions and values of wetlands greater than .5 acre are known for water quality, water storage, fish support and habitat, public recreation and use, and education.
2. The storage and water purification capacity of wetlands in the study area portion of the North Florence Dunal Aquifer is known; information guides City Stormwater System Plans and Projects. (note: combined outcome with water quality and quantity).
3. The functions and values of locally significant riparian areas for water quality, flood management, thermal regulation, and wildlife habitat are known.
4. Significant wetlands and riparian areas are known and proposed for protection for their functions and values.
5. The viability of constructed wetlands to store and slow the velocity of stormwater prior to discharge into natural creeks and estuary is better understood.
6. Wetlands / Riparian areas on City-owned property capacity for flood management, water purification, thermal regulation, and fish and wildlife habitat is known.
7. Opportunities for restoration of wetlands on City owned properties are known.

Streamside Erosion Protection (Non-estuary)

1. Soil characteristics and vegetation cover in study area riparian zones are known and the shoreline erosion resistance capabilities in study area are better understood.
2. Significant riparian areas are known and proposed for protection for their functions and values in protecting significant streambanks from erosion.
3. Potential for shoreline erosion on City owned properties is known.
4. Possibilities for shoreline restoration are known.

Aesthetics, Recreation, and Education

1. The value of wetlands for aesthetics and recreation is known and the information guides local Parks and Recreation Plans.
2. The value of riparian areas for aesthetics and recreation is known and the information guides Parks and Recreation Plans.
3. Significant wetlands are proposed for protection for their educational functions and values.
4. Significant riparian areas are proposed for protection for their recreation and aesthetic functions and values.
5. Wetlands and riparian areas on City owned property with capacity for recreation facilities are known and inform proposed modifications to the City Parks and Recreation Plan.

Medium Term Outcomes

Wetland / Riparian Function

1. The functions and values of wetlands greater than .5 acre are protected for water quality, water storage, fish support and habitat, public recreation and use, and education.
2. City Stormwater System Plans and Projects take into account the storage and water purification capacity of wetlands in the study area portion of the North Florence Dunal Aquifer. (note: combined outcome with water quality and quantity).
3. The functions and values of locally significant riparian areas for water quality, flood management, thermal regulation, and wildlife habitat are protected.
4. Significant wetlands and riparian areas are protected for their functions and values.
5. Constructed wetlands are incorporated into stormwater system plans and projects to store and slow the velocity of stormwater prior to discharge into natural creeks and estuary.
6. Wetlands and riparian areas on City-owned property are protected for their capacity for flood management, water purification, thermal regulation, and fish and wildlife habitat.

7. Opportunities are pursued for restoration of wetlands on City and other publicly-owned properties.
8. Restoration and protection of privately-owned wetlands and riparian areas are encouraged through specific education and incentive programs identified by the City.

Streamside Erosion Protection (Non-estuary)

1. Soil characteristics and vegetation cover in study area riparian zones and the shoreline erosion resistance capabilities in study area are monitored.
2. Significant riparian areas are protected for their functions and values in preventing erosion on significant streamsides.
3. City owned riparian areas are protected from shoreline erosion.
4. Shoreline restoration of City-owned riparian areas is commenced.

Aesthetics, Recreation, and Education

1. The Florence Parks and Recreation Plan and Comprehensive Plan recognize the value of wetlands for aesthetics and recreation.
2. The Florence Parks and Recreation Plan and Comprehensive Plan recognize the value of riparian areas for aesthetics and recreation.
3. Significant wetlands are protected for their educational functions and values.
4. Significant riparian areas are protected for their recreation and aesthetic functions and values.
5. The Florence Parks and Recreation Plan and Comprehensive Plan incorporates wetlands and riparian areas on City owned property with capacity for recreation facilities.

Long Term Outcomes

1. Significant wetlands are protected for water quality, water storage, fish support and habitat, public recreation and use, and education.
2. City Stormwater System Plans and projects incorporate wetlands as part of the system to store and purify water; and constructed wetlands are incorporated into stormwater system plans and projects to store and slow the velocity of stormwater prior to discharge into natural creeks and estuary.
3. Significant riparian areas are protected for water quality, flood management, thermal regulation, and wildlife habitat.
4. Wetlands and riparian areas on City and other publicly-owned property are restored and protected for their capacity for flood management, water purification, thermal regulation, and fish and wildlife habitat; and protected from streamside erosion.
5. Restoration and protection of privately-owned wetlands and riparian areas are encouraged through education and incentives.

6. Shoreline vegetation cover is retained and significant streamsides are protected and monitored for erosion.
7. The Florence Parks and Recreation Plan and Comprehensive Plan incorporate wetlands and riparian areas for aesthetics and recreation, including wetlands and riparian areas on City-owned properties.
8. Significant wetlands are protected for their educational functions and values.
9. Significant riparian areas are protected for their recreation and aesthetic functions and values.

4. Key Estuary Wetlands¹³² Restoration

Guiding Principles

1. Protect and restore key estuary wetland functions and values, including water quality, water storage, fish and wildlife habitat, research, education, historic, and cultural resources.

Measurable Outcomes

Please note: These are provided for illustrative purposes only. Endorsement of Outcomes is not requested or required.

Short Term Outcomes

1. Permanently protect two key/priority estuary wetlands.
2. Collect baseline data on two key/priority estuary wetlands.
3. A management plan is developed and implemented to protect a key/priority estuary wetland.

Medium Term Outcomes

1. Tidal influence is restored to a key/priority estuary wetland.
2. Native vegetation is restored or maintained on two key/priority estuary wetlands.
3. A key/priority estuary wetland is managed according to the management plan to maintain the protection of the estuaries.

Long Term Outcomes

1. Wetland processes are restored or maintained on key/priority estuary wetlands.

¹³² “Key” Estuary Wetlands are among the tidal wetlands identified as priority wetlands for restoration in the report, Brophy, L.S. (Green Point Consulting), and K. So. 2005a. Tidal wetland prioritization for the Siuslaw River Estuary. Prepared for the Siuslaw Watershed Council, Mapleton, OR.

2. Key/priority estuary wetlands functions are restored, improving and maintained for water quality, water storage, fish and wildlife habitat, research, education, and cultural resources.
3. Answers to key questions regarding the practice of restoring tidal estuary wetlands are known and inform further estuary restoration projects.

5. Ecological Growth Planning

Guiding Principles

1. Use Guiding Principles to guide environmental policies, products and processes.
2. Work toward achieving long-term outcomes for land use and water management policies and practices that:
 - maintain and protect rearing, migrating, and spawning habitat for resident and anadromous fish, and habitat for birds, mammals, amphibians and reptiles;
 - ensure that water quality and healthy stream conditions are maintained as rural lands are converted to urban densities;
 - protect and restore the functions and values of wetlands and riparian areas;
 - promote the benefits to the economy of recreational and scenic resources;
 - support commercial fishing;
 - provide jobs through environmental restoration;
 - incite an appreciation for the area's rich and complex ecosystem, creating an attraction for residents and visitors; and
 - promote local environmental programs, such as STEP, as a model for other small coastal cities.
3. Develop protection measures such as low impact development requirements, revised stormwater management Best Management Practices (BMPs), green spaces and riparian buffer Plan designations and zoning, and requirements to protect unique wetland features (such as forested wetlands, darlingtonia patches, and blueberry bogs), and unique riparian areas (such as gravel beds for salmon spawning).
- 4.¹³³ Recognize private property rights by requiring due process and thus avoid the unconstitutional "taking" of private property.

¹³³ The Florence City Council added this Principle after the Guiding Principles were endorsed by the Siuslaw Watershed Council, the Siuslaw Soil and Water Conservation District, and the Heceta Water District.

5. Use the base line data and monitoring regimes established through this Siuslaw Estuary Partnership project to set the stage for analyses of environmental impacts of development.

Measurable Outcomes

Please note: These are provided for illustrative purposes only. Endorsement of Outcomes is not requested or required.

Short Term Outcomes

1. Guiding Principles are endorsed by City and by other public and non-profit bodies and the tribal council, as willing.
2. Land use and water management policies and practices are proposed that:
 - maintain and protect rearing, migrating, and spawning habitat for resident and anadromous fish, and habitat for birds, mammals, amphibians and reptiles;
 - ensure that water quality and healthy stream conditions are maintained as rural lands are converted to urban densities;
 - enhance functions and values of wetlands and riparian areas;
 - improve the economy through improved access to recreational opportunities for visitors;
 - create a renewed appreciation for the area's rich and complex ecosystem, making it attractive to residents and visitors; and
 - promote local environmental programs, such as STEP, as a model for other small coastal cities.
3. Protection measures are proposed, such as low impact development requirements, revised stormwater management BMPs, green spaces and riparian buffer Plan designations and zoning, requirements to protect unique wetland features, such as flooded forests and blueberry bogs, and other measures to address environmental impacts of growth.
4. Base line data and monitoring regimes are established through this Siuslaw Estuary Partnership project that can be used to set the stage for analyses of environmental impacts of development.

Medium Term Outcomes

1. Guiding Principles guide environmental planning and projects by the City and by other bodies that endorsed the Principles.
2. Land use and water management policies and practices are adopted that:
 - maintain and protect rearing, migrating, and spawning habitat for resident and anadromous fish, and bird habitat and migration, mammals, amphibians and reptiles;
 - ensure that water quality and healthy stream conditions are maintained as rural lands are converted to urban densities;
 - enhance functions and values of wetlands and riparian areas;

- improve the economy through improved access to recreational opportunities for visitors;
 - create a renewed appreciation for the area's rich and complex ecosystem, making it attractive to residents and visitors; and
 - promote local environmental programs, such as STEP, as a model for other small coastal cities.
- 3. Protection measures are adopted, such as low impact development requirements, revised stormwater management BMPs, green spaces and riparian buffer Plan designations and zoning, requirements to protect unique wetland features, such as flooded forests and blueberry bogs, and other measures to address environmental impacts of growth.
- 4. Funding is pursued to use the base line data and monitoring regimes from this project to set the stage for analyses of environmental impacts of development.

Long Term Outcomes

1. Guiding Principles are used to guide environmental policies, products and processes.
2. Long-term outcomes are achieved for land use and water management policies and practices that:
 - maintain and protect rearing, migrating, and spawning habitat for resident and anadromous fish, and habitat for birds, mammals, amphibians and reptiles;
 - ensure that water quality and healthy stream conditions are maintained as rural lands are converted to urban densities;
 - enhance functions and values of wetlands and riparian areas;
 - improve the economy through improved access to recreational opportunities for visitors;
 - create a renewed appreciation for the area's rich and complex ecosystem, making it attractive to residents and visitors; and
 - promote local environmental programs, such as STEP, as a model for other small coastal cities.
3. Unique wetland features, such as flooded forests and blueberry bogs are protected.
4. The base line data and monitoring regimes established through this Siuslaw Estuary Partnership project are used to analyze the environmental impacts of development.

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Appendix B

Table B.1: Summary of Climate Change Phenomena: Observed and Projected Changes¹³⁴

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
<p>Increasing Air Temperature</p> <p>Note: With the exception of ocean acidification, all phenomena listed here are driven by increasing air temperature.</p>	<ul style="list-style-type: none"> ■ Heat waves ■ Drought ■ Wildfire ■ Invasive species ■ Shift in species range ■ Changes in timing of ecological events ■ Loss of sea ice ■ Reduction in snowpack 	<ul style="list-style-type: none"> ■ Illnesses, injuries, and loss of life ■ Loss/degradation/alteration / migration of coastal ecosystems and the goods and services they provide ■ Decline in quantity and quality of freshwater ■ Destruction and damage to coastal property and infrastructure ■ Economic losses 	<ul style="list-style-type: none"> ■ The average temperature has risen more than 2°F over the past 50 years, generally resulting in longer warm seasons and shorter, less intense cold seasons ■ The number of days with high temperatures above 90°F is projected to increase throughout the country 	<ul style="list-style-type: none"> ■ By 2100, the average temperature is projected to increase by approximately 7 to 11°F under a higher emissions scenario and by approximately 4 to 6.5°F under a lower emissions scenario
<p>Rising Sea Levels</p>	<ul style="list-style-type: none"> ■ Coastal inundation ■ Erosion ■ Storm surge flooding ■ Rising water tables ■ Saltwater intrusion ■ Nonpoint source pollution ■ Introduction of toxics 	<ul style="list-style-type: none"> ■ Illnesses, injuries, and loss of life ■ Destruction and damage to coastal property and infrastructure ■ Loss/degradation/alteration / migration of coastal ecosystems and the goods and services they provide ■ Loss of beach access ■ Decline in quantity and quality of freshwater ■ Loss of cultural resources ■ Population displacement/ 	<ul style="list-style-type: none"> ■ During the last 50 years, sea level has risen up to 8 inches or more along some areas of the U.S. coast and has fallen in others ■ Global average sea level rose 1.7 mm (~.067 in)/year during the 20th century, 1.8 mm (~.071 in)/year between 1961 and 2003, and 3.1 mm (~.122 in)/year between 1993 and 2003 (it is unknown if the increase in the latter reflects natural variability or a long- 	<ul style="list-style-type: none"> ■ Recent estimates substantially exceed IPCC estimates, suggesting global sea level rise between 3 and 4 feet by 2100 ■ Global average sea level is projected to rise from 8 to 24 inches by the end of the century (this excludes contributions to sea level rise due to changes in ice

¹³⁴ *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA, pp. 8-11.

* This includes both tropical and cold-season storms (extratropical).

Table B.1: Summary of Climate Change Phenomena: Observed and Projected Changes¹³⁴

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
		<ul style="list-style-type: none"> ■ migration ■ Economic losses 	term trend) (IPCC 2007b)	sheet dynamics)
Declining Great Lake Levels	<ul style="list-style-type: none"> ■ Water loss ■ Bluff erosion ■ Hypoxia ■ Harmful algal blooms ■ Invasive species 	<ul style="list-style-type: none"> ■ Decline in quantity and quality of freshwater ■ Water dependent coastal infrastructure impairment ■ Navigational challenges ■ Loss/degradation/alteration of coastal ecosystems and the goods and services they provide ■ Destruction and damage to coastal property and infrastructure ■ Reduced access to waterfront facilities ■ Public trust conflicts ■ Economic losses 	<ul style="list-style-type: none"> ■ Since 1961, with the exception of Lake Superior, Great Lakes water levels have dropped almost .25 feet, on average ■ Since the early 1970s, there has been a decrease in extent of Great Lakes ice coverage, which leads to more evaporation 	<ul style="list-style-type: none"> ■ Under lower emissions scenarios, Great Lakes water levels will fall no more than 1 foot by 2100, but under high emissions scenarios, they will fall between 1 and 2 feet
Increasing Storm Intensity/Frequency*	<ul style="list-style-type: none"> ■ Flooding ■ High wind ■ High waves ■ Erosion ■ Salinity shifts ■ Nonpoint source pollution ■ Introduction of toxics 	<ul style="list-style-type: none"> ■ Injuries and loss of life ■ Destruction and damage to coastal property and infrastructure ■ Loss/degradation/alteration of coastal and marine ecosystems and the goods and services they provide ■ Decline in quality of freshwater ■ Economic losses 	<ul style="list-style-type: none"> ■ The power and frequency of Atlantic hurricanes has increased in recent decades, but there has been little increase in the number of hurricanes that make landfall ■ Since the 1980s, the number of tropical storms in the eastern Pacific has decreased, but the strongest storms have become stronger ■ Cold-season storm tracks have shifted northward and the strongest storms have become stronger 	<ul style="list-style-type: none"> ■ The intensity of Atlantic hurricanes is likely to increase, but more slowly than observed in recent decades ■ The strongest hurricanes are likely to get stronger in both the eastern Pacific and the Atlantic oceans ■ Cold-season storms will continue to track northward; strong cold season storms are likely to become stronger and more

Table B.1: Summary of Climate Change Phenomena: Observed and Projected Changes¹³⁴

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
Changing Precipitation Patterns, Increasing Precipitation	<ul style="list-style-type: none"> ■ Flooding ■ Erosion ■ Nonpoint source pollution ■ Introduction of toxics ■ Salinity shifts 	<ul style="list-style-type: none"> ■ Illnesses, injuries, and loss of life ■ Destruction and damage to coastal property and infrastructure ■ Loss/degradation/alteration of coastal ecosystems and the goods and services they provide ■ Decline in quality of freshwater ■ Economic losses 	<ul style="list-style-type: none"> ■ Total average precipitation increased by about 7% during the 20th century (5% in the last 50 years) ■ The amount of rain in the heaviest 1% of downpours increased about 20% in the last century ■ Regional patterns indicate that precipitation increased the most in the wettest areas 	<p>frequent</p> <ul style="list-style-type: none"> ■ The widespread trend toward more heavy downpours is expected to continue; precipitation will be less frequent but more intense ■ Regional patterns will continue
Changing Precipitation Patterns, Decreasing Precipitation	<ul style="list-style-type: none"> ■ Drought ■ Wildfire ■ Nonpoint source pollution ■ Salinity shifts 	<ul style="list-style-type: none"> ■ Illnesses, injuries, and loss of life ■ Loss/degradation/alteration / migration of coastal ecosystems and the goods and services they provide ■ Decline in quantity and quality of freshwater ■ Destruction and damage to coastal property and infrastructure ■ Economic losses 	<ul style="list-style-type: none"> ■ Droughts have become more frequent and intense during the past 40 to 50 years 	<ul style="list-style-type: none"> ■ Droughts are likely to become more frequent and severe in some regions
Increasing Water Temperature	<ul style="list-style-type: none"> ■ Coral bleaching ■ Hypoxia ■ Pathogens and disease ■ Harmful algal blooms ■ Invasive species ■ Shift in species range ■ Changes in timing of ecological events 	<ul style="list-style-type: none"> ■ Loss/degradation/ alteration/migration of coastal and marine ecosystems and the goods and services they provide ■ Decreased water quality ■ Economic losses 	<ul style="list-style-type: none"> ■ Since the 1970s, coastal water temperatures have risen by about 2 °F in several regions 	<ul style="list-style-type: none"> ■ Increases in water temperature will accompany increases in air temperature

Table B.1: Summary of Climate Change Phenomena: Observed and Projected Changes¹³⁴

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
Ocean Acidification	<ul style="list-style-type: none"> ■ Dissolution of calcium carbonate in marine shell-forming organisms 	<ul style="list-style-type: none"> ■ Loss/degradation/ alteration/migration of coastal and marine ecosystems and the goods and services they provide ■ Economic losses 	<ul style="list-style-type: none"> ■ Globally, the pH of seawater has decreased significantly (0.1 units) since 1750, making it more acidic (IPCC 2007c) 	<ul style="list-style-type: none"> ■ Globally, the pH of seawater will drop much more dramatically (0.14-0.35 units) by 2100 if carbon dioxide concentrations continue to increase (IPCC 2007c)

Appendix C

Common Acronyms

The following acronyms are used in this report. In addition, scientific terms and their abbreviations are individually defined in the relevant text.

BLM:	U.S. Bureau of Land Management
DEQ:	Oregon Department of Environmental Quality
DLCD:	Oregon Department of Land Conservation and Development
DSL:	Oregon Department of State Lands
IARU:	International Alliance of Research Universities
IPCC:	Intergovernmental Panel on Climate Change
NFS:	National (U.S.) Forest Service
NOAA:	National Oceanic and Atmospheric Administration
OCCRI:	Oregon Climate Change Research Institute
ODFW:	Oregon Department of Fish and Wildlife
ODHS:	Oregon Department of Human Services
ODOT:	Oregon Department of Transportation
ODWR:	Oregon Department of Water Resources
PNW:	Pacific Northwest
RSL:	Relative sea-level
SLR:	Sea-level rise
STEP:	Salmon Trout Enhancement Program
SWCD:	Siuslaw Soil and Water Conservation District
SWC:	Siuslaw Watershed Council
UNEP:	United Nations Environmental Program
USACE:	U.S. Army Corps of Engineers
USEPA:	U.S. Environmental Protection Agency
USFS:	U.S. Forest Service
USGCRP:	U.S. Global Climate Research Program
USGS:	U.S. Geological Survey