How Local Effects of Climate Change Could Affect Physical Features in the Lower Coos Watershed

There are several climate-related changes expected on the Oregon coast that could potentially affect the physical features of the Coos estuary:

- *Sea level rise will likely alter land uses in shoreline areas.*
- *The structural integrity and function of tide gates, levees, and other waterway structures may be affected by sea level rise.*
- *Climate-related changes in river and stream hydrology may change key natural processes such as sediment transport and erosion that shape the existing landscape.*
- *Climate change may affect local weather conditions, including air temperature, precipitation, and high wind events.*

Top: Entrance to the Coos Estuary Photo: SSNERR

Middle: Eroding Hillside Photo: SSNERR

Right: Peak Flow below Coos River Subsystem's Gold and Silver Falls Photo: SSNERR

This climate change summary focuses on the effects of climate-related changes to physical features of the project area (i.e., land cover, hydrology, geology, meteorology, and water course structures). Although the anticipated changes to these physical features may result in ecosystem responses (e.g., shifting hydrology may affect the distribution of plants and foraging species such as deer and elk), these feedback effects are not discussed here. For a discussion of the effects of climate change on plant and animal communities in the project area, refer to the Table of Contents to find the applicable climate change summary.

Climate change may affect the physical features of the lower Coos watershed through sea level rise and changing weather patterns (meteorology). Even relatively minor changes in sea level and meteorology could alter local geophysical processes such as sediment transport in local waterways, as well as erosion and landslides hazards elsewhere. Anticipating the exact effects of these changes is difficult for a number of reasons, not the least of which is the fact that coastal processes are complex and will likely respond uniquely to climate-related change along different parts of the coast (Scavia et al. 2002). Despite this uncertainty, existing research offers some important clues as to how the physical aspects of the project area may change as the climate continues to evolve.

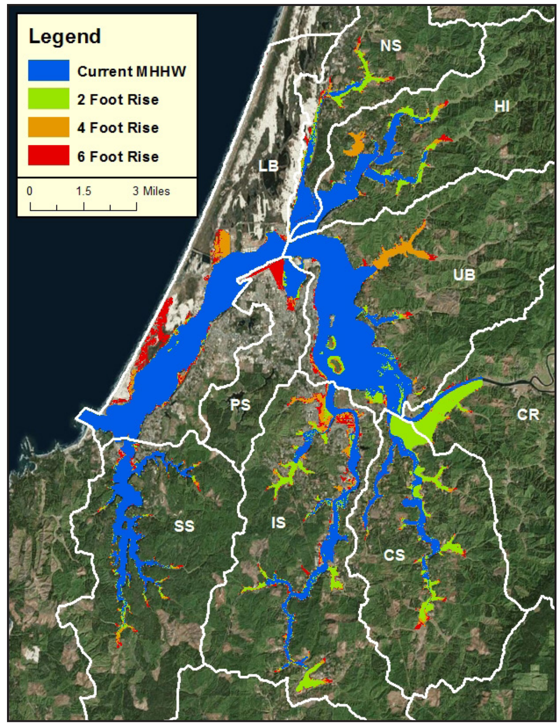


Figure 1. Sea level rise scenarios in the Project Area. Data: USDOC 2012. Subsystems: CR- Coos River; CS- Catching Slough; HI- Haynes Inlet; IS- Isthmus Slough; LB- Lower Bay; NS- North Slough; PS- Pony Slough; SS- South Slough; UB- Upper Bay

Sea Level Rise

Sea level rise (SLR) has the potential to expand the amount of land within the project area that floods on both a regular basis (tidal flooding) and during storms. The project area and subsystem maps presented in Figures 1 through 6 illustrate flooding associated with four tide levels relative to Mean Higher High Water (MHHW): 1) current regular tidal flooding at MHHW level; 2) regular tidal flooding with MHHW level raised two feet by SLR; 3) regular tidal flooding with MHHW level raised four feet by SLR; and 4) regular tidal flooding with MHHW level raised six feet by SLR. MHHW is the average of all higher high tides during the current National Tidal Datum Epoch (1983-2001), and is about equal to the elevation of the highest part of a salt marsh, just below the tree line. Figure 1 includes the entire project area and Figures 2-6 show detailed views of project area subsystems. These maps show normal higher high tide flooding levels and do not illustrate possible tidal inundation during extreme high tide conditions (any above average higher high tide levels). It's important to note that storm-driven high tides will cause flooding problems for developed areas in the lower Coos watershed

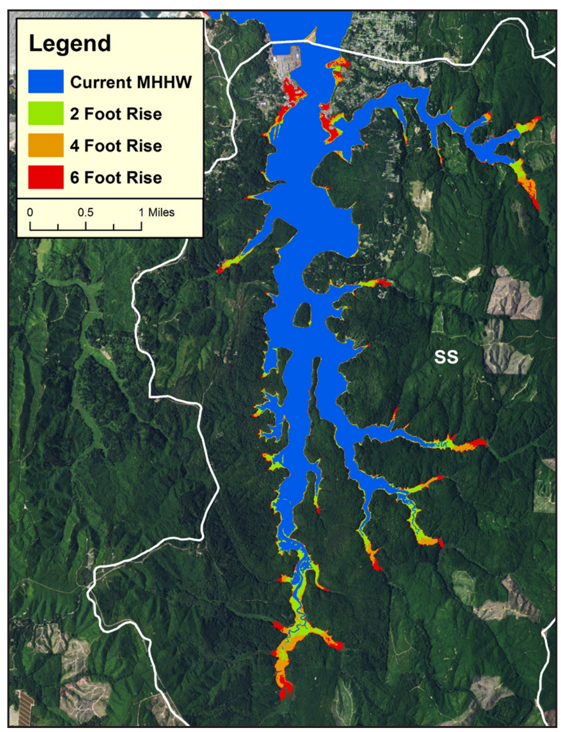


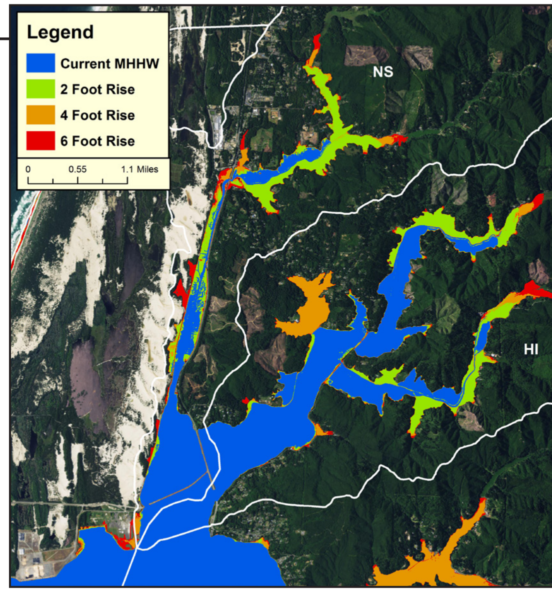
Figure 2. Sea level rise scenarios in the South Slough subsystem. Data: USDOC 2012.

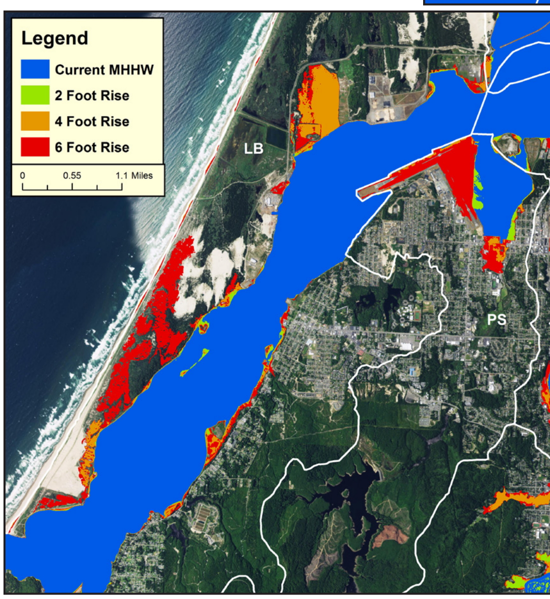
Top: Figure 3. Sea level rise scenarios in the North Slough and Haynes Inlet subsystems. Data: USDOC 2012.

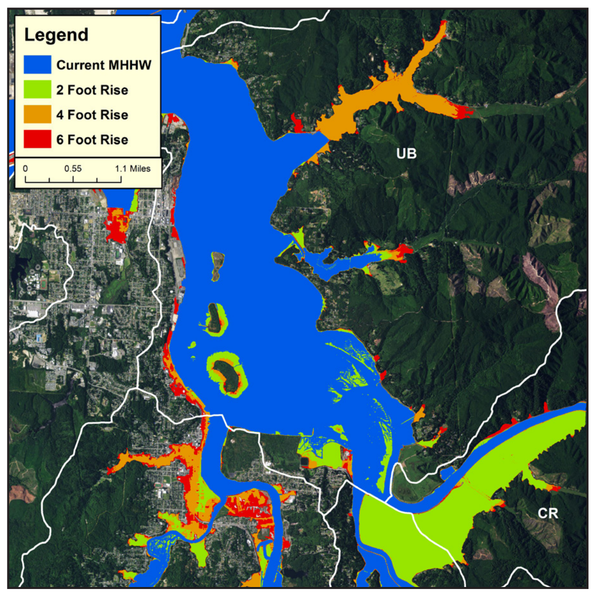
Below left: Figure 4. Sea level rise scenarios in the Lower Bay and Pony Slough subsystems. Data: USDOC 2012.

Below right: Figure 5. Sea level rise scenarios in the Upper Bay and lower Coos River subsystems. Data: USDOC 2012.

Bottom: Figure 6. Sea level rise scenarios in the Isthmus Slough and Catching Slough subsystems. Data: USDOC 2012.

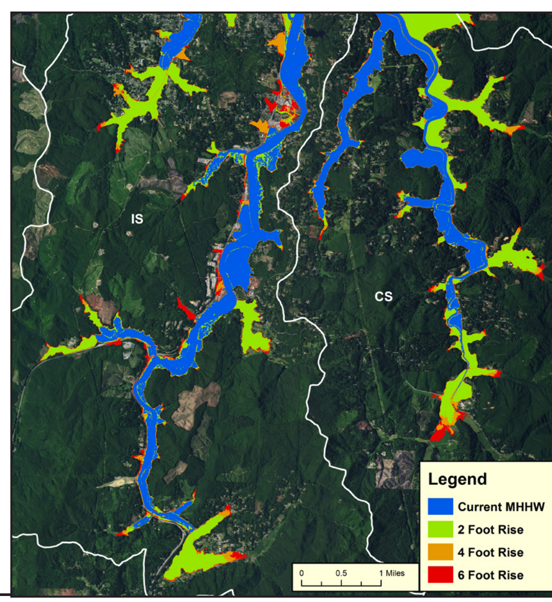






long before SLR causes current upland areas to flood during regular higher high tides. Storms frequently help create above average higher high tide flooding.

In the future SLR has the potential to "drown" tidal marshes and eelgrass beds important for supporting local fisheries. Those habitats remain at a constant elevation relative to tidal flooding through the incremental accumulation of sediments imported with each high tide. Scientists have not yet determined whether marshes, eelgrass beds, or even sand



and mud flats will be able to keep pace with sea level rise (see sidebar). Sedimentation accumulation rates may adjust with sea level rise resulting in very little change to the estuarine habitats. However, if SLR accelerates, it may out-pace sediment accumulation and cause significant change in the Coos estuary.

Accelerated SLR could result in substantial changes to current land use within the project area. Scavia et al. (2002) explain that coastal communities may adopt one of two basic strategies for dealing with SLR: hold the sea back or allow shorelines to move inland. Although this is a simplification of a complex trade-off between development and SLR, it highlights a fundamental climate change-related land use issue: SLR is likely to facilitate the conversion of existing terrestrial land uses (e.g., agriculture, development, forest) into aquatic systems (e.g., estuary, forested swamp, open water) in low-lying shore lands where tide waters are permitted to migrate inland (Rosenzweig et al. 2002). This conversion will likely not occur in areas where rising ocean levels are managed through shoreline defenses (e.g., levees, revetments, tide gates).

Although it's difficult to determine exactly how SLR might change future land use in the project area, existing land use may offer some clues. For example, some researchers suggest that it is unlikely the existing shoreline will be allowed to migrate inland near the existing high tide zone in areas where high value real estate already exists (Glick et al. 2007; Yamanaka et al. 2013).

Sea Level Rise

Our local NOAA tide station in Charleston has documented an average rate of sea level rise (SLR) of 0.84 mm (0.03 inches) per year averaged over the past 30 years (0.27 feet in 100 years). The rate of SLR is expected to accelerate over time. For example, according to the National Research Council (NRC), predicted SLR rates for the area to the north of California's Cape Mendocino (the study's closest site to the Coos estuary), are reported as high as +23 cm (9 inches) by 2030; +48 cm (19 inches) by 2050; and +143 cm (56 inches) by 2100 .

Sources: NOAA Tides and Currents 2013, NRC 2012

In addition to potentially affecting land use decisions, SLR could affect the hydrology of the Coos estuary. OCCRI (2010) explains that the Coos estuary is classified as a tidally-dominated drowned river mouth with tidal influence reaching far up the Coos River and other river and stream systems in the lower Coos watershed. Since the ocean's tidal influence plays such a major role in determining the hydrological characteristics of this system, future SLR can be expected to make that ocean influence even more significant than it already is, causing tidal influence to reach even farther up local rivers and streams into freshwater marshes and swamps. Researchers expect SLR to permanently convert many of the region's coastal freshwater wetlands to brackish and salt marshes, moving tidal freshwater habitats further upstream (again, where tide waters are permitted to migrate inland)(Glick et al. 2007; Scavia et al. 2002).

In some cases, SLR combined with other climate-related changes could cause feedback loops that may exacerbate the loss or conversion of wetland areas or otherwise change the existing physical features of the project area. For example, SLR coupled with expected increases in storm intensity may decrease dry land cover, a trend that could result in increased rates of erosion, especially if climate change results in heightened storm surges within the project area (OCCRI 2010; Ruggiero 2008).

SLR may also result in conditions that could challenge the integrity of existing waterway structures. As much of 70-95% of the historical extent of tidally-influenced wetlands in the project area has been converted to terrestrial-based land uses (e.g., urban development, agriculture) by the historic construction of levees, tide gates, and other structures that control water flow (CoosWA 2006; Hofnagle et al. 1976). These structures were constructed to prevent tidal flooding of converted lands during high tide, and allow waterways behind dikes and tide gates to flow into the estuary during low tide. Rising sea levels, especially during storm tides, will put increasing pressure on these and other shoreline structures, thus requiring additional maintenance or mechanical improvements.

Changing Watershed Hydrology

Jones (2011) describes climate-related changes in stream flow as "one of the most significant consequences" of global climate change. In Oregon, watershed hydrology is likely to change as precipitation and temperature continue to evolve with climate change (OCCRI 2010). For example, in those parts of Oregon affected by snow pack, climate change experts predict streams will likely experience increased winter flow and decreased summer flow due to changes in temperature (IPCC 2007; OCCRI 2010). But since snow pack does not affect stream flows in the project area, and significant changes in Oregon coast precipitation are not expected (see below), experts remain unsure how much change in watershed hydrology to expect locally.

Changing Meteorology

Generally, it's hypothesized that climate change could alter local weather by affecting air temperature, precipitation, and wind (i.e., increasing storm frequency and intensity). Researchers emphasize the Pacific Ocean's influence on project area meteorology which will both enhance and obscure the effects of climate change on local weather. For example, Dalton et al. (2013) explain that climate variability in the Pacific Northwest is "dominated by the interaction between the atmosphere and ocean in the tropical Pacific Ocean responsible for El Niño and La Niña." They cite warmer than average temperatures and drier than average conditions that are typical of El Niño winters and springs as an example of the Ocean's influence on Pacific Northwest weather. Even though climate change signals may be made "noisy" by the influence of the Pacific Ocean, experts project that the following changes to weather may occur in the project area.

- Increasing air temperatures: Although data from the project area show no discernible warming trends since the early 20th century, this may be an anomaly worth investigating further. Mote (2003) suggests that the "vast majority" of temperature monitoring stations in Oregon, Washington, Idaho, and British Columbia have indicated that air temperature has increased since the 1920s. These conclusions have been corroborated by researchers and policy makers who found that the average increase in annual temperature has been about 0.6-1.7° C (1-3° F) in the Pacific Northwest over the past century (OSU 2005). While this warming trend may be explained by natural climatic variation in the first half of the 20th century, it appears that increased concentrations of atmospheric greenhouse gases may have contributed to the continuation of this trend in recent years (Water Resources Breakout Group 2004 as cited in OSU 2005). Air temperatures are expected to continue warming, with the average increase in annual temperature expected to reach approximately 2.3°C (4.1°F) by 2040 (Mote 2003).

- Precipitation: The effects that climate change will have on Pacific Northwest precipitation patterns is a matter of continued debate. On one hand, researchers suggest that precipitation regimes seem to be changing in the Pacific Northwest. For example, Dalton et al. (2013) explain that since the 1970s there have been larger than average year-to-year changes in precipitation, concluding that precipitation in the Pacific Northwest has become increasingly volatile over the past 40 years. Similarly, the United States Global Change Research Program indicates the Pacific Northwest has experienced a modest increase in precipitation since 1915, with annual precipitation totals about 10% higher than their early 20th century levels (USGCRP 2001 as cited in OSU 2005). But even though OCCRI (2010) and Mielbrecht et al. (2014) suggest possible climate change-related decreases in summer precipitation and more intense winter rain events for Oregon, researchers emphasize uncertainty by pointing out that precipitation has shown no clearly increasing or decreasing trend in the Pacific Northwest during the 20th century (Dalton et al. 2013)(see sidebar).

- Changes in Wind Patterns: The local effects of climate change may affect the frequency and intensity of extreme wind events on the southern Oregon coast. However, the exact effects of climate change on wind remain uncertain. Ruggeiro et al. (2013) explain that intense winter storms crossing the Northern Pacific ocean typically make landfall in the Pacific Northwest latitudes (i.e., between 42°- 48°N) and sometimes achieve hurricane force wind speeds. Some climate change experts report that these storms may have become stronger since the 1970s, as suggested by statistically significant increases in both wind speeds and average wave height on the Oregon coast (OCCRI 2010, Ruggeiro et al. 2013). Similarly, others have documented a clear increase in wind speed during "extra-tropical" storm events (storms occurring outside of the tropical latitudes) in the north Pacific Ocean since the 1940s (Graham and Diaz 2001; Favre and Gershunov 2006). Despite evidence to suggest that climate change may result in increased intensity and frequency of wind storms on the Oregon coast, some researchers conclude that the impact has been negligible on the Oregon coast, because storm surge records show no increase in surge levels since the late 1960s (Allan et al. 2011).

Changes in Precipitation Timing, Frequency, and Intensity

In the future, precipitation in coastal Oregon is expected to remain a predominately wintertime phenomenon (i.e., most precipitation will continue to occur in winter), but the extent to which precipitation timing, frequency, and intensity on the Oregon coast may change remains uncertain. There is some evidence that high-intensity storms are becoming more frequent, and that the frequency of weak to moderate-strength storms is declining.

Sources: Sharp 2012, OCCRI 2010, OSU 2005

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