Building Climate Resiliency

in the Lower Willamette Region of Western Oregon

A Report on Stakeholder Findings and Recommendations

The Resource Innovation Group's
Climate Leadership Initiative

January 2011

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The Resource Innovation Group (TRIG)

TRIG is a 501(c)(3) that provides innovative solutions to the challenges of sustainability, climate change and other social, economic and ecological concerns. TRIG was founded in 1996, as an affiliate of the Portland State University Hatfield School of Government. In 2005, TRIG established the Climate Leadership Initiative (CLI) with a specific mission of fostering the development and application of innovative thinking and approaches to the complex causes and solutions to climate change. From 2001 through 2010 TRIG had an affiliation with the Institute for a Sustainable Environment at the University of Oregon. Today, TRIG is engaged in partnerships with a number of academic institutions, non-profits, private companies and government agencies nationwide.

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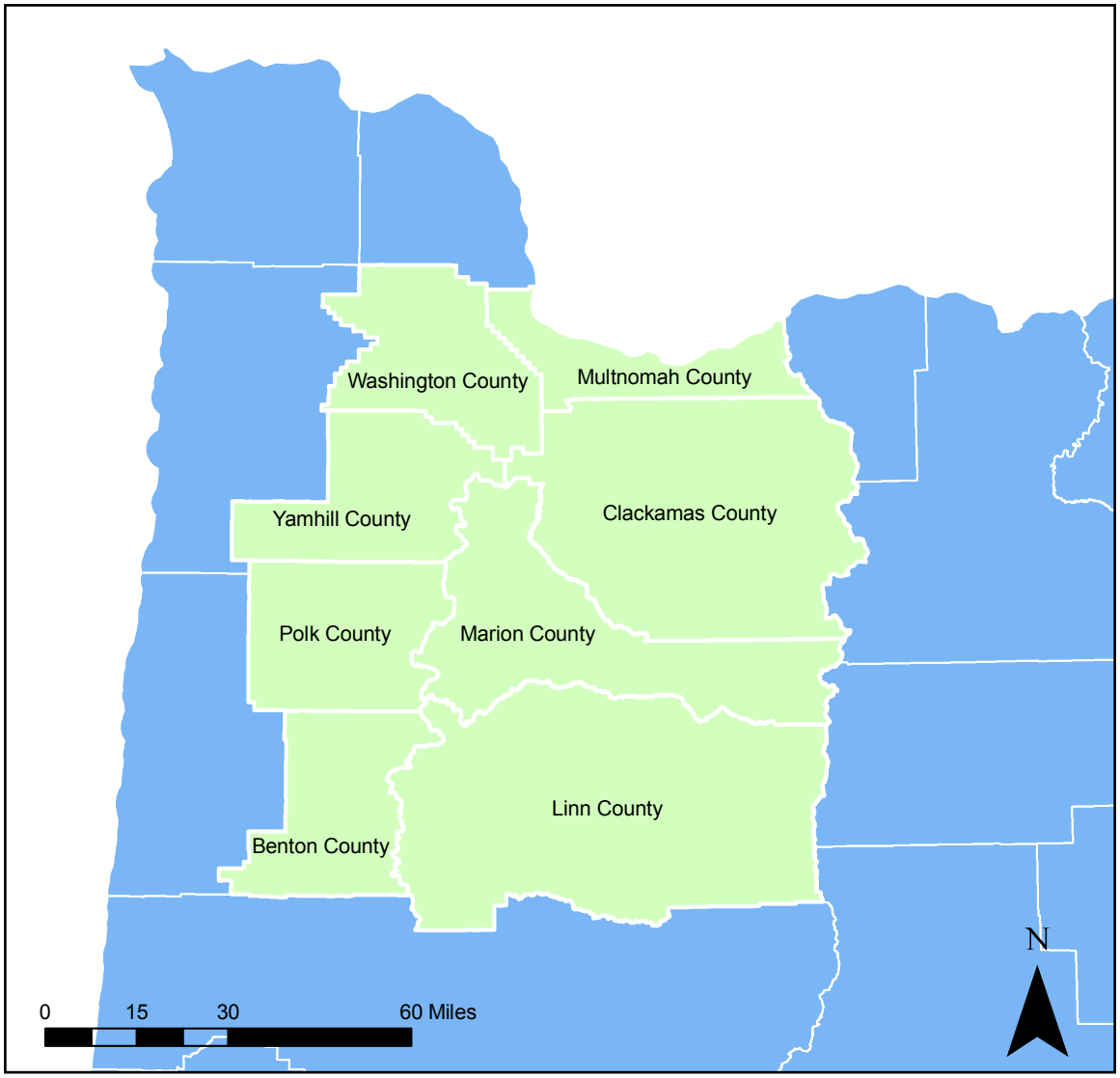

The counties of focus for this report are presented here. The Oregon Department of Environmental Quality (DEQ) defines the Mid Willamette as the Willamette River at Canby, including the North and South Santiam, Yamhill, and Molalla-Pudding subbasins, and the Lower Willamette as the region around the mouth of the Willamette River and the Tualatin and Clackamas subbasins. Willamette Falls (located between Oregon City and West Linn in Clackamas County) is the upper end of tidal influence. Map courtesy of Kathie Dello, Oregon Climate Change Research Institute.

Introduction and Summary

The Lower Willamette region of western Oregon will face significant impacts across its natural, built, economic, human and cultural systems as a result of increasing temperature, changes in precipitation patterns, and loss of snowpack. Climate change will challenge decision-makers due to the complex interactions and linkages between changing climatic patterns, biological systems, and socio-economic factors and the present uncertainties inherent in modeling projections.

It is essential that global and local action be taken to reduce greenhouse gas emissions; even so, the existing level of emissions in the atmosphere will continue to cause considerable changes to the climate for the next 50 to 100 years. As temperatures rise, changes in climate patterns affect land and water resources and the plants, animals, and humans that rely on them.

To address these challenges, the Climate Leadership Initiative (CLI) conducted a series of workshops in 2010 called Climate Futures Forums in the Mid and Lower Willamette region of Western Oregon (collectively referred to as the Lower Willamette in this report). Over 200 stakeholders were involved, with expertise in natural, built, economic, human and cultural systems. CLI's intent in initiating this project was to inform those responsible for developing climate mitigation and preparedness strategies with the combined wisdom of professionals representing multiple disciplines and with deep experience in the Lower Willamette region.

Workshop participants were asked to: 1) assess local climate projections provided by the Oregon Climate Change Research Institute (OCCRI) and Portland State University (PSU); 2) identify impacts across systems and sectors; 3) propose strategies to prepare for the projected changes; and 4) provide a vision of what the Lower Willamette would look like by mid-century should the recommendations be implemented. This report summarizes the results of the Climate Futures Forums.

Although the climatic impacts will be significant, the Lower Willamette may also prove to be one of the more resilient areas of the state – and the nation – in confronting the challenges of climate change over the next century. This resiliency is based on its physical locality, geography, and existing efforts by many communities and organizations to increase regional sustainability.

A possible and unintended consequence of the region's relative resilience is that the Lower Willamette may become a haven for climate refugees from other regions of the country. Accommodating population growth and development may be just as difficult as managing the impacts of temperature increases, extreme weather events, and water supply constraints resulting from reduced snowpack.

Implementing strategies to cope with these impacts will also intensify the pressure from climate change on fish, wildlife and ecosystems. The natural systems, vital to the region's fundamental environmental, economic, and cultural values, are already suffering from observed climate shifts over the past century. New response mechanisms, coordinated across jurisdictions and among diverse economic interests, will be required to build and sustain resilience to climate and development impacts.

The strategies presented here are intended to build natural and human community resilience (i.e. the ability to recover from impacts) and resistance (i.e. the ability to withstand the negative effects of impacts as they occur), by reducing short- and long-term risks and capitalizing on resource management opportunities. Several preparedness strategies also help to reduce greenhouse gas emissions and therefore reduce future impacts from climate change. The following page lists the key discussion points addressed throughout the Climate Futures Forums.

The impacts and recommendations described in this report were proposed by the Forum participants, with additional research by student interns and the Climate Leadership Initiative. All participants were presented with the same climate projection data for the Lower Willamette and attended the forums as experts in their fields. Individual experiences and assumptions are reflected in the impacts and recommendations herein. This report should not be considered a prediction of what will occur mid- and end-of-century in the Lower Willamette or how agencies and organizations should respond. Instead, decision makers should view this document as a summary of possible scenarios and opportunities for strategic responses that can be considered for implementation across the region.

Key Projections

Key projections participants responded to include:

- Overall warming trend, with an increase of 10-15° F in summer by the end of the century under the IPCC Business as Usual emissions scenario;
- Changes in precipitation patterns (more rain then snow, more precipitation falling in a shorter amount of time; wetter winters and drier summers);
- Change in conditions to favor warmer vegetation types;
- Significant loss of snowpack in the Cascades of about 80% compared to current conditions by end of century;
- Higher stream runoff in winter and early spring (due to more precipitation falling as rain and in shorter periods), and decreased flows in summer for some locations; and
- Higher intensity and increased distribution of fires.

Full modeling results are available at: ***www.theresourceinnovationgroup.org/climate-preparedness-pubs/***

Key Impacts

Common themes of impacts identified by participants include:

- Reduced water quality and shifts in water availability (i.e. more in winter, less in summer);
- Mis-match in life history timing of many species, possibly leading to population decline due to diminishing availability of essential resources when needed by each species;
- Decline in efficiency of, and potentially significant damage to, public works, transportation, and communication infrastructure;
- Extended duration and shifts in timing of seasonal peak water demands;
- Diminished productivity or total loss of some agricultural commodities, but potential opportunities for new crops and longer growing seasons;
- Increases in number of invasive, non-native plant and animal species (i.e. additional species coming into the area), and expansion of ranges (i.e. spread) of others.
- Increased instances of heat illness, vector- and water-borne disease, mental health illness, respiratory distress; and
- Loss of cultural resources (e.g. salmon) and historical landmarks (e.g. covered bridges, century old barns and iconic natural features).

Key Recommendations

Common themes of recommendations identified by participants include:

- Protect floodplains, wetlands, and groundwater recharge areas;
- Further assess anticipated habitat changes in order to preserve existing high quality habitat and promote restoration where feasible;
- Preserve, expand, and connect existing high quality habitat and restore habitat of lesser quality that is crucial to species' survival;
- Update infrastructure with projections for future population growth and climate change;
- Anticipate increased energy needs and provide incentives for efficiency and conservation;
- Diversify businesses, as well as agricultural and timber crops;
- Increase preventative health initiatives, notification and warning systems, and diversify health and emergency management partnerships; and
- Protect key cultural resources and improve historical architecture resiliency to extreme events.

In addition to response strategies, Forum participants provided suggestions for new local and statewide policies, governance structures, and communication strategies. They also offered creative ideas for developing new crops, energy technologies, and water efficiency measures in order to turn climate change threats into economic opportunities.[1]

These and many other recommendations contained within this report can be used to support local, regional, state and federal climate adaptation strategies as appropriate. Throughout the Forums, participants posed insightful questions that point the way to further climate-related research and monitoring needs.

Among the most striking conclusions of this project is the ability for the complex web of governance systems in the Lower Willamette to serve as a national and global model for effective and efficient climate resilience. In order for this to occur, decision-makers and community leaders throughout the region need to collectively address the challenges and coordinate their response.

Recent climate-related events during the summer of 2010 in Pakistan[2] (floods), Russia[3] (catastrophic wildfires and record temperatures), China[4] (floods), and in the continental United States[5] (record temperatures) serve as a sobering reminder that climate change is already impacting the planet.

This report offers a starting point for climate preparedness planning and implementation in the Lower Willamette to confront a future very different than the one anticipated just a few decades ago.

There are valuable lessons to be learned as the world collectively faces threats on a scale unprecedented in recent human history. However, with well-developed climate preparation and adaptation strategies, communities may be able to reduce the severity of many near- and long-term economic and human hardships, while accommodating increased development and population growth.

Common Terms in This Report

Resilience strategies build the capacity of systems to recover from the climate change impacts that they cannot withstand.

Resistance strategies increase the capacity of systems to withstand the negative effects of climate change.

Climate Preparedness/Preparation is pro-actively reducing the vulnerability of systems to the negative impacts of climate change.

Climate Adaptation is adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Climate Mitigation is the act of reducing greenhouse gas emissions to lessen future impacts from climate change.

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1 *The State of Oregon Climate Adaptation Framework was released in December 2010. The document provides priority actions for state government in the 2011-2012 biennium and a longer term framework for building resilience in Oregon. See: www.lcd.state.or.us/LCD/docs/ClimateChange/Framework_Summary.pdf?ga=t*

2 *The 2010 flooding in Pakistan is the worst in the country's history, with two million people homeless, 20 million affected, more than a million acres of croplands flooded, and signs of a cholera epidemic. The UN called this crisis the world's worst humanitarian disaster in recent history. (www.pewclimate.org)*

3 *The 2010 heat wave and drought in Russia is the worst in its documented history, with unprecedented high temperatures in Moscow and hundreds of wildfires burning out of control. The combination of extreme heat and thick smoke and smog from the fires doubled the city's death rate at the peak of the heat wave. The drought and fires destroyed a quarter of Russia's crops, prompting the government to ban grain exports for the rest of this year in hopes of keeping domestic food prices under control. (www.pewclimate.org)*

4 *Floods and landslides in China in early summer 2010 killed over 3000 people and affected over 230 million people. Nearly 15.2 million people had to be evacuated and 16.5 million hectares of crops were affected. (Xinhua News)*

5 *2010 was the fourth warmest summer on record in the United States. Three climate regions had temperatures in the top five: the Southeast (warmest), the Central (third warmest) and the Northeast (fourth warmest). Several cities broke summer temperature records, including New York (Central Park); Philadelphia; Trenton, N.J.; Wilmington, Del.; Tallahassee, Fla. (tied); and Asheville, N.C. (NOAA State of the Climate Report)*

Overview and Purpose

Climate Futures Forums

The likely impacts and proposed actions in this report are the result of a series of Climate Futures Forums held throughout the Mid and Lower Willamette Subbasins, collectively referred to as the Lower Willamette. Through the Climate Futures Forums process, the Climate Leadership Initiative (CLI) encourages the development of community and basin-wide planning as a proactive step toward building climate resiliency.

The Forums provide opportunities for local experts and stakeholders to review regional climate change projections, identify likely local impacts, and propose recommendations to prepare for those impacts. The subject area includes Benton, Clackamas, Linn, Marion, Multnomah, Polk, Washington and Yamhill counties. The climate change projections presented in the Forums were provided by the Oregon Climate Change Research Institute (OCCRI) and Portland State University (PSU).

CLI applies a whole systems approach, purposefully encouraging participants and public and private policy and decision makers to integrate strategies across different systems. This approach helps ensure that climate change preparedness actions produce complementary benefits, while also managing conflicts across systems.

Participants share their views at the April 2010 Community Systems workshop in Gresham.

Over 200 Forum participants represented a broad cross-section of expertise and knowledge from within each of the affected systems, including state and federal agencies, public health agencies, county planners, research institutions, community leaders, city managers, social service, private sector, and community organizations, and others (see Appendix E for participant list). In total, six Forums were held throughout the Lower Willamette in Spring 2010:

- February 24, 2010: Natural Systems, Portland
- April 7, 2010: Community Systems, Oregon City
- April 9, 2010: Community Systems, Cornelius
- April 13, 2010: Natural Systems, Albany
- April 15, 2010: Community Systems, Gresham
- June 4, 2010: Community Systems, Albany

In each Forum, participants were provided with a broad scale overview of climate change projections that are likely to affect the Lower Willamette. They were then divided into expertise-based groups. Through a facilitated process, participants identified impacts to their systems or sectors of expertise and provided recommendations for building resilience.

During the final session, participants collectively shared their mid-century vision for the Lower Willamette. This exercise was intended to conceptualize a climate resilient Lower Willamette. It provides an end-goal from which multiple sectors can work backwards, identifying management

Systems

Natural Systems: aquatic and terrestrial ecosystems and species

Community Systems:

- **Built Systems:** communication and transportation infrastructure, buildings, public works infrastructure, etc.
- **Economic Systems:** employers, production, etc.
- **Human Systems:** public health, education, emergency services, etc.
- **Cultural Systems:** communities, species, places, and artifacts of tribal and cultural importance; historical architecture; commonly held values; etc.

and policy strategies to achieve the vision. At the conclusion of the Forums, a team of University of Oregon students conducted additional research under the supervision of CLI staff to supplement insights provided by Forum participants. Finally, all Forum participants had an opportunity to review and comment on this report prior to publication.

This report provides a starting point for discussion among decision-makers. The communities of the Lower Willamette will need to evaluate the variety of strategies outlined in this document. Elements that jurisdiction will bring to the evaluation include:

- Cost/Benefit: What are the net costs of the proposed strategy, inclusive of economic, human and natural dimensions?
- Timing: What is the timing of the impact, and therefore the timing needed for implementation?
- Feasibility: How feasible is the strategy for implementation?
- Efficacy: To what extent will the strategy, if successfully implemented, reduce risk to a given impact?
- Robustness: How resilient is the proposed infrastructure or ecosystem strategy to impacts?
- Co-benefits: Which strategies have positive effects on other systems or sectors? (See Appendix A)
- Unintended consequences: Which strategies may undermine the viability or the strategies of other systems or sectors?
- Equity: How does the strategy take into account environmental justice, intergenerational equity, and social justice concerns?[6]

Current Conditions and Projections for Global Change

The Earth's climate system is influenced by many natural and human-caused components, including volcanic eruptions, ocean dynamics, vegetation growth, fossil fuel combustion, and deforestation. Scientists have determined that the evidence is now "unequivocal" that the earth is warming and that the primary causes are human induced greenhouse gases and deforestation (USGCRP 2009, IPCC 2007).

Average global temperature has increased 1.4° F (0.7° C) since 1900 (NRC 2006) mainly due to greenhouse gas emissions such as carbon dioxide (CO_2) (ibid, IPCC 2007 - see Figure 1). Ice core data indicate that atmospheric CO_2 levels are 30 percent above peak levels from the last 800,000 years and that concentrations have risen 37.5 percent over the past 150 years, up from preindustrial peak levels of 280 parts per million (ppm) to current levels of 387 ppm (IPCC 2007, NOAA 2010). This rise in CO_2

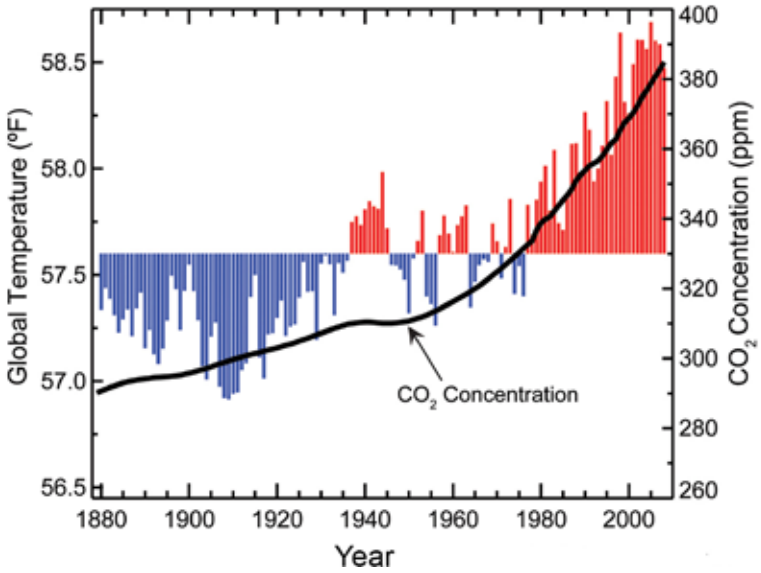

Figure 1: Global annual average temperature (as measured over both land and oceans). Red bars indicate temperatures above and blue bars indicate temperatures below the average termperature for the period 1901-2000. The black line shows atmospheric carbon dioxide (CO2) concentration in parts per million (ppm). While there is a clear long-term global warming trend, each individual year does not show a termperature increase relative to the previous year, and some years show greater changes than others. These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Ninos, La Ninas, and the eruption of large volcanoes. Image and description from: http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/full-report/global-climate-change.

6 *Adapted from Chapter 11 "Adapting to Change" of the New York State Climate Action Council Interim Report 11.9.10*

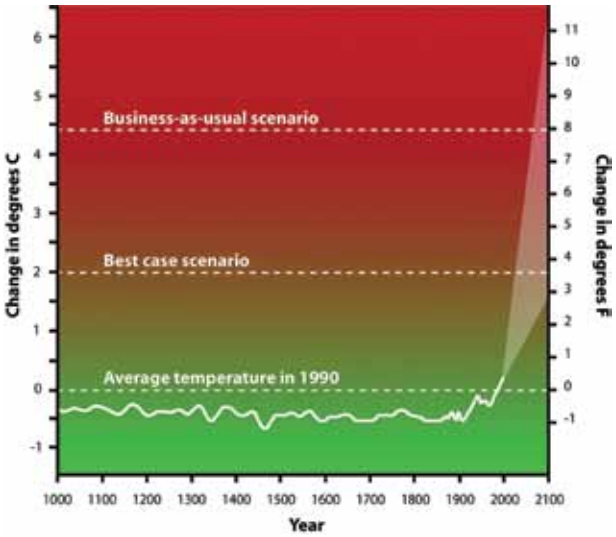

Figure 2: The last 1000 years of global mean temperature, in comparison to projected temperature for 2100. Drastic cuts in greenhouse gas emissions would lead to an increase of about 2°C by 2100 while the current trajectory will lead to an increase closer to 4.5°C and as high as 6°C (adapted from IPCC 2007).

and other greenhouse gases such as methane and nitrous oxide, has already caused significant global impacts, including:

- Changes in global seasonal precipitation, reduced snowpack, earlier snow melt, and increased storm severity (USGCRP 2009);
- Global increase of 0.2° F (0.1° C) in sea surface temperature since 1961, and substantial ocean acidification (USGCRP 2009);
- Global sea level rise of 8 inches (203 mm) in the last 100 years (USGCRP 2009), after 2,000 years with little change; and
- Decline in the amount of Arctic sea ice by about 20 percent since the 1950s (Curran et. al. 2003).

By the end of this century, CO_2 concentrations could reach levels two to three times those of previous peak levels. If the current trend in emissions remains unchanged, global projections for the coming century include:

- Increase of 2° to 11.5° F (1.1 to 6.4° C) in average global surface temperatures (USGCRP 2009 - see Figure 2);
- Sea level rise of 3.3 - 9.8 feet (1 to 3 meters), with greater rise (20-200 feet) possible depending on ice sheet stability (IPCC 2007, USGCRP 2009); and
- Storm events, wildfire, and heat waves likely to become more extreme (Krawchuk et al. 2009; USGCRP 2009).

Current Conditions and Projections for Change in the Lower Willamette[7]

The Lower Willamette, like much of the Pacific Northwest, enjoys a relatively moderate climate due to the modification of air systems moving over the Pacific Ocean. Snowpack in the Cascades average 50-100 inches with most snow falling December through April (Oregon Climate Service 2010). On occasion, the Lower Willamette experiences a severe snow event, with 20-25 inches falling in a 24-hour period (OCS 2010).

Table One presents the region's seasonal temperature ranges (average low and average high) and precipitation.

	Fall	Winter	Spring	Summer
Temperature (°F)	38-55	33-50	36-65	50-80
Precipitation (inches)	10	15.5	8.8	3.5

Table 1. Seasonal Temperature Range and Precipitation Averages for the Lower Willamette. Based on 1971-2000 data from Oregon Climate Service.

Severe storms (any destructive storm, but usually applied to severe local storms in particular, e.g., intense thunderstorms, hailstorms, and tornadoes) are not common west of the Cascades, as they are east of the Cascades, with only 4 to 5 days of thunderstorms typical over the year. Likewise, severe wind events are rare, as they most commonly occur in Oregon on the coast and in the Columbia Basin. The Willamette Basin drains both the east slope of the Coast Range and the west slope of the Cascades. Even with damming and intense management, severe flooding still occurs every few years. This is typically the result of a late spring snowfall followed by a "Pineapple Express"[8] or several days of moderate to heavy rainfall (Western Regional Climate Center 2010).

7 *Please note that this report was prepared and released prior to completion of the Oregon Climate Adaptation Report from the Oregon Climate Change Research Institute. For a much more extensive treatment of future climate projections in Oregon and their likely consequences, please see: http://occri.net/ocar*

8 *Also known as Pineapple Connection, this is a non-technical term for a meteorological phenomenon characterized by a strong and persistent flow of atmospheric moisture and associated heavy rainfall from the waters adjacent to the Hawaiian Islands and extending to any location along the Pacific coast of North America.*

Observed changes in climate over the last century for Oregon and the Northwest include:

- Annual average temperature over the Northwest region as a whole rose about 1.5°F over the past century, with some areas experiencing increases up to 4° F (Mote 2009, USGCRP 2009);
- Loss of Cascade snowpack by 18-20 percent from historical average (PSU, see next page of this report);
- Shifts in seasonal distribution of stream flows (Cue 2009);
- Sea level rise of 2.8-3.1 mm per year, up from 1.8mm per year mid-century; and
- Decline in glaciers (OSU 2010).

Climate scientists use global climate models to estimate how climate change might affect conditions at mid- and end-of-century. These models incorporate the physical laws and chemical interactions of the Earth, solar insolation, and solar-earth orbital relationships. Future conditions are calculated based on different "scenarios" (or estimations) of future greenhouse gas emissions, policies and regulations that would limit emissions, technological improvements, and behavioral changes.

Due to variations in the interpretation of the climate processes and feedbacks as well as the use of different emissions scenarios, the modeling projections vary slightly. It is important to note that the scenarios used in this process utilize the best available information. However, they are not predictions and instead should be considered as possible outcomes. Actual conditions may vary quite substantially from those depicted in these scenarios.

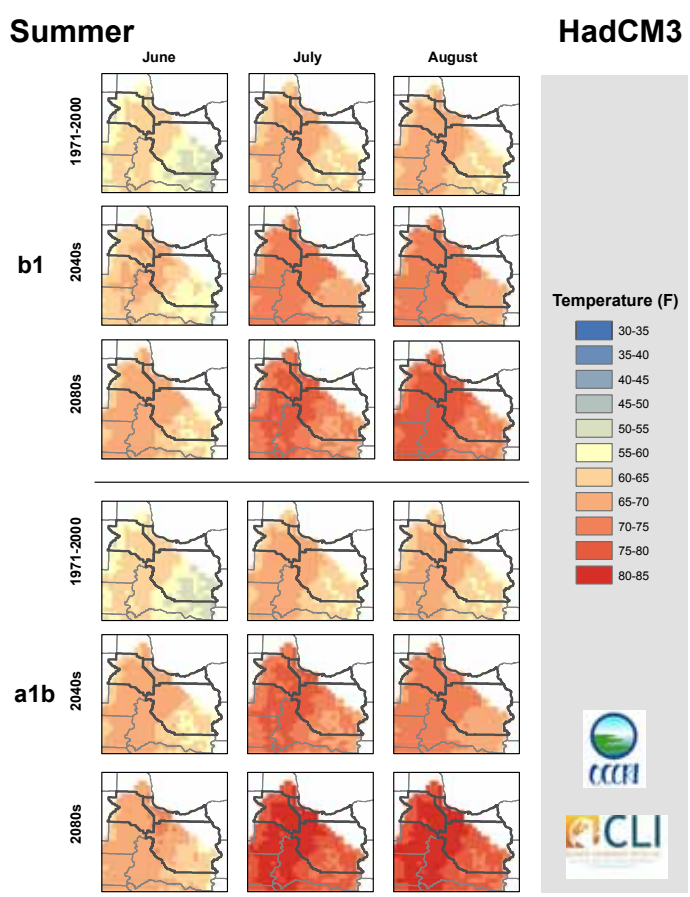

Figure 3: Sample spatial maps for summer temperature projections for the HadCM model for both scenarios.

Readers are urged to focus on the range of projections and the trends they suggest, as opposed to relying on the outputs of a single model or on a particular number.

The modeling results provided by the Oregon Climate Change Research Institute (OCCRI) at Oregon State University for the Lower Willamette are based on global modeling conducted by the Intergovernmental Panel on Climate Change (IPCC 2007), Northwest modeling data (Mote and Salathé 2009), and historical PRISM data (1971-2000). OCCRI selected three global circulation models based on their ability to perform effectively for the Northwest (HadCM2, PCM1, CSIRO) as well as their ability to meet the requirements for the MC1 vegetation model to project fire and vegetation change. (The MC1 model requires data from the MIROC global circulation model.)

Although sea level rise is an important issue for areas adjacent to the Willamette mainstem below Willamette Falls, projections of sea level rise were not provided for assessment by Forum participants.

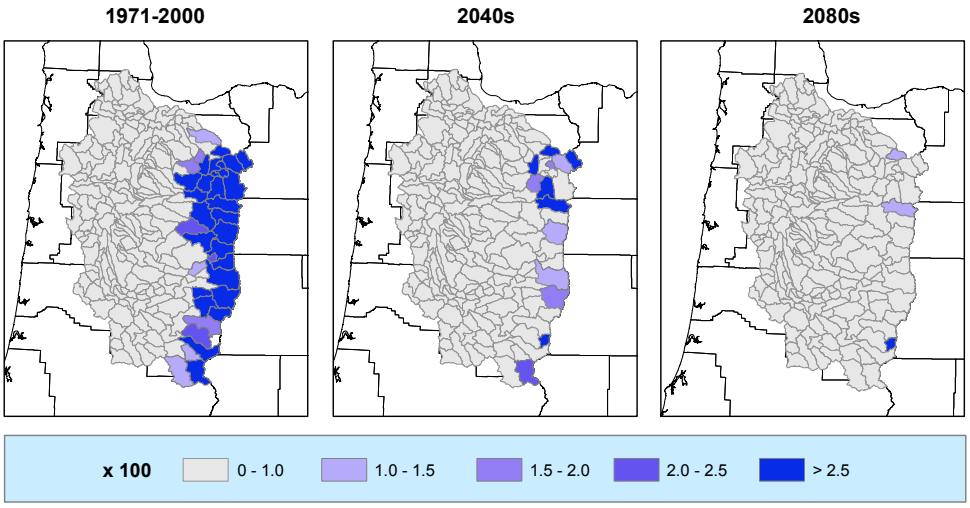

Figure 4: Ensemble mean changes in April 1 snow water equivalent

Climate projections were provided for mid and end of century, using two emissions scenarios provided by the IPCC: the A1b "business as usual" scenario; and the B1 "greener" emissions scenario. See the Resources Section in Appendix D for more information on global circulation models and scenarios.[9]

A summary of projections for the Lower Willamette include[10]:

- The overall trend for temperature shows warming for the entire Lower Willamette by the end of the century. The most intense warming of 10-15° F is during the summer. Winter warming of 3-5° F will have significant impact if precipitation falls as rain as opposed to snow (with resulting impacts on runoff and stream flow - see Figure 3).
- Precipitation is one of the most difficult variables for climate models to project, particularly for the Pacific Northwest. An increase in precipitation is likely in the winter, with less change in the spring, and mixed results in the summer (some models show severe drought, others show little change).
- Severe decrease in snow water equivalent (water content in snow) with near disappearance (greater than 80 percent loss) is projected by the end of the century. (Data provided by Heejun Chang, Portland State University - see Figure 4.)
- Stream hydrographs are likely to be altered, with greater peaks in winter, a lowering of spring snowmelt peaks, and moderate decreases in summer flows relative to historical conditions. Snowmelt influenced systems are likely to be more affected than non-melt driven systems.
- Projections show a greater proportion of biomass burned, up from less than an average of 50 acres per year to an average of 100 acres per year by the end of the century. (Data provided by Ray Drapek, United States Forest Service Pacific Northwest Research Station.)
- Vegetation projections show a decline of Maritime Evergreen Needleleaf species (coastal spruce, Hemlock, cedar, Douglas and silver fir) and likely increase in Temperate Evergreen Needleleaf species (Douglas fir, true fir, and ponderosa pine). Subtropical Mixed Forest species (hardwoods, mixed pines, madrones, and live oaks) are also likely to increase.[11] (Data provided by Ray Drapek, United States Forest Service Pacific Northwest Research Station.)

9 *The full set of modeling results for the Lower Willamette, as well as additional discussion on model and emissions scenario selection can be found here: http://www.theresourceinnovationgroup.org/climate-preparedness-pubs/*

10 *Unless otherwise noted, modeling results are provided by OCCRI for the Business as Usual scenario and for end of century ~2080.*

11 *The models do not provide projections for wetlands, oak savannah, prairie or other specific habitats. Instead, natural systems managers provided their own estimations based on expertise and related model projections. See Natural Systems section below.*

Impacts and Recommendations for Natural Systems

Climate change will directly affect the urban and rural natural systems of the Lower Willamette, including reductions to air and water quality, further stress on habitat for species of concern, and providing opportunities for some wide-ranging and generalist species. Local natural resource managers anticipated the likely impacts of changing climate conditions on the natural systems of the region based on climate models projections and their own expertise and experiences from working in the region. These impacts include changes to aquatic and terrestrial systems, opportunities for existing and new ecosystems and species, and impacts to specific watersheds within the Lower Willamette. The natural resource managers also provided recommendations to strengthen systems in both urban and nonurban areas to deal with the projected changes and resulting impacts.

Background

The current condition of natural systems within the Lower Willamette region range considerably: some areas are of high system quality, while other areas have been degraded by historic settlement patterns and industrial activities. The current overall water quality in the mainstem of the Lower Willamette ranks poor to very poor as determined by Oregon Water Quality Index scores (Oregon DEQ 2007). Warm temperatures, nutrient enrichment, and high levels of total solids are the major water quality concerns. Air quality in the Lower Willamette currently meets federal Clean Air Act standards, but the region is classified as a "maintenance area" due to previous nonattainment with the National Ambient Air Quality Standards (Oregon DEQ 2008).

The region's existing upland habitat is pressured by a growing number of invasive exotic plants including English ivy, reed canarygrass, and Himalayan blackberry, as well as animals such as the Brook trout, Eastern snapping turtle and European starling (ODFW 2006). Species of significant management concern in the Lower Willamette include Lower Columbia River Chinook salmon (threatened, 1999), Columbia River chum salmon (threatened, 1999), Lower Columbia River coho salmon (threatened, 2005), Lower Columbia River steelhead (threatened, 1998), Yellow-breasted Chat, Acorn Woodpecker, Pacific and brook Lamprey, Fender's Blue Butterfly, Western Painted Turtle, Northern Red-Legged Frog and Northwest Pond Turtle (ODFW 2006).

Participant Vision for Future Climate Resilient Natural Systems

The natural landscape will be more abundant and ecologically balanced with a biologically diverse forest, tributaries that are healthy with native salmon, and habitats suitable for healthy wildlife. The cities will contain natural areas with a diversity of habitats made up of native trees and plants. Gardens of climate-tolerant species will be vast, and cities will be designed to absorb stormwater runoff in order to protect the streams. Watersheds will be healthy, with reestablished soils and riparian areas, and able to reliably supply water and groundwater storage.

Likely Impacts to Aquatic and Terrestrial Ecosystems

Shifts in stream flow. Shifts in stream flow as a result of extreme precipitation events could impact systems in a variety of ways. In some cases, the increased incidence of extreme precipitation events could result in short- and long-term changes to river and stream morphology (i.e. shape and pattern), with a potential long-term shift to a different hydrologic regime. Drinking water availability may be impacted due to a reduction in storage levels. As a result, the springs that serve as important cold water sources could be impaired, and insect and other invertebrate communities affected as increasingly scoured streambeds offer less habitat for eggs and larva (therefore resulting in less food for fish and amphibians). Riparian area degradation would occur over time, leading to more flooding of agricultural land and housing developments.

However, if there is a sufficient amount of large wood and gravel sources in the river and stream systems, habitat complexity may increase. Extended and frequent periods of flooding could lead to increased complexity through the creation of new channels. In addition, sea level rise impacts on the Columbia River System (which was not projected by OCCRI) could lead to very different channel dynamics, as rivers and streams have more opportunity to interact with their floodplains than they do at present in incised channels (streams that cut channels along bed of valley floor, as opposed to on floodplain).

Flooding may become more likely with an increase in precipitation falling as rain as opposed to snow, as well as during intense warming events following a heavy snow. While flooding may damage infrastructure and buildings, it also allows for recharge of groundwater, dispersal of organisms, and creation of new habitats through disturbances.

Some aquatic experts project increasing 'flashiness' of streams (a high stream flow lasting for a short period – typically less than six hours – following rainfall or snowmelt) due to increased warming and rainfall. These events may reshape the stream systems. While some aquatic organisms and habitats are adapted to this, typically these events result in increased erosion, flushing of organisms due to excessive flows, scouring of streambeds, and loss of opportunity for ground water recharge. Flashiness could become a positive impact for some systems with sources of large woods and gravels, providing more debris for cooling in streams and possibly deterring invasive vegetation from taking root.

Salmon redds may be buried or stranded due to higher variability of flows, and Pacific salamanders may be negatively impacted by increased hydrological extremes.

Reduced air quality. Climate change amplifies air pollution problems in both rural and urban areas, increasing ozone (O_3) and particulate matter concentrations (Paoletti et al 2007, CEPA 2010). Reduced air quality can disrupt regional ecosystem processes and genetic and population diversity, cause extensive damage to vegetation, and also acidification of ecosystems.

Reduced water quality. Increased precipitation events and runoff could lead to erosion and increased nonpoint pollutant loading to streams. A simulation study of the Tualatin River shows that both nutrients and sediment loads are projected to increase in winter (Praskievicz and Chang 2011). Increasing stream temperatures may also lead to decreased water quality from nutrient loading and algae blooms (see below). (See Appendix B for more information on impacts to specific watersheds).

Changes in chemical composition and nutrient loading. With extended periods of extremely low flows during the summer, reduced levels of dissolved oxygen (warmer water holds less dissolved oxygen) available to aquatic species and a prolonged "pooling up" or concentration of excessive nutrients and toxins is likely in stream segments (Covich, Crowl, and Scatena 2003). This would result in further water quality impacts. Moreover, fish

stressed and weakened by high water temperatures and low oxygen may be more susceptible to toxic chemicals (Richter and Kolmes 2005). A growing human population and the accompanying demand for freshwater could exacerbate these conditions.

Research suggests that the altered climate conditions likely to occur in the Lower Willamette will benefit cyanobacteria (commonly referred to as blue-green algae), which is toxic to humans and animals. Higher rates of precipitation falling in a shorter amount of time may lead to greater nutrient run-off into water bodies coupled with rising temperatures (cyanobacteria prefer temperatures above 77° F), will spur the growth of cyanobacteria blooms (Paerl and Huisman 2008). Cyanobacteria may predominate in water bodies as it grows more successfully in warmer temperatures compared to other bacterium (e.g. diatoms and green algae). (See the Public Health section for more information on human impacts from cyanobacteria.)

Increased water temperature. There are various temperature thresholds for salmon and steelhead during their lifecycle, as smolts, migrating adults, and during spawning (Richter and Kolmes 2005). Elevated summer temperatures are likely to push streams past thermal limits and create barriers to migration, possibly threatening salmon and steelhead survival. Egg viability is damaged in temperatures above 55° F, while temperatures of 66 to 73° F serve as thermal barriers to migration and temperatures at or above 79° F pose a direct threat of mortality. Currently there are already many waterbodies in the Lower Willamette on the Clean Water Act 303 (d) list for water quality impairment due to elevated temperatures that threaten steelhead and salmon during the summer and/or throughout the year (ODEQ 2006). These areas are likely to face greater temperature increases. Elevated water temperatures may also impact the red tailed frog and Pacific giant salamander.

Increase in breeding grounds for water-borne disease. An increase in flooding and warmer temperatures may lead to more still water and consequently, more breeding grounds for mosquitoes. Expansion of irrigated agriculture as a response to drier summers may have the same effect. This would exacerbate the transfer of disease to wildlife and humans. Warmer temperatures and increased drought may lead to increased West Nile Virus infection rates in avian and mammal populations (The Center for Health and the Global Environment 2005). More chemical control for breeding grounds would negatively impact water quality and avian and bat populations, as well as sensitive aquatic species. (See the Public Health section for more information on impacts on humans.) Chytrid fungus is currently present throughout the Willamette Valley and has been detrimental to some amphibian populations such as the Oregon Spotted Frog (Adams 2010). While some experts project that Chytrid fungus may increase in warmer conditions, other studies have indicated that the disease may be sensitive to warmer temperatures and thus have a lower infection rate in warmer conditions (Berger et al. 2004; Adams et al. 2010; Pearl et al. 2007).

Loss of genetic diversity and shift in species gender balance. Reptiles such as the western pond turtle and western painted turtle may experience changes in male to female ratios, since gender is temperature dependent: females are produced at higher incubation temperatures than males (Lovich n.d). Both the western pond turtle and the western painted turtle are listed as Species of Concern by the U.S. Fish and Wildlife Service (Rosenberg et al. 2009. 2009; Gervais et al. 2009). Currently, the western pond turtle is sparsely populated north of Salem and abundantly populated south of Salem. The western painted turtle is primarily located north of Salem, in the northern portion of the Willamette Basin and in the Columbia River Basin (Rosenberg et al. 2009). These species may also see impacts to available habitat and far greater range restriction (see below). Cold water aquatic species or high alpine terrestrial species are also at greater risk with increasing stress, possibly leading to localized species extinctions and a loss of genetic diversity.

Shifts in quality of habitat and refugia. Aquatic and terrestrial habitats will experience varying degrees of impacts depending on current conditions, type, and location.

Changes to wetlands: Wetlands exist in the transition zone between aquatic and terrestrial environments, and can be dramatically affected by slight alterations in hydrology (USGCRP 2009). Slight shifts in temperature and precipitation may reduce wetlands in size or convert them to dry land. Even if annual precipitation remains constant, wetlands may be impacted by seasonal shifts (such as increased precipitation falling as rain in the winter and spring), which would affect bird migration and nesting (USGCRP 2009). Some wetlands may expand with increased precipitation and experience increased vegetation growth from greater availability of atmospheric CO_2 (Burkett and Kusler 2000). However, drier summers and increased temperatures may also lead to shrinkage of other wetland areas.

Amphibians in the Willamette Valley can utilize both ephemeral (short lasting or seasonal) and permanent wetlands. Currently ephemeral wetlands tend to dry out by the mid to late summer. If climate change causes the wetlands to dry earlier, amphibians as well as some butterflies may not be able to complete their metamorphoses (USGS 2004). The western pond and western painted turtles rely on having access to permanent water bodies and can only utilize ephemeral wetlands seasonally (ODFW 2010).

Loss of prairie and oak woodland habitat. The Lower Willamette was historically dominated by prairie and oak habitat (TNC 2008). This habitat has largely been lost due to a change in the fire regime (cessation of regular fire that was used by Native Americans in the region), and destroyed to accommodate agricultural and urban development (Boyer 2010). Presently, there is 1%, or 10,000 acres, of the original 1 million acres of prairie lands left in the Willamette Basin and 7% of the original 400,000 acres of oak habitat (Boyer 2010); making these habitats one of the most rare of North American ecosystems. Climate change will pose further fragmentation risk through shifting precipitation patterns and increased fire intensity, impacting the ability of prairie-dependent species to migrate. This will impact many types of species that are dependent on oak and prairie habitat, such as songbirds (TNC 2008).

Prairie habitats provide critical habitat for three endangered species, Fender's blue butterfly (*Icaricia icarioides fenderi,* ESA listed in 2000), Willamette daisy *(Erigeron decumbens var. decumbe*, ESA listed in 2000), and Bradshaw's lomatium (*Lomatium bradshawii*, ESA listed in 1988); three threatened species, Kincaid's lupine (L*upinus sulphureus ssp. Kincaidii,* ESA listed in 2000; one of two lupines the Fender's blue butterfly is dependent on), Nelson's checker-mallow (*Sidalcea nelsoniana*, ESA listed in 1993), and golden paintbrush (*Castilleja levisecta*, ESA listed in 1997); and one candidate species, Taylor's checkerspot butterfly (*Euphydryas editha taylori*, ESA listed in 2001) (USFWS 2010).[12] These species will face further threats as climate change impacts their habitat.

Shifts in forests and upland habitat for key species. Elevated temperatures, changing precipitation patterns, loss of snowpack, and seasonal shifts will lead to deterioration, loss of function, and significant changes in ecosystems that provide habitat to key species. Isolated populations of terrestrial wildlife may be most at risk, as they become more isolated and lose genetic viability. Shifting habitats may favor species adapted to the new habitats, or those with high mobility.

12 *Although there has been a dramatic reduction in prairie habitat, the Mid Willamette Basin has some of the best remaining prairie habitat in the entire Willamette Basin (TNC 2008; ODFW 2010). In 2008 The Nature Conservancy created the 272-acre Yamhill Oaks Preserve in Yamhill County, an area with some of the highest quality prairie lands and 27-at risk species (TNC 2008). In 2006 USFWS designated approximately 3,720 acres of critical habitat for the three Oregon species native to the prairies of the Lower and Upper Willamette Basin including: 3,010 acres for Fender's blue butterfly in Benton, Lane, Polk, and Yamhill Counties; 585 acres for Kincaid's lupine in Benton, Lane, Polk, and Yamhill Counties, and Lewis County (Washington); and 718 acres for the Willamette daisy in Benton, Lane, Linn, Marion, and Polk Counties (ODFW 2010).*

Forest amphibians that rely on soil and ground cover may experience habitat loss, including the Northwestern salamander, the Pacific giant salamander, long-toed salamander, the tailed frog, and the Oregon slender salamander. The ESA listed northern spotted owl (*Strix occidentalis caurina)* may experience further habitat fragmentation and lack of suitable habitat.[13] Existing threats to the spotted owl include the growing presence of the barred owl (a complex relationship, but believed to involve competition for habitat and resources), loss of habitat from land-conversion and timber harvest, loss of habitat from natural events (e.g. catastrophic wildfire) and disease, and inadequate legal protection (USFWS 2007, 2010). Climate change may amplify these threats by increasing forest disturbance from wildfires, insect and disease infestation, or unsustainable harvesting for biomass as an alternative energy source.

Forests that have generally been limited in growth due to snowpack may see some benefits of a longer growing season, particularly at elevations over 3000 feet. Increased competition between tree species may become more common; resulting in both negative and positive impacts on forest health. Low elevation forests (below 3000 feet) are most at risk from hotter, drier summers. The risk is decreased productivity and increased threat from insects and disease. The impact to natural ecosystems, forestry and the economy could be significant. (See Economic Systems section for more information.)

Reduction in ecosystem services. There is likely to be a reduction in the capacity of the Lower Willamette region to provide ecosystem services at historical and current levels. For example, the Lower Willamette may not be able to store as much water as it currently does or did historically due to a reduction in stream length and complexity. Reduction in complexity would also impact sediment movement, cause water to move faster through watersheds, reduce ground storage and the cycling of needed nutrients. Additional consequences include reduced capacity to provide drinking water and filter effluent and storm water.

Native pollinators (such as bees, butterflies, moths, and some birds) may be negatively impacted by elevated temperatures, extreme weather events, and shifting native flora, resulting in economic impacts to agricultural systems and a loss in vegetative biodiversity. Honeybees have shown a great adaptive capacity to environmental conditions and have high genetic variability, which may enable them to adapt to climate change; however, the specific impacts of climate change on bees are still unknown. Climate change may compound the stresses already endangering honeybees such as pesticide use and disease, leading to further decline (Le Conte and Navajas 2008). The resulting impacts would be felt by food and crop producers as well as pollinator dependent native vegetation.

Increase in extreme events. Extreme events, such as precipitation, fire, and wind, are expected to increase with climate change. These events will pose threats and opportunities for natural systems in the Lower Willamette.

Increase in high precipitation events. With greater precipitation in a shorter period of time and more extreme weather events, some areas of the Lower Willamette, such as the West Hills of Portland, may become more vulnerable to landslides. Changes in weather patterns may also overwhelm storm water management systems resulting in increased pollutant loads to streams and rivers. (See Built Systems for more information on storm sewer system impacts.)

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13 Currently, the spotted owl's range extends from British Columbia as far south as Marin County, California. This range is divided into 12 physiographic provinces. Out of these 12 provinces, the Willamette Valley, including the Upper Willamette Subbasin, has the lowest number of pairs of spotted owls of any province (< 5) (USFWS 2007).

Change in fire regime. Fires are likely to become more intense under a period of warming conditions and drier summers, and then less so over time as fuels are consumed more consistently and the range of fire-prone conifers diminish. Periods of intense smoke, affecting both wildlife and human communities, may occur. Heightened frequency and intensity of fires will also increased erosion and sedimentation into streams, affecting water quality. Systems that evolved with periodic fire and with fire-dependent species are likely to thrive. With an increase in fire, woodpeckers, olive-sided flycatchers, and nighthawks may benefit from the increase in dead wood in snags and fallen trees enhancing insects, nest site availability, and cover from predators (Hutto 1995). These factors and the benefits they provide for bird species vary depending on the severity of the fires (Smucker, Hutto, and Steele 2005).

The ranges of Oak habitat and associated species may expand due to more favorable conditions under an elevated fire regime (Garmon 2006; Savanna Oak Foundation 2010). Examples of associated species are acorn woodpeckers, western gray squirrels, starlings, and pileated woodpeckers (Oregon Wildlife Institute 2010; Savanna Oak Foundation 2010; NRCS 2008; Ryan and Carey 1995). Huckleberries' range may expand under low to moderate intensity fire conditions because fire controls competing vegetation (USFS 2010). In the past, Native American communities across the Pacific Northwest used fire to increase huckleberry production.

Change in wind patterns. Studies from the United States Global Change Research Program predict that wind patterns are likely to change with alterations in the climate; however, at this time the exact nature of the change in wind characteristics due to climate change is unknown (USGCRP 2009). Should it occur, a change in wind patterns will affect seed dispersal: higher wind speeds moving pollen and seeds farther from their sources could lead to an expansion of forest tree populations if soil and climate conditions are suitable (Williams 2010). Changing wind patterns may also disperse non-native invasive plant species. If fires and wind events increase, communities may experience greater smoke presence in urban environments, especially areas downwind from wildfires (Kinney 2008). Climate change is also projected to increase the frequency and intensity of hailstorms and tornadoes, even in the Pacific Northwest, due to an increase in intensity of thunderstorms that contribute to tornado formation (Dale et al. 2001).

Increased intensity of urban heat island effect. Urban areas with substantial impervious surfaces and concrete, devoid of vegetation and wetlands that moderate warming, may experience a more rapid warming compared to rural forested areas and smaller communities. This is referred to as the urban heat island effect,[14] which leads to greater negative climate impacts on urban forests, parks, waterways, fish, wildlife, and vegetation. The following urban areas may be most at risk for urban heat island effect: Portland, Oregon City, Gresham, Hillsboro, Beaverton, Tigard, Salem, Albany, and Corvallis.

Loss of specialist and low mobility species. Species that specialize in a particular habitat, prey, or whose current populations are rare, unhealthy or isolated, are very susceptible to climate change impacts. Examples of such specialist species include the Fender's Blue Butterfly, acorn woodpecker, White-crowned Sparrow, Spotted Towhee, Willow Flycatcher, Western Tanager, Black-headed Grosbeak, western pond turtle, western painted turtle, beaver, and otter (Schultz

14 As urban areas develop, changes occur in their landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist become impermeable and dry. These changes cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures in the landscape. http://www.epa.gov/heatisld/about/index.htm.

and Dlugosch 1999; Metro 2010). Low mobility species that are unable to get to higher elevation or reach cool refuges will also be most at risk, including mollusks, turtles, salamanders, and temperature sensitive plants.

Species that must travel long distances to escape heat or find water will be very susceptible to changes in climate. Amphibians and turtles, such as the western painted turtle, may not be able to adapt quickly enough to changes due to their small, specialized home ranges and limited mobility (Metro 2010). Some smaller mammal species (e.g. shrews) may be susceptible to warmer temperatures because they are limited in their ability to move upland or northward to cooler temperatures, or due to decreases in ground moisture.

Increase in invasive, generalist, and heat tolerant plant and animal species. An increase in high intensity fire may make some ecosystems less resilient to invasive species colonization following disturbance (however, fire can also act as a control for invasives). Some invasive plant species currently existing in the Lower Willamette may do well under a climate change future (e.g. knotweed, reed canary grass, false brome, Himalayan blackberry, and clematis [Campbell 2004]), while new invasives are likely to extend their range into the Lower Willamette.[15] This spread is driven by their propensity for colonizing disturbed land, generous reproduction both vegetatively (asexual) and from seed, and ability to tolerate a diverse range of conditions. Invasives may be more adapted to soil disturbances associated with fire and extreme events, as well as to a warmer climate. English ivy may also expand with warming temperatures, but could be negatively impacted with drier summers. Poison oak, a native invasive, may also expand with warmer temperatures.

Introduced fish such as carp, largemouth bass, bluegill, mosquito fish, oriental weatherfish, and pumpkinseed sunfish may proliferate as water bodies become too warm for native species like salmon (USGS 2004); the presence of these fish has been found to significantly decrease native amphibian populations and facilitate the spread of the invasive bullfrog, which some studies have demonstrated as detrimental to native turtles and amphibians. Beyond competing with native species for food and habitat, invasive species may also prey on, and spread disease to, natives.

Species not dependent on cold water or that thrive in warm water environments are likely to expand their range. In the Lower Willamette, the fish that are best adapted to warm water are non-native species (Galovich 2010). However, there are some native species that have been found to tolerate seasonal increases in temperature, forcing other native fish to find cooler water, including the peamouth, chiselmouth, northern pikeminnow, speckled dace, redside shiner, three-spine stickleback, sand roller, and Oregon chub. Cutthroat trout, largescale sucker, and brook and juvenile Pacific lamprey have been found in warmer, summer streams in conditions which salmonids have not been able to tolerate. Most native fish are adapted to cooler water: although they may be able to survive in warmer water they will likely experience stress and increased incidence of disease. Additionally, the natives that have been found in warmer water are believed to be taking advantage of increased habitat and forage availability, but are challenged by the presence of non-native species better adapted to these warm water conditions.

Species that can thrive in a variety of habitats and on a variety of food sources (i.e. generalists) may not be impacted severely with climate change; for instance, bald eagles, crows, coyotes, and some types of owls. Typically, these species also thrive in urban areas. Moreover, species such as coyotes, raccoons, and ants that can move across a broad geographic range and are adaptable to humans and suburban landscapes are likely to readily adapt to climatic change.

Shift in migration patterns and habitat range. With changes in vegetation conditions, species may migrate or shift habitat range. Riparian systems may experience reduction in flow and seasonal drought, affecting biodiversity, survival and reproduction of many aquatic species, native vegetation and birds (TNC 1996).[16] The ranges of pond breeding amphibians, such as the red-legged frog, are likely to respond to a changing climate given their relative susceptibility to drought and the spread of predators.[17]

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15 A 2010 Oregon Department of Agriculture study for the City of Portland Bureau of Environmental Services identifies invasive animal species already present and established in Portland, present but not yet established, and species likely to invade habitats in the next 5-10 years. The assessment contains recommendations for target species, management actions, and identifies appropriate lead agencies, entities and partners. Although focused on the City of Portland, it is part of a statewide assessment and is therefore inclusive of the Lower Willamette.

16 There are 32 species of rare plants and animals dependent on the wetland and riparian areas of the Willamette Valley, such as the Willow flycatcher (Empidomax traillii brewsteri) (TNC 1996).

17 It has been suggested that the presence of the red-legged frog in the Willamette Valley has declined, but according to recent studies documented by Pearl (2007), reproductive populations remain throughout much of the area.

Impacts to butterflies. Changes in butterfly ranges have been observed in the United States and Europe (JP 2010). Generalist butterflies are expanding their ranges under current climate changes whereas specialist species have been moving northward or are being squeezed out of their ranges. These changes in butterfly ranges are believed to be indicative of future shifts in other species' ranges (JP 2010).

Impacts on avian migration. A 2009 analysis of four decades of North American bird count data by the National Audubon Society found that 58% of the observed bird species are spending more time in northern latitudes during the early winter months, as these areas have gotten warmer. In addition, these birds have been moving from coastal to inland areas because the warming climate has

moderated inland winter temperature extremes that were prohibitive to birds in the past (NAS 2009). The report identified these trends across nearly all species. Locally, changes in avian migration have been observed in the Lower Willamette, such as increased populations of overwintering geese (Rakestraw 2008). Several types of geese such as Taverner's Cackling Geese, Canada Geese, Snow Geese and Greater White -fronted Geese have shifted their wintering ranges northward from central California to the Willamette Valley, likely due to changes in temperature and shifting habitats. Additionally, a study of 30 years of bald eagle nest data from Western Oregon revealed that the egg-laying season began 5 days earlier in 2003-2007 as compared to 1971-1992 (Anthony and Isaacs 2010). Shifts in egg-laying dates have also been found in other species and have been attributed to warming conditions, as temperature has an important influence on the timing of avian reproduction.

A report by the American Bird Conservancy and the National Wildlife Federation forecasts changes to Oregon's summer distributions of songbirds (2002). Potential changes include species no longer present in Oregon during the summer, species' summer ranges expanding or contracting, and species without a current presence coming to Oregon in the summer. With warmer winters, there may also be an increase in resident waterfowl, leading to overgrazing of grasslands (ABC 2010).

Bird species with ranges south of the Lower Willamette, such as the acorn woodpecker, may migrate or expand their ranges northward to more favorable conditions. Others, such as the loggerhead shrike and yellow-breasted chat, may expand ranges to Oregon if adequate habitat is available. However, as they require extensive, wide riparian forestland that is often converted to agricultural land or development, limited available habitat may prevent range expansion.

Raptors such as the red-tailed hawk, rough-legged hawk, bald eagle, America kestrel falcon, merlin falcon, and peregrine falcon, may become more common with wetter winters, negatively impacting prey species such as fish, voles and other ground-based mammals (Davis 2010).

Impacts to invertebrates. Climate change is likely to have both positive and negative impacts on invertebrate species. Warming temperatures may allow for range expansion northward and to higher elevation of some species (like the Bark Beetle and some butterflies), while some species may become less common in the southern portion of their range (EPA 2010, IPCC 2007). Shifts in ranges of invertebrates may impact ecosystem processes, as well as timber and agricultural sectors.

Changes in intra-species interactions and life history timing. With changes in vegetation, symbiotic relationships between benthics (bottom dwelling), aquatics, and terrestrials will change, likely to the detriment of many native species. For instance, beaver populations could be reduced by a decrease in willow trees in areas where willow is

the primary food source and a limiting population factor, which would reduce the instream channel complexity that supports salmon and trout (Baker et al. 2005). Other interactions that might be impacted include those between insects and insectivorous birds, butterflies and host plants, pollinators and flowering plants (including crops), and soil fungus and associated plant communities.

Key timing for life history requirements may become out of sync for some species. For instance, food availability may not match ingrained migration timing (i.e. plants complete their flowering prior to bird or pollinator arrival). Prey species availability and diversity may change, shifting the food web to the detriment of the top-level feeders. Hibernators such as the Townsend's Big-eared bat, California myotis bat, the Oregon Spotted Frog, and western pond turtle may shorten their hibernation and thus experience changes in food availability (Inouye et al 2000).

Loss of culturally important species and landscapes. Warmer temperatures and changing vegetation conditions may lead to a loss of species of tribal and general public importance as well as places that people identify with Oregon. Examples of such potential losses are glaciers on Mount Hood, fish such as lamprey and salmon, Douglas fir (resilient to drought, but vulnerable to storms and high winds), huckleberries (loss on south and west slopes), western red cedar (temperature sensitive), wapato plant (shallow wetland dependent), and bear grass (wetland dependent). (See more information in the Cultural Section).

Recommendations for Climate Resilient Aquatic and Terrestrial Ecosystems

Protect and restore floodplains and connect them to their rivers. Maximizing connections between streams and their floodplains will reduce impacts from flooding on human and natural communities and encourage water storage. Management should focus on creating and maintaining off-channel habitats and reserves for deep-water storage in order to support resiliency of the floodplain system during times of extreme events, and reduce stream flashiness through diversion of water. In particular, local government, in collaboration with the state, can strengthen floodplain restoration policies and non-structural flood storage to improve flood control and reduce vulnerability to extreme flooding. Levee and other flood control management efforts should be integrated with natural systems protection to achieve win-win solutions in adapting to climate change. FEMA is currently reviewing the National Flood Insurance Program, which includes its Flood Hazard Mapping Program. This review will take into account information produced by The White House Task Force on Climate Change Adaptation and could lead to remapping of floodplains in light of climate change, but how and to what extent this information will be incorporated is unknown (FEMA 2010). It will be essential that the floodplain remapping process considers climate projections. In the meantime, local governments can consider zoning and building codes to reduce development impacts on floodplains.

Increase the complexity of streams. Participants identified stream complexity restoration as an effective strategy for ensuring coldwater availability and reducing stream flashiness. Recruitment of large wood to stream systems supports this, but may require an amendment to Oregon Forest Practices rules to encourage interplanting of evergreens in Riparian Management Areas. Large woody debris placement can provide a short term, interim solution. The Oregon Water Resources Department, Department of Land Conservation and

Recommendations with the thermometer symbol (🌡) are also greenhouse gas emission reduction strategies, also referred to as mitigation. Taking action to reduce emissions will decrease climate change impacts in the future.

Development, local governments, Soil and Water Conservation Districts, Department of Forestry and Fish and Wildlife, irrigation districts and watershed councils can all play a role in reviewing and revising local policies and restoration projects that affect stream systems to identify improvements. This process will also need to consider limitations of managing natural systems in the urban environment, private property rights, and public perceptions. The Oregon Watershed Enhancement Board may be a possible financial resource for stream complexity projects initiated by watershed councils.

Protect, expand and connect (where appropriate) existing, high quality habitat and restore and connect (where appropriate) habitats of lower quality. Habitat protection policies under local, regional and state management, as well as habitat managed by nongovernmental conservation organizations, should focus on protecting high quality urban and rural habitat with greater resilience to climate change. Threatened urban and rural habitats that are vital for survival of keystone and umbrella species, or that will be key habitat for anticipated resident species, should also be protected as appropriate.[18] In identifying key habitats for protection, land managers should carefully consider future projections for vegetation species change and range shifts.

Strategic Habitat Conservation (SHC)

The U.S. Fish and Wildlife Service has adopted a new strategy – Strategic Habitat Conservation (SHC) – to deal with changing needs for threatened and endangered species. The strategy recognizes the need to take landscape approaches to species conservation, use adaptive management techniques, manage for species migration and movement due to climate change, and work across jurisdictional and agency boundaries. A key component of the SHC strategy is the Landscape Conservation Cooperatives (see Resources section for more information on LCCs).

Increasing connectivity between habitats using buffers, anchors, and corridors should be encouraged. However, managers should also prevent "highway" corridors through which invasives and diseases can spread rapidly. Protected habitat should be large enough for natural processes to occur and stressors should be reduced. The principle of redundancy, protecting as many areas as possible of specific habitat types or areas that shelter species of concern, should be incorporated into habitat protection, restoration, and connection plans at the ecoregional scale. A dedicated funding mechanism (by regional jurisdictions, state agencies, nongovernmental conservation organizations, lottery funds, etc.) can support protection and restoration of key habitats.

Use a landscape approach to conservation. To maximize protection of habitat and increase resiliency of species and ecosystems to climate change impacts, a landscape approach is needed to integrate efforts happening at a more localized scale with broader regional approaches.[19] A landscape scale approach allows for a holistic approach, taking into consideration habitat needs, agricultural, local economics, and the health of human and natural communities. It helps to ensure a diverse and viable ecosystem that can better adapt to climate impacts (USFS 2009). Conservation organizations, watershed councils, private landowners, and state and federal agencies can work throughout the Willamette to create networks of habitats.

Revise species management. To increase effectiveness and avoid duplication of species management programs and policies, participants recommended greater communication and collaboration between researchers and land managers. There is also a need for greater connections and coordination between federal, state, and local species management agencies. The Urban Ecosystem Research Consortium (UERC) of Portland and Vancouver is an example of an organization that facilitates information sharing across educational institutions, state and federal agencies, local governments, non-profit organizations, and businesses, as well as independent professionals and students who are interested in and conducting urban ecosystem

18 A keystone species is a species that plays an essential role in the structure, functioning or productivity of a habitat or ecosystem at a defined level (habitat, soil, seed dispersal, etc). Animals identified as umbrella species typically have large home ranges that cover multiple habitat types. Therefore, protecting the umbrella species effectively protects many habitat types and the many species that depend on those habitats. (from www.worldwildlife.org and www.eoearth.org)

19 The broad concept of a landscape-scale conservation initiative includes three basic ideas: (1) encompass some regional system of interconnected properties/habitats; (2) organized to achieve one or several specific conservation objectives; and (3) various landowners and managers within a given conservation region cooperate or collaborate in some concrete fashion to achieve those objectives. From James Levitt. 2004. Landscape-scale Conservation. Land Lines. 16:1.

The Intertwine Alliance and Regional Conservation Strategy

The Intertwine is the Portland Vancouver Metropolitan Region's system of parks, trails, natural areas, ecosystems, and watersheds. The Intertwine Alliance is the people and institutions that protect, restore, and enjoy these areas. The Alliance focuses its efforts in five primary areas: Regional System, Conservation Education, Land Acquisition, Active Transportation, and Conservation. As one project that falls within the Conservation "petal", the Regional Conservation Strategy will serve as the primary guiding document for the Conservation initiative. The objective of the Regional Conservation Strategy (RCS) is to build on work already completed in the Portland-Vancouver metropolitan region with regard to mapping and describing significant fish and wildlife habitat, landscape features, and the region's biodiversity. The RCS seeks to update and synthesize disparate existing initiatives into an integrated strategy that will provide practitioners, agencies, elected officials, funders and the public with a description of our region's biodiversity today and a roadmap to desired future conditions. The four main components include a Biodiversity Atlas, Maps and Data, Conservation Strategies (including climate change adaptation), and an Executive Summary that provides highlights of the RCS. The RCS will also ensure that people and wildlife continue to flourish together on both our urban and rural landscapes for generations to come. Visit *http://theintertwine.org* for additional information. (Text contributed by Mike Houck.)

research and data collection (UERC 2010).[20] UERC can serve as an example for a consortium regarding researching, managing, and monitoring climate change impacts on species.

ODFW, in coordination with the USFWS, need to reconsider how invasives, as well as Threatened, Endangered and Sensitive (TES) species are identified and managed. For example, what currently qualifies as an "invasive" species may eventually become a resident species. For TES species, local extirpations from the area may be inevitable as habitat conditions change. Species management should also anticipate a shift in community composition to include focus species that will be migrating into the Lower Willamette from southern areas. To adjust to a changing climate, species management will need to be flexible and adapt to new conditions.

Species protection efforts under the federal Endangered Species Act (ESA) will need to be evaluated in light of a changing climate, including the possibility or likelihood that species' current habitats may have limited ability to support these species in the future. Presently, the use of the ESA to protect threatened and endangered species from climate change has been unsuccessful. In 2008 the Department of the Interior listed climate change as a threat to the polar bear because of the melting Arctic sea ice, but it was determined by the court that the ESA may not be used to require greenhouse gas reductions to protect the species (Goldenberg 2009).[21] Additional lawsuits for the USFWS to consider climate change as a threat in ESA listings are likely, particularly for a number of glacier species (e.g. penguins, Kittlitz's Murrelet) and corals. While there are skeptics on whether

20 UERC invited citizens to blog about what they see in their watersheds as a means of involving citizens in monitoring www.uercportland.org.

21 The Oregon Endangered Species Act has a much more limited scope than the federal ESA (Callens 2004). It is likely that actions regarding climate change under Oregon's ESA will follow the more broad and comprehensive federal ESA and guidance of the USFWS (Nugent 2010). Species conservation in Oregon and actions under the state ESA are also guided by the Oregon Conservation Strategy, a federally mandated plan. This strategy currently does not address climate change as a primary threat to deal with in species management, but likely will in its future form: it will be fully revised by 2015. Although this plan is non-regulatory, it guides habitat and species conservation for government agencies, entities, and individuals across the state and will be a central tool for future species management efforts in regards to climate change in Oregon (ODFW 2010; Nugent 2010).

the ESA will be able to restrict greenhouse gas emissions, major revisions to the ESA and wildlife management to consider climate change impacts are likely (Ruhl 2008).

Fish harvest management will need to shift effort to across effort across the run to avoid a disproportionate impact on later migrating fish (i.e., avoid the tail ends of runs) and heightened attention to which fish are targeted is necessary. Hatcheries can use local brood stocks and rearing practices that mimic natural situations. Habitat availability will need to be maximized and passage barriers eliminated to the extent possible. More coldwater refugia and stepping stones for cold water species will need to be created and existing high quality coldwater refugia protected by watershed councils, ODFW, and landowner restoration projects.

Restore and manage beaver presence in riparian communities. Restoration of beavers will support aquatic habitat resilience, as they are a keystone species with a strong influence on ecosystems as a result of their dam-building and feeding activities (Driebe, Martinsen & Whitham 1998). Riparian plant communities (willow, cottonwood, and alder) thrive with beaver cuttings. This results in denser growth patterns, which benefits other species such as nesting songbirds and arthropods (Baker et al. 2005; Hagar 1999; Martinsen, Driebe, & Whitham 1998). Beaver dams and ponds also create slack water habitat for juvenile salmon to feed and grow (Steelquist 1992). Beaver dams help with water storage, delay, and groundwater recharge, which in turn provide a buffer against winter flooding and summer drought. Beaver dams may also provide hyporheic recharge (mixing of shallow groundwater and surface water to stream systems, which is critical for groundwater/surface water interactions and fish spawning), positively shifting the hydrography to retain more of the fall to spring run-off and release waters during summer low flow (C. J. Westbrook et al. 2006).

Bryant (1984) found beaver ponds provided a large and complex volume of water for anadromous (live in ocean, breed in fresh water) fish habitat and produced densities of coho generally higher than those reported in other systems of southwest Alaska (Morgan and Hinojosa n.d.). Debris jams, fallen trees, and brush distributed by beavers provide cover for fish to hide from predators and refuge during high flows. Accumulation of downed woody debris in channels and surrounding floodplain areas provide nesting and roosting habitat, and food and cover for upland wildlife, waterfowl and songbirds, mink, otter, turtles, frogs and salamanders. Recruitment of beavers to the region requires further behavior changes among timber companies (many pay bounties), private landowners, and public utilities. The benefits of beavers will need to be weighed with some of the negative impacts of beaver dams, which can act as threats to private structures and public infrastructure. Stormwater management facilities would need to allow for beavers, and road crossings for beavers will need to be constructed.

Reassess allocation of water rights. Overappropriation of streams in the region negatively affects water quality and quantity. The Oregon Water Resources Department may need to consider a review of water rights and potential shifts in regulation. Various "water banking" programs (a mechanism that facilitates legal transfer and market exchange of various types of surface, groundwater, and storage entitlements) now being implemented in the Klamath Basin and elsewhere may serve as important models for the Lower Willamette. Water banking might also be used to implement removal of drain tiles from farmlands located in floodplains to enhance subsurface water storage.

🌡 **Incorporate climate change preparation strategies into watershed management plans.** Watershed councils and local governments should develop, adopt, and begin implementing local watershed management plans that set climate resiliency objectives for hydrology, physical habitat, water quality, and biological communities. The

Portland Watershed Management Plan and its supporting document, the *Framework for Integrated Management of Watershed Health* (2006) (see Resources Section) provide good examples of addressing the many aspects of watershed health in a management plan. However, climate change preparation is not explicitly addressed and should be considered in project planning and prioritization. Integrating climate change into these documents strengthens their effectiveness by building resiliency in the system, and serves as a model for other watershed management plans throughout the Lower Willamette and beyond.

Increase riparian vegetation. Supporting riparian vegetation growth (along river margins and banks) could help to protect water quality from increased erosion and associated pollutants. Increased riparian vegetation will also improve water quality through shading, habitat diversity, and cover for wildlife.

Restore natural fire regimes. Natural fire regimes should be restored in order to build the resilience of ecosystems to climate impacts, as fires maintain diverse assemblages of vertebrate species and forest types. In addition, a number of species in the Willamette are adapted to exploiting different stages of regrowth and habitat change that results from burns. By reducing fire suppression efforts, ecosystems may become more resistant to higher intensity and frequency of fires under climate change, and the negative impacts to ecosystems may become less severe. In addition, fires may support ecosystem resistance to invasive species.

Prescribed burning may be necessary to restore the natural fire regime. However, land managers will need to consider Human and Built Systems when using prescribed fire. In collaboration with the Oregon Department of Forestry, federal and state land managers can increase prescribed burning while still protecting public health and safety. More prescribed burning should occur in lower elevation areas in particular as a means for building ecosystem resiliency and reducing likelihood of invasive species and disease outbreaks. The Oregon Department of Forestry Smoke Management Program manages burning to ensure it occurs on days that will generate the least amount of smoke impacts to nearby communities and the lowest chance of violating particulate matter standards under the Clean Air Act (Finneran 2010). It oversees burning on forestlands by federal land managers of the Bureau of Land Management, Forest Service, Fish and Wildlife Services, and state land managers. More education for residents living in fire prone areas on the value of prescribed burning and how to protect infrastructure and buildings can be provided by emergency managers, public health workers, and community-based organizations.

Reduce impervious surfaces. Local governments should minimize the extent of impervious surfaces to protect the water quality of streams, improve infiltration, and reduce stream flashiness. High-resolution multi-spectral satellite imagery can be used for mapping the extent of impervious surfaces and local governments can use policy mechanisms to provide incentives to minimize its growth. The City of Denver, for example, is piloting the use of high resolution mapping for billing storm sewer use by property owners based on the amount of impervious surface on their property. Low-use publically owned impervious surfaces can be prioritized for conversion to pervious surfaces in order to reduce runoff, while flow-through planters[22] and other alternatives can support run-off management. The City of Portland has implemented a number of projects to reduce impervious surface, serving as models for other communities.[23]

Expand carbon sequestration efforts. Some participants recommended consideration for carbon sequestration programs as an objective for improved land management efforts. An ecosystems service or carbon sequestration market could be established by individuals (e.g. on nurseries, vineyards, or timber land), counties, tribal communities, or cities. However, standards should be set by the state Department of Forestry for species approved for sequestration planting to improve native processes and systems (e.g. no eucalyptus or over-planting of Douglas Fir).

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22 *Planters are structural landscaped reservoirs used to collect and filter stormwater runoff. Infiltration planters allow water to infiltrate through the planter soil and into the ground. Flow through planters include the use of a waterproof lining, and include an overflow to an approved stormwater conveyance system.*

23 *The city of Portland has a long history of implementing green/sustainable stormwater facilities. There are nearly 1000 facilities in the ground currently; constructed both by the city and by private entities in compliance with Portland's Stormwater Management manual. Portland's Grey to Green Initiative (in its third year) expands the city's green infrastructure to sustainably manage stormwater runoff, stop the spread of invasive plants, restore native vegetation, protect sensitive natural areas, and replace culverts that impede fish passage. Grey to Green investments improve water quality, air quality, wildlife habitat, and neighborhood livability while also providing safer routes to schools, and supporting adaptation to a changing climate. The city began funding the initiative on July 1, 2008, with a 5-year planned investment of $55 million. Visit www.portlandonline.com/bes/tabortoriver also please see www.portlandonline.com/sustainablestormwater for case studies and information on Portland's programs.*

Establish an ecosystem services market.[24] Some stakeholders recommended the development of regional ecosystem services markets to provide additional financial incentives for building resilience. Local decision-makers should monitor efforts by The Willamette Partnership (a nongovernmental organization) to establish an ecosystem services marketplace for the states of Oregon, Washington, and Idaho. The partnership has launched pilot projects to begin to utilize this tool on a smaller scale (Cochran 2010). Oregon Senate Bill 513 passed in July 2009 provides further support for this initiative through its requirement for policies to stimulate the development of ecosystem services markets across Oregon. State agency staff is currently developing policy recommendations for implementation (Cochran 2010).

Increase and refocus monitoring efforts. Monitoring will need to be more adaptive and integrated with management regimes as a result of shifting climate conditions. Species' responses to habitat impacts from climate change, both short and long term, will need to be monitored, as well as the effectiveness of management strategies that are attempting to address those changes. Monitoring efforts by conservation organizations, watershed councils, state and federal governmental agencies should focus on umbrella or keystone species which can act as indicators for the resiliency of the ecosystem and other wildlife species. Involving the public in monitoring would increase citizen education while building support for management objectives. More funding is needed from private and public foundations, or from lottery funds, for increased monitoring. (See Research and Monitoring section for additional recommendations.)

Early Detection Rapid Response (EDRR) applications, used by governmental agencies and nongovernmental organizations, will increase the likelihood of keeping invasive plant species populations under control or eradicating them before they become widespread. A similar system should be established for invasive animal species (particularly insects).

Conclusions

The impacts identified by the natural systems experts provide an overview of how species and ecosystems may shift under various climate conditions. The experts' recommendations provide a variety of tools and strategies that can be used to make natural systems more resilient to climate change impacts. Together, these impacts and recommendations can be used to increase and improve understanding of the future effect of climate change on the natural systems of the region and strengthen the capacity of the Lower Willamette to protect these invaluable resources.

24 *An ecosystem services market provides a mechanism for the buying and selling of quantified ecosystem services in the form of credits (Willamette Partnership 2010). The credits quantify the value of different ecosystem services provided by intact environments such as water filtration by wetlands and riparian areas that provide cool water for salmon. Potential buyers in this market are industries, businesses, developers, and individuals who impact the environment and need to mitigate their actions to meet a regulatory standard or individuals and entities that choose to participate to benefit the environment.*

Impacts and Recommendations for Community Systems (Built, Economic, Human and Cultural)

Projected changes in the climate of the Lower Willamette are expected to significantly influence the region's built, economic, human, and cultural systems (collectively referred to as "community systems"). Participants highlighted likely impacts and opportunities to these systems, while also identifying strategies to take advantage of opportunities and remain resilient to the impacts of climate change.

Built Systems

Background

There are numerous public and private utility providers throughout the Lower Willamette, including the Bonneville Power Administration (BPA), Portland General Electric (PGE) and PacificCorp (operating as Pacific Power in Oregon). Cities and water associations in the region manage water and sewer systems for residents. Much of the current water and sewer infrastructure in the Lower Willamette region is 30-50 or more years old and in need of repairs (OECD 2007). These systems were designed for historic conditions without consideration of climate change impacts, such as increased frequency and volume of flooding events and changes in stream runoff.

Comcast, Qwest, and Verizon are major telecommunication companies providing telephone, television, and internet services. Private-public partnerships are becoming more common in the region, particularly for linking rural communities to emergency services and distance learning opportunities.

The state's largest and busiest airport is Portland International Airport (PDX), which handles 90% of passenger flights and 95% of air cargo for Oregon. TriMet ground transportation serves the Portland metropolitan area (portions of Multnomah, Washington, and Clackamas Counties) with bus service and the Metropolitan Area Express (MAX) light rail system. The region is well connected with Interstate 5 and Highway 99 running north and south, as well as an extensive bridge network crossing the Willamette River. Amtrak connects

Portland to Salem and Albany as well as Seattle, Sacramento and southern California. The Port of Portland is a deepwater seaport located downtown on the Willamette River providing docks and loading and unloading facilities for grain and manufactured goods. Multnomah County has a well-connected bike lane system, and other communities are working to expand connectivity of pedestrian and bike lanes between cities.

Participant Vision for Future Climate Resilient Built Systems

Energy production will come from renewable, local, and diverse sources. Residential, commercial, and industrial buildings will be retrofitted with rainwater catchment systems and be capable of gray water use. Infrastructure (homes, buildings, roads, sewer treatment, etc.) will be out of areas that are at high risk to floods, landslides, and fires. Public transportation and non-motor transportation are easily accessed and well-utilized. Communities are denser and designed for walkability and use of bike transportation to and from work, play, and home. Retrofitted and new buildings are well insulated and more energy efficient. Furthermore, there is a non-carbon based transportation system that provides connectivity between cities such as high-speed trains or electric public transportation.

Likely Impacts to Built Systems

Climate change impacts such as increased flooding and frequency of extreme weather events will strain the Lower Willamette's built systems, which are already subject to deterioration from age and recent extreme weather events. The infrastructure has already been tested during major events. For example, Highway 6 to the coast and Highway 30 are occasionally closed due to storms, ice, and landslides. During the 1996 flood, thousands of people were isolated due to rivers flooding major roads such as Highway 99 W, Highway 34, Highway 20, and Interstate 5 (Neville 1996).

Increased population from climate refugees and more compact housing will further strain infrastructure due to higher rate of use. This will require the need for additional public transportation, and place greater demand on the public water supply systems. Aging dams along the Willamette River may also face increased stress from extreme events.

Damage to water and sewer infrastructure. The greatest strain on water and sewer infrastructure may be felt during early winter and spring, when projections show an increased likelihood of intense rain events. The possible consequences of system failure include sewage system backup, submersion of sewage treatment plants, overwhelming of filtration systems from silt and other debris, and reduced availability of safe-drinking water through raw sewage leakage.

Flooding is not the only issue facing water supply system infrastructure. As water utilities face longer summer-demand seasons from their customers, in addition to reduced summer flows in some or many of their surface water sources, they will increasingly turn towards groundwater as a supplemental source.

Strain on public transportation and road conditions. Roads may be more frequently damaged due to increased temperatures, fire, and extreme weather events. This could cause interruptions in emergency response, as well as decreases in worker productivity due to commuting disruptions. With increased storms and runoff there may be large sediment increases from blowouts of forest roads. These roads will need to be closed or maintained.

If climate refugees move to the region as anticipated, regional transportation infrastructure would be impacted. Increased population will increase the need for local transportation options, as well as maintenance and repair expenditures. In addition, participants anticipate growing populations and rising gas prices, which would increase the need for bicycle and public transit alternatives to relieve congestion. While many communities have extensive bike lanes, some are not equipped to meet the alternative transportation demands of a growing population.[25]

Bridge failure. A number of bridges in the region, particularly the Sellwood Bridge in the Portland area, Dairy Creek Bridge, and the Olson Bridge (East 217), are structurally unsound and in need of repair or replacement. While ODOT is gradually working to make improvements (ODOT 2009), the efforts may not be enough to ensure structural soundness of these bridges with climate impacts – particularly "flashier" floods following heavy precipitation events- or their capacity threshold may be overwhelmed. A case study of two Portland streams (Johnson Creek and Fanno Creek) shows that, under climate change scenarios, floods with return periods of less than 25 years will become more frequent, which is likely to overflow bridges that have a history of chronic flooding (Chang et al. 2010).

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25 *In the Portland metropolitan area, which contains nearly half of the state's population, 71% of residents currently drive alone to work, 11% carpool, and 8% use public transportation (OPDR 2009). Moreover, for those who reside in the counties of Benton, Lane (the non-coastal portion), Linn, Marion, Polk, and Yamhill, the average commute time to work is 21 minutes each way. In these counties 71% of the residents drive alone, 14% carpool, and approximately 3% use public transit to get to work (OPDR 2009). One local expert noted that Beaverton was characterized as being dependent on automobiles and not having adequate infrastructure for pedestrian and bike travel, such as sidewalks and bike lane access.*

In urban areas, bicycle and pedestrian safe-access passages consist of sidewalks, crosswalks, crossing islands, and marked bike lanes. However, in rural areas the highway shoulders serve as bikeways and walkways (ODOT 2005). The Lower Willamette is within the Department of Transportation's boundaries of Region One and Two. In Region One there are 99 miles of highway with bike lanes and sidewalks, 112 miles of shoulder bikeways, and 10 miles of separated paths within the right-of-way. In Region Two there are 104 miles of highways with bike lanes and sidewalks, 296 miles of shoulder bikeways, and 8 miles of separated paths within the right-of-way (ibid). In Western Oregon, which includes the Department of Transportation's Regions One, Two and Three, 68% of roads outside of city limits (non-interstate rural state highways) are suitable for bicycling (ibid.) The City of Corvallis has 50 miles of striped bike lanes and 95% of its arterial and collector streets are bike friendly (ibid). Moreover, in Portland there are 75 miles of bike trails, 176 miles of separated in-roadways, 30 miles of bicycle boulevards, and 28 miles of signed connections for a total 309 miles of bike access (City of Portland Office of Transportation 2010). However, a 2008 assessment of Portland's bikeways found that only 33% of the designated main streets in Portland's Transportation System Plan and only 20% of the streets in Metro's 2040 Growth Concept had a developed bicycle facility (ibid). Portland's new bicycle plan for 2030 seeks to improve this and will add an estimated 681 miles to the existing 309 miles of bicycle access (ibid.)

Impact of the 1996 Flood on Water and Sewer Infrastructure in the Lower Willamette Subbasin

During the flood of 1996, nearly 117,000 acres of land were inundated and the region's infrastructure faced severe impacts (FEMA 2010). When the water flowing into the Duram Road wastewater treatment plant pushed the plant beyond its intake threshold, several sewer systems backed up into homes throughout Washington County and into the Tualatin River (Oregonian 1996). Further, poor home construction led to sewage backup in the southern edge of Cornelius near the Tualatin River: contractors who had built the homes 15 to 20 years prior tied the storm drainage system into the subdivision's sewers (a broadly accepted practice at the time) causing overflows to occur during heavy rain (Danks et al 1996). Additionally, the location of some sewer treatment plants posed problems: in the city of Lafayette (Yamhill County), the sewage treatment plant and sewage lagoons were completely under water (Oregonian 1996).

Throughout the region, filtration systems for drinking water supply were overwhelmed due to flood-washed silt and debris in waterways. The Willamette River knocked out sewer plants from Corvallis to Milwaukie and forced millions of gallons of raw sewage downstream. Silt in other rivers and streams clogged water system intakes and overwhelmed filtration systems in Portland. Residents throughout the region were encouraged to conserve water due to the limited capacity of many cities to filter water, and in Salem, flooding and turbidity forced the city to shut down its water treatment plant (Oregonian 1996).

Power outages also caused wastewater treatment plants to dump raw sewage into the rivers and creeks and contributed to water shortages. In Clackamas County, in the city of Molalla, heavy rainfall caused a power outage and the city's water intake plant burst a dike in the city sewage treatment plant, which caused raw sewage to flow into Bear Creek. Additionally, a power outage at the Tri-City Service District's sewer pump station in Oregon City caused an estimated 30 million gallon discharge per day of raw sewage into the Willamette. Impacts to pump stations left some communities without potable water for days (Oregonian 1996).

Drinking water treatment plants were impacted by high turbidities causing some reduction in available supply capacity for filtration, the need to switch to backup supplies, or sharing of supplies through interconnections. Erosion of river structures and debris in rivers had some impacts on intake and river crossing facilities. However, very few systems in the Portland Metropolitan area were short of supply or had to cut off supply for any length of time beyond a few days. (Please see report on the 1996 flood and drinking water system impacts from DHS, Drinking Water Program *www.leg.state.or.us/comm/commsrvs/floods.pdf*).

Throughout some parts of the region, residents of smaller systems were asked to boil water, or to obtain water from the Oregon National Guard for areas where the water was too contaminated for boiling. Some communities also implemented water restrictions, but despite conservation measures many continued to face depleting reserves. Mandatory daytime shutoffs were implemented in some cities to further protect reserves. For people using private wells, there was great concern that contamination went undocumented and untreated (Kohler, Kadera and Scott 1996).

Climate Refugees

A climate migrant, or "climate refugee" is a person displaced by climatically induced environmental disasters. Such disasters result from incremental and rapid ecological change, resulting in increased droughts, desertification, sea level rise, and the more frequent occurrence of extreme weather events such as hurricanes, cyclones, fires, mass flooding, and tornadoes. All this is causing, and expected to further cause, mass global migration and border conflicts. Because the Pacific Northwest is expected to experience less extreme climate events compared to other parts of the country and world, many planners and climate scientists believe that population increases will be above norm due to resettling of climate refugees. No formal projections have been made on how climate refugees will affect population increases in the Northwest: therefore, projections for impacts related to climate refugees in this report are speculative and not scientifically based.

Definition adapted from "Climate Refugees" a documentary film.

http://web.mac.com/lathinktank/climaterefugees/Home.html; www.iom.int/jahia/Jahia/definitional-issues

Air and rail disruptions. Rail lines may be affected by flooding as many miles of railroad are along rivers and streams. For example, Amtrak (from Eugene to Portland) was shutdown during the 1996 floods. Rail lines are also susceptible to icing from winter storms, as well as buckling under significant temperature increases. Additionally, the Portland International Airport (PDX) is the busiest airport in Oregon, with 90% of passenger movement and over 95% of freight movement through the state. The airport may be vulnerable to flooding and extreme events as well as sea level rise (not modeled in this analysis), resulting in flight delays or cancellations.

Impacts to power generation and utility transmission. With increased temperatures due to climate change, there may be increased energy demands during historically low-demand seasons of late spring, summer, and early fall, as well as impacts to the hydroelectric supply due to reduced stream flow (NPCC 2010). Hydropower meets 44% of Oregon's electricity demand (ODOE 2008). The Bonneville Power Administration, which provides much of the power to the region, relies on hydropower as a primary source of electricity (BPA 2008). The Northwest Power and Conservation Council confirms that an inadequate electricity supply can cause blackouts and affect public health and safety (NPCC 2010). Transmission lines may also be at risk from high temperatures, flooding, and extreme wind or precipitation events.

Interruptions in communications infrastructure. Communication infrastructure (internet, phone, television, etc) is at risk to high temperatures when above ground, flooding, fires, and extreme storm events such as wind and heavy precipitation. This would put communities at greater risk during the events due to lack of information from emergency service providers. For much of the Willamette Valley, communications providers are installing underground fiber optic networks, which will reduce vulnerabilities to climate change related impacts.

Impacts to buildings.

Flooding. FEMA floodplain maps likely underestimate areas vulnerable to flooding given climate projections. This, and other inadequacies in mapping, can result in development of homes, essential service infrastructure, and businesses in floodplains, putting them at risk to damage from floods. When authorizing development, Metro's

urban growth boundary policy considers the 100-year floodplain and 1996 flood inundation area (Metro 2002), but under Title 3 of Metro's Stream and Floodplain Protection Plan, construction in the floodplain is allowed with balanced cut and fill. Participants anticipate that these requirements may decrease future construction in the floodplain due to earth-moving costs. However, most jurisdictions allow construction in the floodplain as long as the finished floor elevation is located at least one foot above the FEMA flood elevation (Metro 2002) per FEMA floodplain program provisions. In addition, there are a large percentage of houses in the Willamette Valley that were built prior to 1980, which are identified as being more prone to flooding and landslides (US Census, Profile of Housing Characteristics 2000).

Wildland-Urban interface and wildfire risk. Of the 11 western states, Oregon is ranked third in the amount of forested public land with adjacent homes. Clackamas County, for example, ranks in the top 10 counties in Oregon for number of homes (8,033) and percent of wildland interface developed for housing (31%) (Headwaters Economics 2010). With projections showing wildfire likely to increase in frequency, intensity, and distribution, more homes are likely to be damaged.

Recommendations for Climate Resilient Built Systems

🌡 **Update and improve water and sewer infrastructure.** Water and sewer infrastructure needs to be designed to deal with bigger and more frequent storm events (See Portland's Grey to Green model in the Natural Systems section). In addition, updates to infrastructure by local utilities, state and local governments should consider projections for future population growth, including the possibility of future climate refugees. To decrease storm water runoff stress on treatment plants, local utilities should consider storm water catchment from gutters, green rooftop designs, increased green space, and separate storm water and wastewater systems with new pipe systems and upgrades. For cities experiencing low flow impacts, they should consider incorporation of grey water reuse and strengthening of local water conservation policies into plans. In addition, participants recommended water pricing to deal with shortages by providing efficiency and conservation incentives as well as capital to finance system upgrades.

Water supply portfolios need to be diversified to prepare for climate impacts. Participants recommended integrating groundwater as a supplemental supply source and conjunctive water management such as Aquifer Storage and Recovery (ASR). ASR stores surface water underground during the winter and spring for retrieval during the peak summer demand. See ASR textbox for more information. Improved system interconnections to allow sharing of supplies along with ASR may allow utilities to adapt to changing conditions. In addition, uncertainties associated with identifying the timing and magnitude of climate change impacts on watersheds and groundwater needs to be understood by the public. Utilities need to utilize decision support planning methods that address this uncertainty through multiple adaptation strategies. This can provide robust and reliable infrastructure for sewer, stormwater, and water systems.

🌡 **Identify critical infrastructure in floodplains and relocation needs.** Floodplain management plans need to consider the projected impacts of a changing climate, while agencies producing maps (such as FEMA) need to update maps for likely floodplain areas. This will help to reduce the impacts of flooding on infrastructure, improve resiliency for natural and built systems, and also support relocation of critical infrastructure outside of flood-prone areas. State and local jurisdictions may need to consider more accurate identification of floodplains if this task is not completed at the federal level.

Improve and safeguard transportation infrastructure.

Roads. ODOT and other local agencies responsible for constructing and maintaining road systems, should explore new paving technologies for transportation infrastructure that reduce the impacts of increased temperatures. New transportation infrastructure should consider future floodplain conditions and possibly rerouting of major roads to prevent flood damage (or at least identification of alternative routes in case of a major flooding event).

Recommendations with the thermometer symbol (🌡) are also greenhouse gas emission reduction strategies, also referred to as mitigation. Taking action to reduce emissions will decrease climate change impacts in the future.

Aquifer Storage and Recovery (ASR)

Aquifer Storage and Recovery (ASR) is a water management technique used by some public water providers in Oregon - and elsewhere - to diversify and increase the reliability of their water supply. ASR is the storage of water in a suitable groundwater aquifer through a well during times when water is available, and recovery of the water from the same well during times when it is needed (Pyne, 1995). More specifically, ASR is used by some water providers when their seasonally high water demands either approach or exceed available supplies during the summer. During the rest of the year, available supplies commonly exceed demands, particularly during the winter and early spring. Consequently, ASR programs take advantage of the availability of surplus water in the winter/spring by injecting treated water into underground aquifers through injection wells, then recovering the majority of this water during the summer to meet peak-season water demands that exceed the availability of other water supply sources. ASR programs are feasible where the underground geologic formation hosting the groundwater aquifer is sufficiently permeable and extensive to allow water to be injected and later pumped from one or more groundwater supply wells. The permeability of the aquifer must be high enough to allow the rates and durations of injection and pumping to match up with summer-time water demands. As water is injected into a well, the injected water displaces native groundwater and creates a mound (a zone of increased water level) around the well (see Figure 5). Storage occurs as a result of filling previously unsaturated pore spaces in an unconfined aquifer, or as a result of increasing the pressure within a confined aquifer. Underground storage of water offers many benefits over surface reservoirs including reduced environmental impacts, no evaporation losses, and increased security. Water utilities also have found ASR to be cost effective compared with developing more conventional supply sources.

Climate change is predicted to increase winter-time and summer-time streamflows in a manner that is especially relevant to the use of ASR as a water supply management tool. Specifically, during the winter and early spring, climate change is anticipated to increase runoff rates and streamflows, making more water potentially available for injection underground at those times of the year. During the summer, climate change is likely to lengthen both the duration of the peak water-demand season and the duration of the low-flow season for surface water supplies. Consequently, during the summer, instantaneous (hourly and daily) water demands and peak-month water demands could rise beyond present-day levels at the same time that surface water availability declines under climate change. Hence, a larger and more diverse water supply portfolio will be needed to build resilience in, and maintain the reliability of, water supplies under climate change. Under an ASR program, the summer-time use of underground water that was banked during the winter and spring reduces or eliminates a water provider's needs to increase withdrawals from surface water or groundwater supplies during the summer. This means that where subsurface conditions are suitable, ASR can be a useful tool for mitigating climate-change impacts on public water supplies. (Text contributed by John J. Porcello, RG, LHG; Senior Groundwater Hydrologist; GSI Water Solutions, Inc. Reference: Pyne, R.D.G. 1995. Groundwater Recharge and Wells: A Guide to Aquifer Storage Recovery. CRC Press. 376 p.)

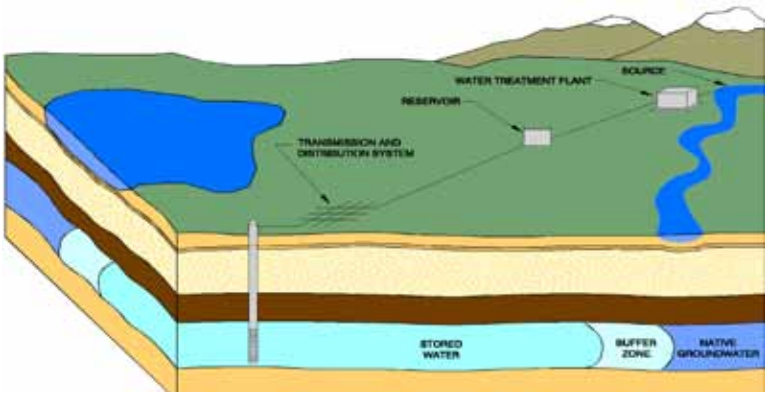

Figure 5: Conceptual ASR Application Illustration. Modified from CH2M HILL.

Public transportation and rail. Cities should improve connections via mass public transit, such as with high-speed rail. High speed rail infrastructure will need to be built in areas less prone to flooding (e.g along Highway 99), or raised for areas where flooding can not be avoided. Amtrak, ODOT, and the Federal Railroad Administration should conduct further studies on impacts of high temperatures to rail and heat tolerant infrastructure used to replace current rail infrastructure during standard repairs. Participants recommended that communities (local and regional governments, including MPOs) plan for mixed-use zones (e.g. employment clusters and mass transit located near condensed residential areas) to build resiliency through less dependency on travel for essential services and on single-car trips.

Bridges. When bridge repairs are made, height plans should consider and incorporate projections for future flooding conditions. Bridges at high risk will need to be identified and re-routing considered.

Airports. Some regional airports will need to consider relocation of runways to higher ground under future projections for flooding. The Portland International Airport may be at high risk to flooding due to its location along the Columbia River and close proximity to the Willamette River.

Improve energy efficiency of buildings (internally and externally). Energy efficiency education and outreach programs by both governmental and nongovernmental organizations will need to be scaled up to teach consumers about energy conservation behavior to reduce the strain on hydropower systems and the potential for black/brownouts. In order to retrofit existing buildings and set standards for future buildings, cities may need to consider incentives to improve energy efficiency in buildings. Encouraging businesses to become Leadership in Energy & Environmental Design (LEED) certified will also reduce the strain on hydropower systems during periods of low-flow. To reduce impacts from warmer summers and the strain on energy systems to provide air-conditioning, landscape design should include natural shade for cooling. Residential and commercial buildings should be west facing to best capture wind for cooling. Local jurisdictions may want to consider restrictions on native tree removal, incentives for tree preservation, and guidance from arborists on appropriate tree removal or preservation. This will improve cooling of buildings and reduction of the urban heat island effect. Government buildings can act as an example by improving the energy efficiency of their buildings and installing or purchasing renewables for the energy that is used. Investment in, and increased incentives for, non-hydro renewables will help to build resiliency to periods of low flow or drought. In addition, it may also help to attract a stronger market for solar and other alternative energy sources to relocate to the region and strengthen local economies.[26]

Identify back-up communication sources. City and county emergency service providers, in collaboration with communications companies, should identify alternative sources of communication during times of emergency events (such as radio communication, satellite phones, door-to-door, and central gathering points). As new communication infrastructure is built or repairs are made by the private sector, providers should consider projections for flooding, heat, wind, and extreme precipitation events to improve the resiliency of the infrastructure.

Update land use codes to prevent flood and fire damage to infrastructure. Planning strategies should consider potential impacts to communities by incorporating future flood, fire and population projections. Participants recommended that the Department of Land Conservation and Development as well as local and regional governments consider increasing the density of cities prior to expanding the urban growth boundary to prevent further risk if the UGB is expanded to fire- or flood-prone areas (see more on this discussion below); employing disincentives for development in flood or fire prone areas; requiring individuals to reduce risk (such as flow-through design, or fire-suppression sprinkler systems) when development is allowed in flood or fire prone areas; and revising development policies to minimize impacts in sensitive areas, especially along floodplains and riparian areas.

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26 *Decentralizing energy generation to the individual infrastructure level may act as an alternative to meeting demand should centralized systems be impacted by major events. The cost of doing so is estimated at $1.5-2 million per megawatt; however, there are no additional transmission lines necessary because power is produced near the point of consumption (Geddry 2010). One example of this is the City of Corvallis's Waste Water Reclamation Plant, which is implementing on-site renewable energy power generation (Future Energy Conference On-Site Generation for Public Owners 2010). In addition, the city has provided land to a private energy developer to own and operate a solar power facility and will purchase the power at a fixed escalator rate for the next 30 years (Geddry 2010). In addition, Clean Energy Works of Oregon is launching energy efficiency programs in seventeen communities throughout Oregon in 2011 as part of a $20 million federal American Recovery and Reinvestment Act grant. The program will help to increase the energy efficiency of homes, while also creating jobs. See van der Voo, Lee. 2010. "Clean Energy Works Expands in 2011." www.sustainablebusinessoregon.com.*

Promote compact housing and protect the urban growth boundary. All cities in Oregon have Urban Growth Boundaries (UGBs), which can be used to promote resiliency of surrounding natural systems to climate impacts. Limiting future growth and promoting compact housing will support climate preparation efforts, as it reduces the strain on emergency services, assists in neighborhood cohesion during major events, and reduces dependency on transportation infrastructure. However, higher density living may require a cultural shift, as many western communities are not accustomed to compact living: some regions of the Willamette have faced pushback from residents regarding infill development.

Metro, and most of its member cities, encourages efficient land use through the following initiatives: directing development to existing urban centers and along existing major transportation corridors; promoting a balanced transportation system which accommodates bicycling, walking, driving, and public transit; and supporting the regional goal of building complete communities by providing jobs and shopping locations near where people live (Metro 2010). State land use law and Metro Code require the periodic review of urban growth boundary assessments for growth capacity every 5-10 years for each 20-year period (Metro 2002). In the event of a housing deficit, Metro Code provides several options such as expanding the urban growth boundary to meet housing demands and/or creating additional capacity by adopting regulations. In other parts of the Willamette Valley, regional planning that integrates land use, transportation, housing, public health and environment can also promote climate resiliency.

Economic Systems

Background

Major employers in the northern part of the Lower Willamette (Multnomah, Clackamas and Washington counties) include hospitals and medical centers, manufacturing firms, local government, colleges and local school districts. Xerox, Sysco Food Services of Portland Inc., Intel and Nike are large corporate employers in the region (Portland Business Alliance 2010). The northern portion of the Lower Willamette's economy is primarily supported by small businesses with 89% of businesses having less than 20 employees (OPDR 2009). Similarly, the southern portion of the region is primarily supported by small businesses with 90% of businesses having less than 20 employees (ibid). The median household income for the three-county area is approximately $61,000[27] (City Data 2010). Major employers in the southern part of the Lower Willamette (Marion, Polk, Yamhill, Benton and Linn counties) include agriculture, food processing, lumber, manufacturing, education, health care, government, and tourism. The median household income for the five-county area is approximately $51,000 (US Census 2010).

The Lower Willamette is known for its greenhouse and nursery commodities as well as raspberries and blackberries. The region's other major agricultural commodities include Christmas trees, poultry, eggs, vegetables, melons, tree nuts, sweet potatoes, nursery, dairy, seed crops, hay, sheep, goats, and wine (ODA 2010). Logging and forest products are still a part of the economy, particularly in the western part of the valley, but have declined since the 1960s (Oregon Encyclopedia 2010).

The area offers cultural and outdoor opportunities for tourists including museums, agri-toursim (e.g. winery tours), parks, skiing and snow boarding, camping, wind surfing, and kayaking. Non-seasonal industries in the region include aircraft services,

27 The state average annual income is $50,169 (2010)

Participant Vision for Future Climate Resilient Economic Systems

The economic profile of the region will be one that is diverse and provides local sustainability. This region will be a leader in green industry research and development, have a strong research and educational capacity, a vibrant ecotourism industry, and plentiful agricultural resources, which will be the base for local food security.

electronics manufacturing, newsprint and steel rolling mills, and dental instrument manufacturing. The economic downturn, however, has had a negative effect on the manufacturing industry and has resulted in significant employment losses for the region (Worksource Quality Info 2010).

Likely Impacts to Economic Systems

The economy of the Lower Willamette is a combination of many small businesses, industrial and port facilities, and high-tech manufacturing and research. Each of these industries will face unique challenges in a changing climate, and in some cases may experience opportunities for expansion.

Vulnerability of small businesses. Compared to larger businesses, small businesses in the Lower Willamette may face greater challenges in recovering from climate change events such as a flood or fire. Regional economies that are dependent upon a few industries, and on small businesses lacking access to capital, may have a more difficult time recovering from a natural disaster (Cogan et al 2008). Clackamas, Multnomah, and Washington counties are all in the top quarter of economic diversity, and may experience greater economic stability under a climate-changed future compared to other counties in the region.

Changes in food prices and agricultural crops. Agriculture and food processing will be impacted by climate change, with higher expenses incurred for managing drought, extreme precipitation events, higher temperatures, and increases in disease outbreaks (Jones 2003). Food being imported from other regions may be sold at higher prices due to increases in management costs, while imported food may be at risk to transportation disruptions. Locally grown food may be impacted by an increase in the frequency of extreme weather events, such as heat, hail, wind, flood, or cold. This could prevent plant recovery in the short term or impair adaptation of crops over the long term. However, opportunities may emerge in the Willamette for crops tolerant of warmer climates (such as those currently grown in the Sacramento Valley).

Changes in grape variety and yield. Climate change will impact the region's wine production because of narrow varietal bands of temperature tolerance, and climate being one of the most significant factors in determining quality and style of wine (Jones 2003). The Willamette Valley is known for its cool-climate grape varieties such as Pinot Gris, Riesling, Chardonnay, and Pinot Noir. An increase in temperature may alter the types of wine grapes grown, quality of grapes, and profitability of this region. This may have strong economic impacts given that the direct and indirect economic impact of the wine industry exceeds $1.4 billion per year (Oregon Wine Board 2010). The Northern Willamette Valley is the largest wine grape production region in Oregon with 495 vineyards, and 13,234 acres in production. In 2009, the area yielded 26,980 tons of wine grapes.

Shifts in timber species and productivity. Linn, Washington, and Polk Counties are in the top 10 timber harvest counties in Western Oregon (OED 2010). Further, 28% of Oregon employment in forestry and logging is in the Willamette Valley and 9% is in the Portland Metro Service Area (OED 2010). Climate change may alter the species of trees that are able to grow in the region, which in turn may impact sector profitability. Climate change will likely favor the highest profit yielding timber species – Douglas fir – on the west side of the Cascades. Species adapted to warmer temperatures and drought will likely be favored. In addition, diseases and pests that strike timber species may expand their ranges with warming temperatures.

Loss of tourism and recreation. Tourism and recreation are important to the economy of the Lower Willamette and with changing temperatures and stream flow, recreational activities may change. Attractions that could be impacted by climate change include wine tours, hot air ballooning, river rafting, camping, agri-tourism (e.g. wine tours), among others. Reduced snowpack will impact the winter sports industry; however, longer summers may allow for more summer recreational activities such as camping, water sports, and fishing (however, many native cold-water species that draw fisherman may be at risk).

Interruptions to freight transportation. Roads are essential for the Lower Willamette's vibrant economy as trucks carry more cargo than rail. The Interstate 5 corridor is the most significant north-south corridor in Oregon (ODOT 2004). Freight transportation is vulnerable to flooding and landslides given that some roads are in floodplains. Important trucking routes, such as Interstate 5 and Highway 84, were blocked during the 1996 flood. Flooding over recent decades has frequently blocked I-5 between Portland and Seattle. In 1996 truckers had to decide between not moving goods or driving east through Yakima on Interstate 84, a detour of about 260 miles that costs an extra $416 (1996 dollars) per truck (Oregonian 1996).

While rail is not as common for freight movement in the region, it is still an essential component of the economy. Sixteen million tons of goods produced in Oregon are shipped out of state by railroad, while 23 million tons of products from other states are shipped to Oregon each year (OPDR 2009). As discussed in the Built Systems section, rail lines in the Lower Willamette are vulnerable to icing during winter storms, high temperatures, and flooding. Disruptions in service due to these events will lead to further economic losses.

Economic Impact of the 1996 Flood

Statewide, the 1996 floods resulted in $400 million in damages. An estimated 1,700 Oregonians lost their jobs and the Small Business Association (SBA) loaned Oregon businesses over $40.5 million to assist with recovery efforts. Source: Flood Hazards In Clackamas County. *www.co.clackamas.or.us/docs/dtd/flood_overview.pdf*

Increasing insurance rates. Insurance rates are likely to rise as risks for floods and wildfires increase. Existing homes and businesses in floodplains and fireplains are highly susceptible to rising prices. In 2009, Oregon homeowners in high-risk areas saw double-digit increases in insurance rates due to high catastrophic claims and replacement costs, primarily triggered by the increased amounts of claims from storms and wildfire (Hunsberger 2009). Companies that insure in areas prone to floods and where storms are causing a great amount of damage will likely raise rates by 100% within the next ten years (Davis 2009). Rising insurance prices will not only impact homeowners, but also influence business decisions. Businesses that are unable to secure or afford insurance may move assets to safer locations less prone to climate change disasters. Moreover, this move could also lead to a shift of employment and economic growth (Davis 2010).[28]

In addition to the insurance companies, investors are also evaluating risks associated with climate change for long-term decision-making. Investors are now seeking more information from companies on their preparedness for climate risks and are using the information to reassess investment decisions (Cogan et al 2008).

Impacts to health care.

Access. Healthcare infrastructure in the Lower Willamette includes for profit hospitals such as Willamette Valley Medical Center (McMinnville), major non-profit and teaching hospitals such as the Oregon Health and Science University (Portland), Legacy Emmanuel Hospital (Portland), Samaritan Health Services (Albany, Corvallis and Lebanon), Salem Hospital, and Providence (Portland), as well as alternative health services and institutions like chiropractic care and the National College of Natural Medicine. These hospitals are major employers for the region. Even with such varied and numerous services, climate change may reduce access and availability to healthcare. An increasing population of climate refugees and concurrent extreme weather events may push healthcare institutions beyond their current capacity thresholds. Moreover, emergency management services will be stressed with increased populations, reducing healthcare provider ability to respond to emergencies.

Insurance. In the Lower Willamette, the increased risk of wildfires and floods is expected to impact both housing and health insurance costs. Since extreme events exacerbate the spread of disease, diminish air quality, and reduce the health resiliency of the population, health insurers will likely see an increase in the number of claims. Medicare and Medicaid programs are also likely to see an increase in the number of participants and claims. While

28 *During the 1996 flood only 11,660 Oregonians had insured their homes and businesses against floods. In 1996, homeowners who did not have insurance bore the full cost of repairing the damage left by a foot or two of water inside their homes, which left damage costs of about 10-20% of the home's value (Oregonian 1996). The Governor's Office estimated there was at least $400 million in uninsured property damage in Oregon as a result of the 1996 flood (Register Guard 1996).*

Northwest insurance agencies have not specifically outlined a climate change strategy, some health insurance companies abroad are beginning to assess how they will provide for populations facing the impacts of climate change and what risks they will be able to cover (Harvard Medical School 2005; CCC 2007).

Cost. A number of risks associated with climate change are expected to increase the cost of healthcare in Oregon. In particular, costs related to new diseases, increased respiratory ailments, increased incidence of water- and food-borne diseases, and decline in nutrition and sanitation, will all likely cause upward pressure on healthcare costs. An analysis prepared by the Climate Leadership Initiative and EcoNorthwest (2009) found that health-related costs are expected to rise $764 million by the year 2020, $1.3 billion in the year 2040 and $2.6 billion by the year 2080 under a high emissions scenario.

Loss of productivity. While healthcare costs accumulate under changing climate conditions, secondary costs will also affect the Lower Willamette. As a result of climate conditions such as heat waves, low-altitude ozone and wildfire smoke, workforce productivity is likely to decline, particularly for vulnerable individuals and those that work outdoors (Bosello et al 2006).

Recommendations with the thermometer symbol (🌡) are also greenhouse gas emission reduction strategies, also referred to as mitigation. Taking action to reduce emissions will decrease climate change impacts in the future.

Recommendations for Climate Resilient Economic Systems

Diversify and promote risk management. Economic diversification (functionality, size and scale) will help the economy recover more easily from a disaster. Regional economic development agencies, Chambers of Commerce, or State economic development agencies can promote climate risk assessment, monitoring, and preparation for all businesses to improve their resilience. For instance, businesses may want to evaluate potential risk to their infrastructure and supply chain, followed by developing strategies to reduce risk.

Research and invest in climate tolerant crops. Growers may want to consider diversification of the crops they are growing, reassessing planting and harvesting seasons, and changing the scale of their harvesting. OSU–Extension and the State Department of Agriculture should invest in research on crops tolerant to higher temperatures and drought. Growers and producers of food, nursery, grass seed, fruits, and wine grapes that are considering new crops should take into account climate change projections for warmer temperatures.

🌡 **Shift industrial forest management practices.** Timber practices should focus on planting a diverse mix of species, increasing buffers to prevent disease and fire, and limiting clearcuts to prevent erosion and landsides. Currently, the Oregon Department of Forestry (ODF) is working to plant a greater diversity of species on state forestlands and move away from the historical single-species planting of Douglas fir. Given the 40-50 year rotations for tree planting, forest managers should consider now what they will plant and how a particular species will perform under new climate conditions over the next half century, such as focusing on heat, fire, and drought tolerant species.

Plan for shifts in transportation of freight. City, state and regional planners should identify roads most vulnerable to landslides, flooding, and fire, and have preparedness plans available for the safest and most cost-effective alternate routes for freight travel. See more recommendations in Built Systems sections for transportation infrastructure.

Meet insurance requirements. Insurance prices will continue to rise as risks increase due to climate change events such floods and fires. Modification of laws and building codes will discourage building on floodplains or in close proximity to the wildland urban interface. However, local emergency managers need to educate homeowners and

business owners that continue to reside in these high-risk areas on the steps necessary to minimize damage and reduce insurance costs. For instance, damage can be minimized and insurance rates reduced if building elevations are raised above the base flood elevation. Furthermore, damage prevention measures such as renting storage space to protect belongings, buying sandbags and lumber to make barricades, and renting pumps are all things that may qualify for reimbursement from insurance companies for damage-prevention expenses (Floodsmart 2010).

Prepare health care for change.

Education: To help prepare for an influx in population and associated health needs, opportunities and incentives can be increased for individuals to join the primary care field. Because the Lower Willamette already has a number of professional health institutions, there is an opportunity to build on existing institutions and programs. In particular, building the preventative care workforce now can reduce the economic strain on health care and insurance in the long run.

Comparative risk assessments and health impact assessments: Participants recommended that insurance companies, governments and local health providers examine potential outcomes under future preparation strategies and compare these with the costs of making no changes. Lower Willamette policy makers could use the Portland and Multnomah Climate Action Plan as a starting point for determining which changes to prioritize. However, they should consider conducting a Health Impact Assessment on various recommendation options, as was recently completed by the City of Eugene as part of its Climate and Energy Action Plan. In particular, insurers should use this approach to begin incorporating climate change preparedness into long-term planning and needs assessments.

🌡 *Preventative healthcare:* In order to control future increases in health costs, preventative health should be a priority for policymakers, educational institutions, and health providers. Strategies to reduce healthcare costs and reduce emissions include tree planting to increase shade and reduce the incidence of heat stroke, building public transportation infrastructure to reduce atmospheric pollutants, and providing walking and bicycle trails to encourage personal exercise. Dissemination of information to the public on new diseases, water and food contamination during floods or heat waves, and atmospheric pollutants caused by anticipated climate conditions is also essential.

Human Systems

Background

There are a high number of colleges and universities in the area including five community colleges, eight four-year colleges, ten universities, and one theological seminary. As a result, the general population enjoys a relatively high level of education.

In partnership with federal agencies like Federal Emergency Management Agency (FEMA) and the Centers for Disease Control and Prevention (CDC), as well as agencies at the state and local level, the counties work with other public agencies, the private sector, and citizens to mitigate against, prepare for, respond to, and recover from emergencies and disasters. Emergency management departments are typically housed within the public health department or office of the sheriff. Additionally, there are Community Emergency Response Teams (CERT) in the area, a FEMA run program that trains citizens as an extension of first responder services following major disasters.

The public health departments of the Lower Willamette provide outreach, education, research, assessments on the state of health, and services to the community. Public health program areas include primary care, mental health, Women Infants and Children (WIC), alcohol and drug treatment, food safety, disease outbreak monitoring, and immunizations.

Likely Impacts to Human Systems

Human systems in the Lower Willamette provide many vital resources and support for the health and vitality of residents and communities. Increased stress from extreme weather events and changes in available resources may render important systems unable to adequately respond to increased demand, including public health, emergency management, social services, and community networks. Experts from these community systems have identified many likely impacts from climate change as well as recommendations to further strengthen resilience to risks.

Amplified risks to vulnerable populations. Projected increases in storm intensity, flooding, and wildfire, may render residents with limited access to healthcare, transportation, and property insurance most vulnerable to disasters. Severe summer heat and changes in precipitation may leave those without access to air conditioning (or cooling centers), limited food and water availability, and

Overwhelmed emergency response systems capacity. Projected increases in the frequency and intensity of extreme weather events, outbreaks of vector-borne disease, and extreme heat may place greater stress on existing emergency response systems. While current systems are prepared for moderate emergencies, such as localized flooding and the H1N1 outbreak, emergency response systems may not have the capacity to adequately respond to a proliferation and accumulation of long-term, large-scale disasters (Merlo 2010).

with inadequate access to healthcare vulnerable to heat illness and disease. This includes low-income individuals, infants, elderly, and rural populations, as well as those with reduced mobility and pre-existing medical conditions. These vulnerable populations make up a substantial portion of the communities of the Lower Willamette. For example, low-income populations currently make up at least 15% of the population in Benton, Linn, Marion, and Multnomah counties. In addition, residents 65 years and older account for 11.3% - 16.8 % of the region's population and are expected to double in the next forty years (US Census Bureau 2010, Oregon Office of Economic Analysis 2004).

Homeless populations, estimated in the thousands around Portland and Salem, have limited resources to evacuate, stockpile food, store medications, and find emergency shelter (Edgington 2009) making them particularly vulnerable to extreme weather events and outbreaks of disease. In addition, outdoor laborers (particularly agricultural and construction workers) may be more susceptible to occupational disease stemming from hotter temperatures, changes in air quality from wildfires and increased ground ozone, as well as vector borne disease and UV radiation exposure (Center for Disease Control 2010).

Many emergency management systems in the region rely on the continuity of operations system, by which government departments suspend all non-critical functions during emergencies and focus solely on critical functions. The police department, for example, will divert resources from towing cars and writing traffic tickets toward essential life-saving tasks during emergencies. Although this system streamlines emergency response during large-scale events, it leaves many government functions neglected (Merlo 2010). An increase in the magnitude and frequency of long-term emergency events may mean increased diversion of resources from other government programs. Rising fuel costs and resource scarcity threaten the ability to deploy emergency response equipment and vehicles as well.

Inadequate individual response capacity. Individual emergency response capacity may not be adequate as emergency events increase in number and intensity. According to workshop participants, many residents in the region are not aware of emergency protocols or the availability of emergency resources. While an extensive collection of household and community emergency response resources are available through state and local agencies, many agencies are challenged

Participant Vision for Future Climate Resilient Human Systems

Community members will be physically and mentally healthy people who take advantage of increased opportunities for biking and walking, elimination of pollutants, and mixed-use areas. These areas increase the quality of life and reduce stress associated with commuting. The education system will provide children with an understanding of their relationship to the natural world and ways that they are able to take action. Furthermore, people and agencies will be well prepared for emergencies and the emergency preparedness systems will have ample capacity and resources for any disaster.

in adequately distributing information to residents without access to the internet and landline phones, and to those who do not speak English. In addition, very little behavioral health information is readily available to the public. Without access to this information, residents may be at risk for mental health and chemical abuse during emergencies (Minnesota Department of Health 2006).

Food and water scarcity. The projected frequency and severity of emergency events due to climate change, along with expected changes in global food supply, leave the Lower Willamette vulnerable to food and water scarcity. Emergency food systems for extreme events, particularly in rural areas, are already widely utilized under non-emergency situations, and the need for emergency food is increasing. For example, one in every five Marion, Polk, Linn, and Benton County families rely on food from an emergency food pantry at least once each year. From 2008 to 2010, demand for emergency food assistance in Marion County increased by 27% and remains at all-time record levels (Marion Polk Food Share 2008). Events limiting travel between counties (such as Willamette River flooding which can prevent travel between Benton and Linn) may put strain on communities that rely on regional emergency food resources.

While organizations such as the Oregon Food Bank and Red Cross are prepared to distribute potable water during emergency events, many communities lack adequate communication systems to inform residents about these resources. As diminished snowpack depletes reservoirs, and fires, landslides, and floods threaten the quality of water within the Lower Willamette, potable water supplies may be reduced.

Stressed social services. Workshop participants throughout the Lower Willamette identified a weakening of social and community networks. The absence of care and support within communities may strain local and state social services as populations deal with the effects of climate change. Large and growing elderly and low-income populations in the region will further stress social services. In addition, declining social networks may yield larger unreachable populations, impairing emergency communication and climate education.

Public safety concerns. Crime rates increase following moderate to large disasters (Cheatwood 1995) and high ambient temperatures are associated with increases in violent crimes including assault, homicide (Castaneda, 1991), riots (Cohn 1990), rape (Michael and Zumpe 1983), and domestic violence (Baumer and Wright 1996, Cheatwood 1995, Morken 2001). Hotter summers and increasing extreme events in the Lower Willamette may amplify local crime rates.

Outdated education. The current education system may not be adapted to new job requirements that climate preparedness will require at the rate necessary. In the current system, new concepts can take three to four years to be implemented in the educational systems. Concepts such as energy and water efficiency as well as community building

and collaboration are needed to foster climate preparedness. In addition, Oregon job codes are not current with new skill requirements needed for climate change preparation, rendering academic institutions unprepared to provide funding and coursework based on new skill requirements. A "bottleneck" at the state level to approve new certificate systems further impedes education systems' capacity to produce a climate literate and prepared workforce.

Public health concerns.

Reduced air quality. Air quality is expected to worsen with climate change as pollens, molds, and dust increase in the atmosphere. These increased air pollutants, in combination with higher likelihood of forest fires, threaten the respiratory health of the population. The Center for Disease Control reports that about 13% of the population in the Lower Willamette has asthma, and 8% of adults have hay fever (2009). Both of these conditions are likely to become more common in both adults and children with changing climate (EPA 2009). Further, respiratory disorders caused by particle

County	City	Good	Moderate	Unhealthy (Sensitive Groups)	Unhealthy	Missing
Multnomah/ Clackamas	Portland	307	54	4	0	0
Washington	Beaverton	330	22	0	0	13
	Hillsboro	288	62	7	0	8
Yamhill	McMinnville	351	8	1	0	5
Marion	Salem	310	48	2	0	5
Linn	Albany	331	28	3	0	3
	Sweet Home	292	60	1	1	11
Benton	Corvallis	327	27	0	0	11

Table 2. Summary of the 2009 Daily Air Quality Index Values in the Lower Willamette (Oregon DEQ 2010). Climate change is likely to shift more of these regions into the Moderate – Unhealthy group.

pollution (i.e. haze) from wildfires, dust, and dry soils, may be aggravated by increased concentrations of ground-level ozone (i.e. smog) (EPA 2009). Ground-level ozone, which is emitted from vehicles and industrial facilities and formed in the presence of sunlight by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOCs), is projected to increase. Climate change could increase the number of air quality alerts due to ozone, which is currently fairly low for the region (see Table 2) (EPA 2009).

Reduced water quality. Projections for increased precipitation and extreme heat events threaten water quality in the Lower Willamette. Increased precipitation as well as earlier snowmelt may contaminate water supplies through floods and overwhelm aging smaller waste water systems (see Built Systems for more information on water infrastructure). In the case of multiple extreme events occurring during a short time, participants were concerned that water providers may be overwhelmed. Potable water could become scarce and supplies limited, resulting in an increase in illness due to lack of clean water access. However, water agencies are required to remove most of the water-based diseases that are likely to occur with climate change in order to meet Safe Drinking Water standards. Many systems are built to withstand extreme events and continue functioning, and many cities have established potable emergency water distribution systems and boiling requirements when water quality standards cannot be met.

Increased mental health concerns. The stress of extreme climate events may be overwhelming for many individuals, especially with displacement through the loss of a home or other property. Effects may worsen for individuals who experience cumulative impacts from repeated exposure to events (Fritze et al 2008). Mental health effects of extreme climate events include grief, depression, anxiety disorders, loss of workdays, somatoform disorders,[29] and drug and alcohol abuse. In particular, children tend to exhibit more severe distress than adults from these events (Fritze et al 2008). Moreover, communities should be aware of the potential for acute- and post-traumatic stress syndrome. Events that may cause exacerbated mental health symptoms in the Lower Willamette include extreme heat events (heat stress, anxiety), flooding (loss of home, displacement), and wildfire (loss of home, respiratory disease).

Disease outbreaks.

- Vector-borne disease: There are mixed projections about the spread of disease under climate change. Some studies and local experts suggest that areas that have been able to control diseases in the past will continue to do so (Haines et al 2006). However, with the spike in floods, warming temperatures, and heavy rain expected in the Lower Willamette, some local experts expect an increased threat of insects that carry disease in the area. Mosquitoes are one of the primary threats as they carry diseases like malaria, filariasis, dengue fever, yellow fever, and West Nile virus. Ixodes ticks, which are more likely during dry summer months, carry Lyme disease and tick-borne encephalitis (Haines et al 2006).

29 *Characterized by physical symptoms that mimic physical disease or injury for which there is no identifiable physical cause.*

- Water-borne disease: Disease outbreaks can occur when water is contaminated by bacteria (e.g. Salmonella, Shigella), viruses (e.g. rotavirus), and protozoa (e.g. Giardia lamblia, amoebas, Cryptosporidium, and Cyclosporta). For those individuals who live in floodplains, the threat is particularly high. During the summer months, outbreaks of toxic cyanobacteria (also known as blue-green algae) can result in public health threats including illness in humans and mortality in domestic animals.
- Food-borne disease: With both warmer weather and increased precipitation, food borne diseases threaten the Lower Willamette. Crop growth, nutritional value and yields may be reduced due to changing climate conditions. Additionally, imported foods may by impacted by local climate change impacts elsewhere. While the Lower Willamette may experience less severe change compared to other regions of the United States, there is still a potential for outbreaks of diseases (e.g. E. coli and salmonella) that may arrive in food imported from other areas.

Increased heat events. Climate projections for the Lower Willamette region forecast an increased incidence of extreme heat events, as well as higher minimum temperatures. These events are marked by several consecutive days of temperatures of 90° F or higher, unusually warm nighttime lows in the 60s and low 70s, and stagnant, warm air (Frich et al 2002). In Portland, the average August temperature is 80° F. Heat waves have occurred in five of the last fifty years: August of 1971 had a 3-day wave of 100° F; August of 1977 experienced another 3-day wave of 101° F to 104° F; August of 1981 had a 4-day heat wave that reached 107° F twice; 1994 had a 3-day heat wave of 101°-103° F; and most recently, the heat wave of July 2009 had four days of 103°-106° F (NOAA 2009). These high temperature days followed by warm nights present health problems for a large portion of the population, particularly those of higher vulnerability like the elderly. Health professionals predict an increase in cases of heat stress and heat stroke. As a secondary effect, air conditioning units will be in higher demand. It is speculated that companies will start making cheaper and lower quality units in response to the increased demand, subsequently lowering the ability of the units to perform during peak events. Moreover, greater use of air conditioning may cause increased mold-creating moisture in interior building spaces, leading to associated illnesses (Morey 2010).

Reduced access to healthcare. With increased population levels (from climate refugees and projected population growth), resources and trained healthcare providers will be stretched, as will hospital space, pharmaceuticals, and medicine (See the Economics Systems section for information on health insurance and economic impacts to healthcare). Individuals will be expected to rely more heavily on preventative practices like healthy eating and exercise, and health providers will need to further develop education and outreach programs.

Cumulative impacts. While emergency responders and healthcare providers are currently able to tend to the needs of the community, there is significant concern among some local experts that the increased need for healthcare under climate change conditions will stress public health systems beyond their capabilities. For instance, if a natural disaster had occurred along side the H1N1 influenza outbreak, public health services would have been depleted of both resources and personnel.

Recommendations for Climate Resilient Human Systems

Community organizations, government entities, the private sector, and individuals in the Lower Willamette can utilize several strategies to build resistance and resiliency to the impacts of climate change on human systems. Preparation efforts should focus on strengthening community networks and bolstering the region's capacity to respond to increased stresses on emergency response systems, social services, and educational systems. Experts identified the following approaches as the most important and effective to preparing human systems for climate change.

🌡 **Identify and build resiliency of vulnerable populations.** State and local health departments and social service providers should assess the scope and needs of vulnerable populations. This information should also be incorporated into preparedness planning for the region. Mechanisms to promote self-resiliency, resource conservation, and efficiency measures may reduce the vulnerability of low-income, elderly, and geographically marginalized (i.e. rural) populations in the region. Climate education programs along with retrofitting and weatherization incentives should expand to promote self-sufficiency for those struggling to adapt. Establishment of stronger social and community networks will ensure a stable network of support and care for those most vulnerable and least resilient to negative climate change impacts.

Recommendations with the thermometer symbol (🌡) are also greenhouse gas emission reduction strategies, also referred to as mitigation. Taking action to reduce emissions will decrease climate change impacts in the future.

Strengthen local social networks. To alleviate potential stress on the region's social services, existing local social networks and community organizations should be strengthened. Cities, neighborhood associations, churches, and community-based organizations can develop events (e.g. block parties, meetings at community centers) to encourage community members to meet their neighbors and fortify networks of support. Currently, there are over 170 neighborhood associations, 30 community centers, and multiple databases of community service and social support organizations

Effective Outreach and Strengthening Social Networks

Our United Villages: The "Community Outreach" program, administered by the Portland-based non-profit Our United Villages, employs grassroots strategies to strengthen social networks and help "neighbors to get to know one another." With a focus on inclusivity, Our United Villages provides resources and creates opportunities for community members to convene, share ideas, and build social capital. Our United Villages organizes free community events, such as cultural historical storytelling and community building workshops, for residents to discover common interests and form networks. In addition, the organization facilitates brainstorming sessions and distributes vast community-building resources including: asset mapping workbooks, surveying and canvassing tools, guides to hosting a neighborhood celebration, guides to hosting intercultural gatherings, and a community resource list for non-profit and volunteer organizations.

Centro Cultural: Centro Cultural of Washington County delivers multi-lingual, culturally sensitive programs and resources to the residents of Western Washington County. Their mission is to promote social and economic development, meet basic human and community needs, and increase cultural consciousness and understanding among diverse groups of the community. The organization seeks to develop inclusive, diverse communities through art and cultural activities; multi-lingual education in Spanish literacy and GED programs; social programs such as a community kitchen, as well as empowerment programs including leadership training and community organizing.

Organizations like these will help communities in the Lower Willamette develop more diverse and effective outreach programs leading to more resilient social networks.

(Source *http://ouvcommunityoutreach.org/*; *http://centrocultural.org/english.htm*)

in the region. These resources can foster strong social support networks to increase outreach on preparedness efforts. An inventory of community resources may provide valuable information about the strengths and weaknesses of social services and community networks as well.

Improve community outreach systems. Expanding outreach programs and materials may provide additional relief to increasingly strained social services. Outreach organizations should ensure that they deliver diverse, culturally sensitive, and multi-lingual resources to the public. For example, the 2010 emergency preparedness calendar, provided by Benton, Linn, Marion, Washington, and Clackamas counties, is distributed in 4 languages. In addition, the content behind public education and outreach may be insufficient. New messages, conveying the public health and economic benefits of adaptation, should be implemented in outreach systems used by local and regional agencies as well as community organizations.

Increase capacity of emergency and social service response systems. Emergency management plans and resources should be evaluated for climate resiliency by local and regional governments as well as nongovernmental organizations and updated to address the specific risks of climate change. Updated plans should incorporate coordinated, regional management and involve contiguous jurisdictions to craft response strategies, recognizing that disasters do not adhere to jurisdictional boundaries (Merlo 2010).

Non-governmental institutions, such as the Red Cross, Salvation Army, and faith-based organizations, respond quickly and effectively in the wake of disasters to provide vital financial and material aid (Baker and Refsgaard 2007). Participants recommended that emergency management systems utilize valuable community organizations like these as additional sources of support in emergency response efforts. Schools, social service agencies, and private organizations such as grocery and hardware stores can be integrated into emergency response planning. Efforts to engage community support must carefully coordinate "spontaneous volunteers" to avoid added stress on emergency systems (Merlo 2010)

Developing centralized distribution systems for emergency resources will strengthen emergency response capacity facing diminishing resources. For example, agencies should establish centralized shelters and sandbag distribution units and improved coordination of emergency response systems to conserve vital resources such as fuel and equipment.

Case Study: Portland Regional Emergency Planning

Since 2003, the City of Portland has received Urban Areas Security Initiative (UASI) funding to develop regional emergency preparation and response capacity. The program is intended to foster regionally-coordinated emergency preparation within the grant region of Clackamas, Columbia, Washington, Multnomah and Clark (WA) counties as well as the City of Portland (much of the money is distributed for terrorism, but communities have taken advantage of "all hazards" planning as a means for using this financial resource). UASI regional projects focus on developing regional capabilities within interoperable communications, search and rescue, medical surge, and hazardous materials. (Merlo 2010). This includes development of web-based emergency coordination center software and a Regional Resource Management system (Multnomah County 2010). UASI regionally-focused emergency planning provides an excellent model for collaborative emergency preparedness in the Lower Willamette. Other regions may employ similar strategies to foster more resilient emergency response systems.

Increase individual response capacity. Communities should focus on increasing individual emergency response capacity as well. Programs to promote 72-hour emergency safety kits may ensure that every household has the capacity to survive for 3-7 days without outside support, as a means for reducing strain on already over-stretched social and emergency services.

Household distribution of education materials should involve multiple streams and multiple languages. The CDC lists 17 avenues for social media outreach including: webinars, blogs, podcasts, and widgets (CDC 2010). The Community Connectors program in Portland uses community leaders in underserved populations to communicate information about emergency protocols and can serve as a model for improving individual preparedness for populations without Internet access and landline phones.

Enhance local food security. To prevent food scarcity during emergency events and in the face of changing global food production, the Lower Willamette should develop more resilient local food systems. Localities, working with nongovernmental organizations, can adopt measures to increase local food production for all seasons, develop opportunities for food preservation, reduce dependence on food imports, and decentralize food sources.

Expanding farmers markets and food donation programs may increase the amount of local food available during emergencies. Community gardens present another opportunity to enhance food security already in place in parts of the Lower Willamette. The Marion-Polk Sustainable Community Gardens Program, for example, has established a system of over 30 local gardens, which produce approximately 100,000 pounds of food per year for the two counties (Marion Polk Food Share 2008).

Urban agriculture includes horticulture, livestock, fodder and milk production, and aquaculture grown or produced within and around cities. Enhancing urban agriculture- particularly horticulture, as raising fowl and livestock in urban areas can be contentious- can support climate change preparedness for urban communities by providing greater adaptability, access, and mobility compared with rural agriculture. Increasing the capacity of the cities to produce food can enhance the food security of the entire population, but in particular the low-income urban population, and ensure greater access to food during emergencies (UNFAO 1999).

Duplicate warehouse systems, such as used by the Oregon Food Bank, can prevent emergency food access issues for the region. For example, the organization has two emergency food warehouses, one in Northeast Portland and a second in Beaverton, to ensure that residents on either side of the Columbia River have access to emergency food when mobility across the river is compromised such as during a flood event.

Increase residential water conservation. There are two types of conservation programs that can be considered to offset the impacts of longer hotter summers and water shortages during extreme events. One is called programmatic conservation where localities can adopt policies to promote water conservation. The other type is curtailments, which can be used during emergencies to reduce

water demands on potable water systems. Curtailment planning and implementation is required by the State of Oregon within the Water Management and Conservation Plans. The City of Portland requires curtailment planning as a part of their wholesale contracts. These types of water conservation programs will improve resiliency of Lower Willamette communities by reducing dependency on water, which may not be available during drought years or extreme events. Incentives or rebates for water conservation can be provided to individual households, businesses, public buildings, and agricultural communities. An example of a tool that might be promoted among businesses or public buildings is an automated centralized control system. These systems are connected to a weather station via phone line or wireless connection, and constantly monitor humidity, temperature, and wind speeds to calculate plant water requirements and irrigation needs.

Decentralize home and community water storage. Localities should ensure access to adequate systems to disseminate emergency water storage information: for example, that individuals and neighborhoods have onsite storage of 3 gallons per person - along with instructions for finding more sources of emergency water, and a database of emergency water resources. Schools and hospitals should develop on-site water storage systems to ensure access to potable water during emergencies. In addition, home water purification systems and decentralized household or neighborhood water storage systems may prevent scarcity and contamination issues during disasters. To increase affordability for lower income populations, the state can offer subsidies or implement surcharges for the region's largest water users.

While Oregon state building codes permit graywater reuse and rain water catchment systems, some local codes, including the City of Portland code, place limits on the use of these systems for drinking water. Localities should reevaluate current regulation on graywater and rain catchment sources (see below). Information and installation assistance for on-site residential rainwater collection and storage systems should be provided by local water utilities and/or building departments. The Oregon Water Resources Department should consider these recommendations with state funding to local jurisdictions for implementation.

However, caution should be taken in considering these recommendations. There are a number of public health and equity issues associated with decentralized systems. Individuals would need to take personal responsibility to ensure systems do not become overwhelmed during intensive rainfall and flooding events, and that the systems are carefully monitored for disease. In addition, backup fees are necessary in case of system failure. For graywater treatment, the economies of scale may not merit public expenditures. Additional research and analysis on cost effectiveness is needed for rainwater catchments and graywater treatment.

Revise job codes and education certificate system. The state system should consider revisions for updating job codes and certificates in order to allow for faster updates. This will better address changing technologies and the skills required to meet the demands for green jobs. New jobs in installation and operation of distributed renewable technologies, energy and water efficiency installations, flood and fire management, and environmental restoration should be incorporated into state job codes and linked to public and private educational curricula, including high schools, community colleges and universities.

Build ecological and climate literacy into the education system. The education system has the potential for promoting climate literacy and preparedness. State and federal education standards should incorporate ecological and climate literacy, building from the standards developed by NOAA (See Resources Section). These standards may be built into existing programs or developed as a separate curriculum. More funding is needed for climate science and outdoor education and climate resilience technologies.

Prepare public health.

Improve and expand communications. Public officials need to understand how information presented to different communities is internalized in order to effectively share messages. The culture, language, and age of audience should be considered in tailoring communications: e.g. text messaging about disease outbreaks, television and radio announcements in multiple languages, reverse 9-1-1, and house calls or mailings for neighborhoods or populations with limited access to information. Climate change projections will be met with fear, confusion, and at times a "dooms-day" feeling, increasing stress levels within the population. Building an understanding of climate change into existing networks and regional plans will help reduce this impact.

Action-oriented education. A campaign to educate the public about health impacts resulting from climate change will help to reduce fear, panic, and also build self-sufficiency so the public is not completely dependent on health services. Deciding on the type of educational campaign that best suits the region will be important for having the

greatest impact on current behaviors. One strategy is "Keep Calm, Don't Carry On," which encourages individuals to not panic about climate change, but also to change their behaviors to help prevent adverse affects (Rose 2010).

Protect water quality. More stringent standards for pesticides, herbicides, fire retardants, etc., will improve water quality and reduce chemical runoff in water systems during larger precipitation events. Increased monitoring of water systems particularly during extreme weather events, coupled with increased communication to ensure the public is apprised of current water quality, will buffer public exposure to contaminated water. Additionally, a reassessment of water systems to ensure they can handle increased flow will reduce the threat of contamination (See Built Systems for more information on water infrastructure).

Expand mental health services. Mental health trauma needs should be built into emergency response systems in order to help service providers recognize and treat symptoms early before they are exacerbated. Healthcare providers should be educated about the signs of mental health symptoms, so they can diagnose symptoms at the time of response, in order to increase the likelihood that they can treat individuals at the onset of behavioral changes.

Air quality notification. Public health agencies will need to continue effective messaging and notification around air quality. TV, radio, text messaging and newspapers can ensure wide dissemination of messages about dangers of being outside during times of poor air quality. This is especially important for vulnerable populations.

Disease outbreak monitoring. Local experts recommend increased monitoring and testing to prepare for increased vector-borne, water-borne and food-borne disease. This will help public health officials communicate early about disease outbreaks that can threaten the population. Additionally, experts recommend ensuring that alert systems are in place (e.g. online, print, radio, cell phone and local news) to communicate the dangers as they arise.

Heat-wave alert systems and education for vulnerable populations. Establishing warning and alert systems within communities will aid in spreading knowledge of extreme heat days. This kind of ongoing monitoring is already under way in many cities across the Lower Willamette. The City of Portland and Multnomah County have designed brochures to help individuals spot and recognize the signs of heat related illness (e.g. heat stroke, heat cramps, sunburn, etc). Radio spots, local news, text messaging, and highway signage (Amber Alert signs) all help spread the word of high heat, low air-quality days. Some local experts recommend using schools with air conditioning as cooling centers for elderly and vulnerable populations. Neighborhood Watch programs could be instituted through neighborhood associations to check on vulnerable populations during times of extreme heat. Additionally, preparing for extreme heat through building plans that include increased insulation, for which many incentives already exist, will help build resiliency in communities.

Conduct Health Impact Assessments (HIAs). Including climate change projections in health impact assessments for the Lower Willamette will help establish preparedness strategies necessary for planning for impending climate changes. This will also help provide guidance for future healthcare needs in the event of an increase in population. Health Impact Assessments should also be incorporated into climate mitigation and preparedness planning. For example, the City of Eugene has recently completed an HIA of the Eugene Climate and Energy Action Plan transportation recommendations. The HIA reviews how recommendations for reducing transportation emissions and preparing the transportation sector for climate change reduces health risks. Similar analyses should be conducted for the Portland and Multnomah Climate Action Plan and other cities that have developed mitigation and preparation strategies. This will provide a 'whole systems' perspective to ensure that climate resiliency strategies for one sector do not have negative impacts on the health sector.

Promote preventative health. Educating individuals on preventative methods for healthy living will create a population more resilient to diseases brought on by climate change. In addition to education, having treatment facilities available to the population will support opportunities to address issues before they become severe. In Multnomah County, as part of the Health People Healthy Communities Initiative, public health officials are providing health education to children, persons with disabilities, and ethnic and racial minorities (Multnomah County Public Health 2010). Encouraging regular doctors visits, exercise, and healthy living is also important for strengthening the health of the community. Prevention will reduce risks to vulnerable populations and lower the economic and capacity strain on the public health sector.

Cultural Systems

Background

The Native American tribes of the Willamette Valley played a strong role in shaping the land over the past 10,000 years. While dozens of tribes divided the area, the dominant ones included the Kalapuya, Chinook and Clackamas. The Confederated Tribes of the Grande Ronde, whose ancestors lived throughout the Willamette Valley, have established territories in Washington, Marion, Yamhill, Polk, Tillamook, and Multnomah counties. They, along with the tribes that depend on the Columbia River (such as the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, and the Confederated Tribes and Bands of the Yakama Indian Nation) will all be affected by impacts and decision-making around climate change in the Lower Willamette. These sovereign nations manage land; aim to protect cultural and burial sites; rely upon salmon, lamprey and other fish as a means of nourishment as well as a connection to cultural traditions; promote timber growth and protect communities from wildfire; serve the health needs of their people; and work to provide education, economic growth, and energy independence.

As the Willamette Valley became known as a productive agricultural, timber and fur area in the 1850's, it became the destination of choice for many people traveling west on the Oregon Trail. Because of this, the region is home to a vast array of historical homes, barns, bridges, and landmarks. Oregon City, the first incorporated city west of the Mississippi, has a number of historic mills, houses and other buildings also prone to flooding.

Likely Impacts to Cultural Systems

How cultural traditions, practices, and artifacts may be affected is rarely addressed in climate change research or discussions. Native peoples have for centuries and millennia relied on plants, animals, and natural features of the landscape that may no longer be viable under future climate scenarios. From salmon and snowmelt-watered cropland to covered bridges, cultural resources that have been readily available in the past to natives and immigrants alike are threatened by climate change.

Loss of traditional resources. Natural resources, namely salmon, represent the cultural, social, nutritional and economic cornerstone of native communities in the Pacific Northwest. Salmon populations are specifically affected by changes in temperature, precipitation, and the aquatic environment (Hanna 2007). The location of Native American communities in the region renders them particularly vulnerable to projected decreases in snowpack, along with temperature changes, increased wildfires, issues of water scarcity and water quality, changes in precipitation, and increased intensity and frequency of extreme weather events. The natural resource dependency of these communities, as well as their limited land

Participant Vision for Future Climate Resilient Cultural Systems

People will be more water and energy conscious and will conserve more. Zero-waste policies will be practiced and consumption will be reduced. Decisions will be made at the regional level using a "Seven Generation" approach in considering impacts to watersheds, airsheds and soils. This will be accomplished through an institutional framework and intergovernmental coalition that can address climate change through open and transparent governance. Neighbors will know each other and work to embrace and enhance cultural differences and similarities. Tribal communities, and the resources essential to their cultural and survival, will flourish and be resilient to the impacts of climate change.

space and inability to change reservation locations, constrains their opportunities for adaptation. On the other hand, native communities may possess a greater capacity to adapt to changing availability of resources due to a history of variable salmon numbers and distribution, as well as due to reductions in tribal land (Hanna 2007).

Deterioration or destruction of historical architecture. The National Register of Historic Places lists 954 historical structures, buildings, and districts "worthy of cultural preservation" in the Lower Willamette. These sites attract significant tourism revenue, provide opportunities for community education, and preserve regional heritage. However, they are acutely vulnerable to climate change. Temperature changes may require architectural upgrades and weatherization. Fragile building material and structures without foundations and structural support are threatened by increasing events such as flooding and extreme precipitation.

Historic covered bridges represent a unique and prominent feature of the region's cultural landscape. These sites, along with other historic water resources such as boat landings, are vulnerable to projected increases in flooding and severe storms. Historic barns and other cultural landscapes related to farming may be affected by flooding in agricultural land and changes in land use. Historic commercial districts adjacent to rivers and streams are at risk for flooding as well.

Conflicts with climate refugees. The Pacific Northwest is likely to experience relatively minor impacts from climate change compared to the rest of the country and many parts of the world. However, it is likely that human migration patterns will shift, and potentially the Willamette Basin will experience growth from climate refugees. An influx of refugees displaced by global climate change impacts will likely exacerbate cultural tension stemming from competing values and identities, scarce water and other resources, which may further strain social services, and create environmental justice and equity issues. Currently, no studies have been conducted on likely population growth in the Willamette from climate refugees, although there is some anecdotal evidence that Oregon emigrants to the southwestern U.S. are beginning to return to the Pacific Northwest. It may be that climate refugees with the financial means to immigrate to the area may also have the means and skills to contribute positively to the Willamette Valley economy.

Environmental justice concerns. While low-income, rural, and native populations may contribute less to anthropocentric climate change, they are the least likely to have the resources for mitigation as well as resistance and resilience to natural, human, economic and cultural impacts. Greater awareness of environmental justice issues may become a prevailing source of cultural tension in the Lower Willamette as these impacts manifest more severely.

Recommendations for Climate Resilient Cultural Systems

🌡 **Protect key resources for tribal communities.** Native communities may need to consider diversifying crops and livestock as well as changes in timing of harvest, hunting and gathering. Diversification or shifts in timing will support efforts to prepare for changes in temperature and precipitation patterns as well as loss of snowpack. Communities living within floodplains may need to consider relocation or modification of infrastructure and buildings if flooding becomes more severe with changing streamflow. Strengthening of floodplain storage capacity can also reduce damage to tribal infrastructure. Outreach on climate change impacts, particularly relating to livelihood resources and public health, can improve self-sufficiency and reduce further strain on social and emergency services.

🌡 **Encourage resource conservation and energy independence in tribal areas.** Measures should be taken by tribal communities to encourage energy conservation in order to reduce dependency on unreliable hydropower systems. Technologies and programs to better inform the public about their consumption habits through energy monitors, water heater timers, and separate utility bills, may reduce the strain on resources. Cooperatives and resource sharing schemes may foster community connectivity while easing competition for resources. Policies involving scarce resources should encourage conservation movements with incentives, rather than restrictions and penalties.

Recommendations with the thermometer symbol (🌡) are also greenhouse gas emission reduction strategies, also referred to as mitigation. Taking action to reduce emissions will decrease climate change impacts in the future.

To reduce dependence on outside sources for energy, as well as to lower emissions, tribal communities should consider investments in wind, solar, geothermal, and biomass energies. Several organizations and agencies (e.g Department of Energy, National Renewable Energy Laboratory, Department of Agriculture, and Office of Native American Programs) offer support and assistance to native communities installing renewable energy systems. NativSUN Solar is a majority owned Hopi organization which provides "installation, maintenance, and technical support" for PV systems on native lands. In the Northwest, the Affiliated Tribes of Northwest Indians provides renewable energy development support. Communities may also consider purchasing renewable energy from utilities including the Bonneville Power Administration or updating land use and building codes for energy efficiency. Governments in the region should consider programs to subsidize and provide technical assistance for alternative energy projects on tribal lands. New climate change policies could incorporate revenue-raising mechanisms to finance native communities resource conservation and adaptation. Solar cooperatives, such as Solarize Portland, allow communities to collectively purchase and install solar systems. When coupled with Oregon's existing solar incentives, volume purchasing can bring the cost of solar electricity down by 90 percent (Portland Bureau of Planning and Sustainability 2010) (See Resources Section). Following the example of New Zealand "Water Users Groups," residents can additionally establish cooperative systems to manage and share their water allocations during times of water scarcity (Marguardt and Russell 2007).

Prepare for increased human population. The Pacific Northwest may see an influx of people escaping less tolerable climates. Water, land use, and transportation planners should consider shifts in population and demographics. Population growth research and modeling by universities as well as state and local agencies should be expanded to consider potential climate change impacts. Planning commissions may need to re-examine urban growth boundaries and lot-size requirements in accord with increased population projections (see section above on land use planning).

Proactively address current cultural tensions and prepare for new cultures. Communities should address and mediate current cultural tension (e.g. Rural-Urban, resource competition) before the climate stressors and demographic changes exacerbate problems. In addition, equity and environmental justice issues must be addressed now with outreach and empowerment programs. Outreach programs should be tailored to marginalized and vulnerable populations, in multiple languages and through multiple streams of communication.

The Institute of Community Cohesion recommends various mechanisms to build unity and monitor tension. Suggested practices include community meetings, collaborative action planning, youth outreach programs, inter-faith coalition building, and the use of neutral community facilitators and conflict managers.

Research and Monitoring Needs

As an important component of the Climate Futures Forums, local experts and stakeholders identified preparation efforts that require additional research for effective implementation and long term monitoring requirements. Research and monitoring programs will help detect trends, prompt appropriate preparation actions or management responses, and help in evaluating the effectiveness of actions to address climate impacts. A summary of suggestions for future research and monitoring needs for the Lower Willamette is provided for each system below.

Natural Systems

- Assess impact of climate change on plant - pollinator relationship
- Identify and monitor the most critical species (e.g. keystone, umbrella, indicator) and related habitats
- Identify hyporheic zones for protection (the region beneath and adjacent to streams and rivers where surface and ground water mix, important for spawning)
- Determine tornado probability for region
- Create high level species and ecosystem indicators for monitoring climate change
- Reassess 50, 100, and 500 year floodplains under climate projections
- Identify restoration capacity of degraded habitat
- Determine expected shifts in plant species, especially in riparian zones
- Evaluate impact of sea level rise on estuaries, rivers, and tributaries
- Monitor avian migration and life cycles
- Improve atmospheric and water resources monitoring to better identify climate trends and patterns
- Assess and monitor groundwater supplies and availability

Built Systems

- Identify groundwater recharge areas and impact of conservation measures
- Research risks and benefits of grey water and rain catchment systems
- Assess needed changes to state plumbing and building codes
- Conduct risk assessment of potential damage to utility transmission lines from fires and increased temperatures
- Determine ability of transmission systems, communication and utility infrastructure, to withstand heat and flood events
- Determine ability of reservoirs, drinking and wastewater systems to accommodate increased runoff and population demands

Economic Systems

- Quantify economic impact of climate change impacts on all systems
- Compile case studies on industry preparedness initiatives
- Determine economic viability of switchgrass and other crops as fuel resources
- Monitor disease and insect outbreaks on tree farms and plantations
- Identify climate change resilient crops
- Assess crop vulnerability to climate change and impact across economy

Human and Cultural Systems

- Produce population projections and planning scenarios for climate refugees
- Determine health campaigns that effectively change behavior
- Increase monitoring and communication around disease and mental health, especially after major climate events
- Determine effective communication methods about public health impacts of climate change
- Research use of social media as an early warning system
- Monitor changes in policymakers' and the public's climate literacy

Suggestions for Implementing Recommendations

Key Steps

The numerous recommendations provided in this report require further assessment by local and regional governments, community organizations, and institutions to determine the best pathways toward implementation. We recommend the following key steps toward implementation:

- Validate magnitude and urgency of impacts;
- Determine feasibility, benefits and cost of implementing a response;
- Determine the entity or entities best suited for management and monitoring; and
- Research tools to improve how climate change projections can be incorporated into the decision-making process, particularly in the way that decision-making addresses the multiple uncertainties inherent in scaled down climate projections along with the other significant uncertainties that must be considered.

The following sections provide an overview of critical implementation considerations to build climate resiliency in the Lower Willamette. An additional tool for prioritizing and organizing implementation tasks and identifying responsibilities is included as Appendix C.

Mainstreaming Implementation of Preparedness Activities

To adequately address climate change, the Lower Willamette region may need to consider the following principles that were recommended through the Forum process:

Integrate climate preparedness into existing and future planning and policies. A number of urban and rural planning processes already exist in which climate preparedness could be incorporated, including transportation, land use, natural hazards mitigation, and economic development. Integration may be more effective than a separate climate change planning process, as it requires fewer resources and builds awareness around the cross-cutting impacts of climate change. Local and regional governments can inventory current policy and priorities to determine where and how climate change preparedness can be incorporated. Projections for flooding and fires can be considered for planning infill, redevelopment, land acquisition, habitat protection and restoration, and urban growth expansion. When upgrading public works infrastructure, agencies may want to consider prioritizing communities or infrastructure most prone to extreme events or flooding. Social and emergency services could incorporate strategies for increased frequency and intensity of events, and relocate essential buildings and services out of flood prone areas.

Plan for future variability, not historic conditions. Participants clearly noted that the ecological, social and economic conditions of the past are no longer reliable indicators for the future. While modeling projections cannot determine the exact size for a culvert or height of a bridge needed to manage future flooding, we do know that future conditions will not reflect those of the past. Planning should consider the range of variability and include the trends that are portrayed in the projections: for example, communities need to plan for extreme precipitation events as well as prolonged drought conditions. Planning for a future of uncertainty and variability may require new information, protocols, funding, personnel, and decision-making mechanisms. Decision-makers may need to incorporate more flexibility into policies in order to allow for adjustment as new information emerges and unexpected conditions are experienced.

Incorporate scenario planning. To support consideration of variability, uncertainty and the need for flexibility, decision-makers should consider a range of scenarios for future conditions. By analyzing and considering the different scenarios in planning, it is more likely that solutions that perform over a large range of variability can be identified.

Consider multi-sectoral impacts of decision-making and planning at the regional level. Participants recognize that decisions made to build resilience in one system or sector has ramifications for other systems, sectors, and subregions of the Lower Willamette (See Appendix A). By increasing collaboration and decision-making across sectors, isolated planning can be reduced and unintended

consequences avoided. An integrated approach to decision-making and planning among public and private lands, as well as between forested, agricultural and urban areas will increase the resiliency of the entire landscape to climate impacts. Opportunities for leveraging efforts and improving efficiency may also be identified. Decision-makers should consider implementing tools that consider wide-ranging positive and negative impacts of decisions, following models used by Health Impact Assessments and Environmental Impact Assessments.[30]

Identify and prioritize co-beneficial, no-regret strategies. Participants identified numerous strategies to support resilience building across sectors and provide benefits to more than one system or sector. For example, groundwater storage in upper stream reaches of the Lower Willamette will enhance water supply and water quality for both fish and municipal drinking water, as well as provide water for irrigation. See Appendix A for a breakdown of how sample recommendations in this report provide benefits to other sectors.

Coordinating Implementation Across Sectors and Local Governments

Each sector and level of government has a critical role to play in building resilience to climate change impacts. For most, building resilience will be essential to assuring continuity of operations in the event of one or more extreme events. As outlined above, significant benefits can accrue from coordinated efforts to build resilience within and across sectors, systems and individuals jurisdictions.

The Lower Willamette is fortunate to have a number of unique governance structures and collaborations in place that may be effective in supporting coordinated planning and implementation. Key regional collaborations include Metro, the Oregon Cascades West Council of Governments, the Mid Willamette Valley Council of Governments, the Benton-Lane-Linn Water Resources Study Group, Regional Water Providers Consortium, Partners for a Sustainable Washington County Community, and the Cascades West Economic Development District.

Stakeholders and local governments within the Lower Willamette may wish to consider the model offered by the Citizens' Conservation Councils on Climate Action developed in British Columbia to advise government on the development of a regional action plan.[31] Other regional scale collaborations include the Southeast Florida Regional Climate Change Compact[32] enacted by four-county region including Palm Beach, Fort Lauderdale, Miami and the Florida Keys and the San Diego Association of Governments[33] response to implementing state climate legislation at the regional level.

Effective Communication and Dialogue

To effectively reach the community and inspire action, participants stressed the importance of identifying the right messenger to communicate the case for climate preparedness. Messengers will vary by community and system, and may include small business owners, local governments, public health employees, church leaders, or neighborhood associations.

Participants noted the importance of providing information on the economic implications of climate change and the benefits of preparedness. Individuals must feel that they have the capacity to make the changes in their lives and communities that will effectively build resilience against climate change as well as reduce emissions that further exacerbate the risks. By discussing preparation as a strategy that can be integrated into other initiatives (energy security, economic development), messengers are less likely to overwhelm audiences.

Stakeholders also recommended the creation of an oversight committee for climate preparation. This committee could be headed by a community-based agency or organization and structured to facilitate planning across all sectors and systems. It could operate within individual counties or across the region, supporting integration of climate preparation efforts into existing programs and planning processes.

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30 *For case studies on how decision makers (particularly the water sector) are being informed by climate projections, please see the Water Utility Climate Alliance http://www.wucaonline.org/html/*

31 *British Columbia Citizen's Conservation Councils: www.livesmartbc.ca/community/citizens.html*

32 *http://www.broward.org/NATURALRESOURCES/CLIMATECHANGE/Pages/SoutheastFloridaRegionalClimateCompact.aspx*

33 *www.energy.ca.gov/2009publications/.../CEC-600-2009-015.PDF*

Conclusions

Changing climate conditions, including higher temperatures, shifting precipitation patterns, reduced snowpack levels, and the consequent changes in species composition and range, will transform the natural systems of the Lower Willamette. These changes will alter the region's economy, infrastructure, human health, educational systems, culture, and way of life. Implementation of proactive strategies to reduce risk and build resilience will significantly reduce the region's multi-million dollar climate change response costs in the coming century (CLI & EcoNorthwest 2009).

The people and institutions of the Lower Willamette have the capacity and innovation needed to effectively prepare for climate change. The region is likely one of the more resilient in the country: by initiating a process now to prepare the natural, built, economic, human, and cultural systems for climate change, the Lower Willamette will continue to prosper well into the future.

This report identifies a number of consequences from climate change on the Lower Willamette, but it also presents many opportunities. Climate change may bring new prospects for locally focused businesses, increased self-sufficiency among residents, and innovative networks to support vulnerable populations. These responses will make the region more resilient not only to climate change impacts, but could also buffer the local economy to rising energy costs and turbulent global markets.

The Climate Futures Forums and the results presented in this report are only the beginning. Forum participants and stakeholders in the Lower Willamette must now assess the recommended strategies, identify priorities based on benefits and costs, and begin implementation. Effective implementation depends on broad coordination and collaboration across the many jurisdictions within Lower Willamette region, state and federal agencies, the private sector, institutions of higher learning, and non-profit organizations. Individuals from each of these institutions are encouraged to use this report to start a dialogue on building resilience to the impacts of climate change in the Lower Willamette.

Appendix A. Co-benefits Matrix

Natural Systems	Impacts on other systems (+ denotes positive impact, - denotes negative impact)			
	Built	**Economic**	**Human**	**Cultural**
Restore natural fire regime	(+) may reduce fire danger to infrastructure	(-) may impact some timber areas (-) may reduce economic value of forest homes	(-) may decrease air quality (+) may reduce risk of fire danger to human populations	(+) supports recovery of culturally important species
Reduce impervious surfaces	(+) reduces flash-flooding events (+) may increase amount of habitat within the built environment	(-) may limit new development opportunities (-) may require use of more expensive materials (+) may reduce the costs associated with water treatment, cooling, etc.	(+) improves water quality for human use	(+) supports recovery of culturally important species
Protect existing, high quality habitat	(+) may increase amount of habitat within the built environment	((-) may limit development (+) increases ecotourism (+) provides ecosystem services (reducing cost of water treatment, etc) (+) may lessen the burden on the built system (+) may boost property values and associated tax base	(+) may improve air and water quality (+) may improve human physical and mental health by providing places to recreate, enjoy nature	(+) supports recovery of culturally important species
Increase Early Detection Rapid Response Efforts (EDDR)	(+) reduces infrastructure damage	(+) reduces long term costs of invasive species removal (+) protects agricultural and timber land	(+) reduces human health risks that some invasives pose	(+) supports recovery of culturally important species
Increase monitoring and adaptive management	(+) may be supportive of infrastructure safety monitoring	(+) more cost-effective long-term management (+) supports recovery of commercially valuable species, protection of timber and crops		(+) supports recovery of culturally important species
Protect floodplains	(+) reduces flood damage to infrastructure	(-) may limit new development opportunities (+) may lessen the cost of rescue, and cost of repairing damage to structures and infrastructure, etc.	(+) reduces flood risk to communities (+) decreases need for emergency management services	(+) prevents impacts to historical architecture
Increase stream complexity	(-) may require removal of infrastructure (+) may reduce risk to infrastructure	(-) may limit new development opportunities (-) may reduce commercial use of water (+) increases tourism (+) supports recovery of commercially valuable species	(+) results in healthier natural system, which may reduce human health risk from animal vector species	(+) supports recovery of culturally important species

Built Systems	Impacts on Other Systems (+ denotes positive impact, - denotes negative impact)			
	Economic	**Human**	**Cultural**	**Natural**
Reduce development in floodplains and fire prone areas	(-) may limit development opportunities (+) may reduce insurance costs passed on to greater community (+) reduces the costs of rescue and repairing damage to structures and infrastructure incurred by communities, individuals and institutions	(+) reduces flood and fire risk to communities (+) reduces need for emergency management services		(+) protects natural systems
Maximize urban density	(+) protects agricultural and timber land (+) strengthens business within urban growth boundary (+) more efficient services (e.g., sewer, public transportation)	(-) strains existing social services (+) public service costs per capita potentially reduced	(+) protects culturally important species outside urban growth boundary	(+) protects ecosystems outside urban growth boundary (-) may reduce amount of urban area habitat, affecting some species
Utilize trees and air circulation for building cooling	(+) reduces energy costs	(+) protects populations from heat illness (+) improves air quality, reducing respiratory distress and asthma		(+) provides urban habitat
Increase water conservation and reuse	(+) reduces water costs	(+) increases availability and reliability of water supplies	(+) supports recovery of culturally important species	(+) increases in-stream flows
Strengthen water and sewer infrastructure for storm events	(+) less investment in future repairs	(+) ensures reliable water and sewer services (+) prevents contamination to drinking supplies		(+) prevents contamination of water bodies
Increase alternative stormwater management practices	(+) reduces costs of flood management (+) reduces water treatment costs	(+) reduces flash-flooding events		(+) provides urban habitat (+) reduces contaminated runoff in water bodies

Economic Systems	Impacts on other systems (+ denotes positive impact, - denotes negative impact)			
	Built	**Human**	**Cultural**	**Natural**
Business diversification	(+) expands business districts	(+) more jobs, more training for a wider variety of skills		
Crop diversification		(+) maintain nutritional value of food		(+) promotes diversity of species (+) reduces impact to soils
Change industrial forest management practices	(-) reduces development in some areas	(+) improves air quality		(x) promotes diversity of tree species [positive if native species, potentially negative if not]

Human Systems	Impacts on other systems (+ denotes positive impact, - denotes negative impact)			
	Economic	**Built**	**Cultural**	**Natural**
Incorporate vulnerable populations into preparedness plans	(-) may increase planning costs	(+) increased demand for more energy efficiency and flood resistant housing	(+) provides greater protection for tribal communities	(+) may result in additional resource protection
Strengthen local social networks	(+) may decrease long-term disaster recovery costs			(+) Stronger communities are more apt to protect their environment (+) increase cohesion
Improve emergency response capacity	(-) short-term costs for reevaluating systems (+) reduces long term costs of disasters	(+) opportunity for updating flood-risk education (+) encourages individuals to move away from floodplains		(+) reduce the impact of fire or storm events on streams due to ability able to mitigate stream conditions before an event (i.e. more complex streams with more logs)
Enhance local food security	(+) keeps money in the community (+) builds local economy	(+) creates opportunities for local food infrastructure	(+) may increase social cohesion (i.e. local farmers markets) (+) reinforces cultural traditions	(+) may provide habitat, encourage pollinators (-) if not done sustainably, could lead to loss of land, reduced water quality and quantity
Promote personal emergency water collection and storage	(-) short term costs of building (+) increases water security	(+) decreases community reliance on a single water system		(+) protects natural water bodies
Build climate literacy into formal education		(+) expands support for infrastructure changes	(+) increases understanding of cultural and tribal needs	(+) may increase opportunities/innovation to strengthen natural systems and protect species
Prepare for increased human population	(+) reduces competition for jobs if anticipate greater workforce (+) may increase innovation or business opportunities	(+) creates opportunities for mixed use planning	(+) reduces cultural tensions	(-) may lead to impacts to habitat or water supply if growth boundary not defined (+) Advanced preparation will better incorporate natural resource concerns than emergency response.
Increase preventative health systems	(+) increases job opportunities for healthcare workers	(+) increases use of active areas and encourages active lifestyles		

Cultural Systems	Impacts on other systems (+ denotes positive impact, - denotes negative impact)			
	Economic	**Human**	**Built**	**Natural**
Encourage resource conservation	(+) keeps resource spending down	(+) builds community cohesion		(+) protects listed species and key habitats as well as other species and habitats
Proactively address cultural tensions		(+) builds social capital		(+) creates a more hospitable atmosphere for discussing environmental issues
Support Native Communities adaptation	(+) builds commerce opportunities	(+) increases equity among population (+) promotes social cohesion		(+) increases environmental justice

Appendix B. Likely Impacts to Specific Watersheds and Tributaries in the Lower Willamette

Willamette Tributaries. The daylighted streams are likely to experience limited change due to cooler temperatures. (Daylighting is the process of returning a stream that has been diverted into a culvert, pipe, or drainage system back into an above-ground channel; generally, the aim of this procedure is to restore the water body back to a more natural state.) Tributary reaches that are closest to the mainstem Willamette and that are not daylighted are likely to be most impacted due to probable temperature increases and decreased water quality. Although not considered in the modeling projections, participants identified that mainstem tributary reaches closest to the Willamette and below Willamette Falls will also likely experience impacts associated with sea level rise.

Tualatin. The Tualatin is a rain fed system that relies mostly on reservoir storage. By 2040, the watershed's annual runoff is projected to be less than its historic average, with summer flows decreasing by 10-20% (Palmer et al. 2004). Drier summers will stress the ability of the system to meet temperature and instream flow requirements (Chang and Lawyer 2010). The Tualatin River and its tributaries serve as critical habitat for winter steelhead, which are listed as threatened species under the Endangered Species Act (Obermeyer and Harza 2003). There will be an increase in winter precipitation, but the increase in ambient air temperature is projected to offset the greater precipitation because of more evapotranspiration, leading to a further reduction in late spring and summer flows (Praskievicz and Chang 2011). If this occurs, these reduced flows will increase the drawdown period for Hagg Lake. As a result, the watershed will have less annual runoff to meet an increased water demand, and in an attempt to meet these demands, annual refill of the system will become more uncommon and the impacts of extended drought more significant.

The watershed is already affected by the prevalence of impervious surfaces (Boeder and Chang 2008), which alter normal surface runoff and groundwater recharge patterns as well as reduce the amount of flow to Tualatin River tributaries during the dry months (Obermeyer and Harza 2003); the impacts from urbanization will continue to increase. Vegetation may also be impacted in the future. For the Lower Willamette region vegetation models (MC1) combined with three climate models show an increase in fire as a potential catalyst for a shift from true fir and spruce dominated forests to mixed species: Douglas fir, ponderosa pine, and deciduous species more adapted to a warmer and fire prone environment. With urban development likely to further exacerbate hydrology and water quality problems, conservation-oriented development will have a lesser impact, suggesting that future land use decisions should be used for climate adaptation strategies (Franczyk and Chang 2009; Praskievicz and Chang 2011).

Clackamas. The Clackamas watershed is groundwater and snowmelt dependent. Climate modeling projections show a dramatic decrease in peak snowpack (36-49% by 2010-2039, and 83-88% by 2070-2099) and a significant increase in evapotranspiration (Graves and Chang 2007). This will lead to earlier runoff and increased winter flows and reduced spring and summer flows. Many sensitive species exist in the subbasin, and small changes in climate may have a great impact on species. Furthermore, the Clackamas watershed is an important cold-water source for the Willamette River and an increase in temperature could result in impacts across the system, particularly below the confluence of the Clackamas and the Willamette. Vegetation change would likely affect aquatic systems. As with the Tualatin, models show an increase in fire as a potential catalyst for a shift from true fir and spruce dominated forests to mixed species: Douglas fir, ponderosa pine, and deciduous species more adapted to a warmer and fire prone environment.

Johnson Creek. Johnson Creek is a rain-fed system that is already extremely flashy and warm. Flash floods are likely to happen more frequently with climate change and ongoing development (Jung et al. 2010), which will disrupt urban travel (Chang et al. 2010). Johnson Creek may dry up in places seasonally with increased summer temperatures, which could result in a large loss of species in the summer. However, it will be less impacted by changes in snowpack.

Yamhill. The Yamhill River runs through agricultural systems, and the soils have low permeability with an increased likelihood of flashiness in the future. The wineries within this river system are likely to be impacted with increased temperature and extreme storm events.

Tryon Creek. Tryon Creek is a highly urbanized, yet well-protected system that is not likely to experience significant change. Many of the tributaries are in good conditions (such as Arnold Creek) and there is potential habitat for climate sensitive species if and when the fish barriers are removed. Some of the ineffective culverts will need to be removed or replaced to improve resiliency. There is also potential for changes in vegetation and soil with changing water patterns.

Columbia Slough. The Columbia Slough is tidal and likely to experience warmer temperatures and become more eutrophic. Trout, freshwater mussels, migrant and neotropical shorebirds and songbirds may be impacted by climate change. Sea level rise could also have a major impact.

Bull Run. The Bull Run watershed provides drinking water to almost a quarter of the population of Oregon (VanRheenen, Palmer, and Hahn 2003). It is likely to become less stable with climate change. The watershed is characterized as transient because it has two flow peaks: one in the early winter from increased rainfall and a second in the spring from snowmelt (ibid). In this type of watershed, even slight climatic shifts may cause changes in the timing and amount of runoff. Increased rain and snowmelt may result in flashier systems with higher winter flows and lower springtime flows. Warmer temperatures in the winter will reduce snowpack in the basin and warmer summer temperatures will likely increase water demand (ibid). If there is a significant decrease in surface storage in the system then there will need to be a change in water management (e.g. implementing increased conservation measures, expanding reservoir systems, altering groundwater operations, and implementing water use restrictions). Although climate change is projected to exacerbate water supply and demand issues, the greatest impact on future water supplies predicted for the watershed is growing demand from increased population growth (ibid). This area is also likely to experience increased frequency of wildfire and storms.

Mary's, Luckiamute, and Calapooia. These tributaries are mostly rain dependent systems that rely on slow release from wetlands. They have non-structural storage, which may not be a dependable source in the future. These three watersheds may also be most at risk for elevated temperature impacts. Watershed councils are working to increase hyporheic storage through encouragement of beavers, increasing channel complexity and gravel accumulations, removal of drain tiling and ditching to encourage off-channel ash swales, and recovery of other valley bottom wetland habitats.

Santiam Subbasins. The Santiam subbasins of Crabtree, Hamilton and McDowell are already at risk for temperature issues, which are likely to get worse and impact the species that depend on the subbasins for lifecycle habitat. The temperature impact may be exacerbated by their dependence on snowpack.

Appendix C: Draft Matrix for Organizing Impacts, Recommendations and Implementation

The sample matrix below provides guidance on how recommendations can be assessed for prioritization and implementation. First, systems are identified (e.g. natural, built, etc) along with subsystems (e.g. forests, roads). For each subsystem, likely climate impacts are listed as well as the impacts' results, timing, and severity. Costs and likely consequences of the impact are identified across other subsystems or systems. With this analysis, prioritization can be made based on severity, timing and costs. Next, proposed actions to address impacts are listed along with who is responsible, how the action is implemented, funding and timing of action, and how existing policies can address this action. This is only one method for identifying impacts and actions for implementation and should be adapted to meet the needs of communities and implementing agencies.

		Response Action								Implementation Pathway							
System	Subsystem (SAMPLE ONLY-NOT COMPLETE)	Likely impacts	Negative/ Positive	Direct/Indirect	Timing	Severity	Costs (L, M, H)	Possible No-regrets / Co-Benefits	Prioritization Rank	Proposed Actions	Responsible Authority	Gaps in Responsibility	New Authorities Needed	Mode of Implementation	Associated Timing	Funding Sources & Timing	Analysis of Existing Polices
Natural	Terrestrial																
	Forests																
	Soils																
	Biodiversity																
	Oak Woodlands																
	Prairies																
	Aquatic																
	Riparian habitat																
	Ground water																
	Wetlands																
	Hydrologic cycle																
	Salmon																
	Biodiversity																
Human	Public Health																
	Emergency Response																
	Education																
Built	Commercial Buildings																
	Residential Buildings																
	Roads																
	Railroads																
	Airports																
	Drinking Water Systems																
	Sewage Systems																
	Community Systems																
Economic	Forestry																
	Agriculture																
	Tourism																
	Manufacturing																
	Fishing																
Cultural	Special Places																
	Special Species																

Appendix D. Resources

Case Studies

University of Washington Climate Impacts Group CASES Database and Adaptation Library

http://cses.washington.edu/cig/cases

This database was created to support climate change adaptation efforts at the state, regional, and local level. The database provides links to a wide variety of reports, studies, and other general information on adaptation planning.

EcoAdapt CAKE

http://www.ecoadapt.org/Projects.html

http://www.cakex.org/

Climate Adaptation Knowledge Exchange (CAKE) is a joint project of Island Press and EcoAdapt which is aimed at building a shared knowledge base for managing natural systems to face climate change and help build an innovative community of practice.

Climate Modeling and Science

Climate Modeling

http://www.oar.noaa.gov/climate/t_modeling.html

This link provides a general description of how climate models are used.

http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf

This link describes how climate models are used and how they differ.

Intergovernmental Panel on Climate Change

http://www.ipcc.ch/

The Intergovernmental Panel on Climate Change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), provides a scientific view on the current state of climate change and its potential environmental and socio-economic consequences.

Oregon Climate Change Research Institute

http://occri.net/

The Oregon Climate Change Research Institute (OCCRI), based at Oregon State University (OSU), is a network of over 100 researchers at OSU, the University of Oregon, Portland State University, Southern Oregon University, and affiliated federal and state labs that fosters climate change research and provides climate change information to the public in an easily understandable form.

Oregon Climate Service

http://www.ocs.oregonstate.edu/

The Oregon Climate Service (OCS) is located on the Oregon State University campus in Corvallis, Oregon which collects, manages and maintains Oregon weather and climate data.

University of Washington Climate Impacts Group

http://cses.washington.edu/cig/

The Climate Impacts Group (CIG) is a research group studying the impacts of natural climate variability and global climate change in which key areas of research include: downscaling global climate model data; regional climate modeling; hydrologic modeling; water resources and terrestrial/aquatic ecosystem modeling and impacts assessment; coastal impacts assessment; climate change vulnerability assessment and adaptation planning; and outreach and education.

US Global Change Research Program

http://www.globalchange.gov/

The U.S. Global Change Research Program (USGCRP) coordinates and integrates federal research on changes in the global environment and their implications for society such as estimating future changes in the physical environment, and vulnerabilities and risks associated with those changes; and providing scientific information to enable effective decision making to address the threats and opportunities posed by climate and global change.

Adaptation/Preparation

EPA Climate Adaptation Resource

http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=180143

This report analyzes information on the state of knowledge of adaptation options for key, representative ecosystems and resources that may be sensitive to climate variability and change.

http://www.epa.gov/climatechange/effects/adaptation.html

The EPA lays down the foundation for why climate change adaptation is necessary and the vulnerable areas impacted by climate change such as: human health, coastal areas, agricultural and forestry, ecosystems and wildlife, water resources, and energy.

IPCC Climate Adaptation Resource

http://www.ipcc-wg2.gov/

The IPCC Working Group II (WG II) assesses the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it.

White House Climate Change Adaptation Taskforce

http://www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation

The Interagency Climate Change Adaptation Task Force formed workgroups to consider the capabilities of the Federal Government to respond to the impacts of climate change on various critical sectors, institutions, and agency mission responsibilities.

wikiAdapt

http://wikiadapt.org/index.php?title=Main_Page

wikiADAPT is a platform to enhance the knowledge base of the climate adaptation community which has community of contributors adding to the content of the site.

weAdapt

http://www.weadapt.org/

weADAPT has been collaborating with Google.org to explore ways of improving access to information on climate adaptation using Google Earth to create a quick and easy way to find out who is working on what and where.

Mitigation

Climate Master Programs

http://www.theresourceinnovationgroup.org/about-climate-education/

The Climate Master programs provides cost-effective, actionable education and training to help individuals, businesses, and youth reduce greenhouse gas emissions and prepare for local climate impacts.

ICLEI Climate Mitigation and Adaptation Planning for Communities

http://www.iclei.org/index.php?id=800

After the initiation of ICLEI as the first global network of cities and local governments to achieve sustainability at the local level, the Urban CO2 Reduction Project, implemented in 14 cities across the US, Europe and Canada, was the first concrete measure in local climate action.

Oregon/PNW

Impacts

http://www.oregon.gov/ENERGY/GBLWRM/climhme.shtml

This link provides a brief overview of how climate change will impact ecosystems and human health in the state of Oregon.

Activity Map

http://www.theresourceinnovationgroup.org/map-of-mitigation-and-prepared/

The map includes information on communities or businesses with climate action plans or preparedness activities; regions with downscaled climate data; communities hosting Climate Master Classes; communities implementing small-scale biomass projects; and regional reports or other information useful for climate change mitigation and preparedness.

Climate Communications

Social Capital Project

http://www.thesocialcapitalproject.org/

The Social Capital Project works with climate leaders from the nonprofit, public, and private sectors to help increase the capacity of groups to communicate effectively with the public about global warming and to develop outreach strategies that overcome barriers to behavior change.

Miscellaneous

Reverse 911

http://www.plantcml-eads.com/reverse-911/

The Portland Watershed Management Plan and its supporting document, the Framework for Integrated Management of Watershed Health (March 2006)

http://www.portlandonline.com/bes/fish/index.cfm?c=33528

The Portland Watershed Management Plan and the Framework describe Portland, Oregon's approach for improving the conditions and ecological functions of its urban-area watersheds by using a watershed management process. These documents offer a definition of healthy urban watersheds, a vision for the future of Portland's watersheds, and watershed health goals and objectives related to hydrology, physical habitat, water quality and biological communities. The Plan also identifies strategies

and actions for achieving the goals and objectives. The Framework lays out the scientific basis for Portland's watershed management process.

Denver Impervious Surface Mapping and Incentives

www.thefreelibrary.com/Denver+Wastewater+Uses+DigitalGlobe+Impervious+Surface+Map+Products...-a0117034508

To help maximize the efficiency of its billing property owners in the City and County of Denver for sanitary sewer use and water drainage, the Waste Management District initiated a pilot project to determine the effectiveness of using high-resolution multispectral (blue, green, red, near infrared) satellite imagery for mapping impervious surfaces in five Denver neighborhoods, including three residential, one commercial, and one industrial neighborhood.

Department of Interior's Landscape Conservation Cooperatives

http://www.doi.gov/whatwedo/climate/strategy/LCC-Map.cfm

Landscape Conservation Cooperatives are management-science partnerships that inform integrated resource-management actions addressing climate change and other stressors within and across landscapes.

Responding to Climate Skeptics: "Setting the Record Straight"

http://www.theresourceinnovationgroup.org/climate-educ-lit-pubs/

This document provides scientifically credible responses to some of the most commonly heard challenges of the reality, causes, and trajectory of human-induced climate change.

Examples of State and Local Retrofit and Weatherization Resources

Oregon	At the state level, Oregon residents are eligible for several retrofit and weatherization assistance programs revolving mainly around financial incentives and support. State-wide programs include: • Residential energy tax credits (RETC) allow personal state income tax breaks for installation of efficient appliances, weatherization, and renewable energy systems. • The state small-scale energy loan program issues bonds to finance small energy projects including weather-stripping and insulation. • GreenStreet lending (low interest loans provided by the Energy Trust of Oregon and Umpqua Bank for the installation of renewable energy systems or efficiency improvements.) • Portland General Electric's weatherization program provides several counties in the Portland area with free weatherization for low-income households. Services include insulation and sealing air leaks.
Multnomah County	Multnomah County residents are provided with several avenues to of assistance including: • The County Weatherization and Energy Assistance Program provides energy audits, insulates homes using a Welfare-to-Work training crew, purchases other weatherization measures for homes as needed, and provides one-time utility payments for low income households • The Clean Energy Works Pilot Program offers weatherization financing for low-income Portland residents.
Washington County	Community Action of Washington County offers cost-free weatherization services to low income residents.
Clackamas County	Community Solutions for Clackamas County's Weatherization program provides low-income households free weatherization services including insulation and weather-stripping.
Marion & Polk Counties	The Mid Willamette Community Action Agency's low income energy assistance program offers *"weather-stripping of doors and windows, floor, wall and ceiling insulation, duct insulation and sealing, water heater insulation and information on health and safety"* to Marion and Polk residents.
Yamhill County	The Yamhill Community Action Partnership weatherization program provides low-income residents with services including energy audits, base load measures, free insulation, and installation and repairs to heat systems.
Linn & Benton Counties	The Community Service Consortium provides free labor and materials for residents' energy efficiency improvements such as insulation, duct sealing, and diagnostics.

Appendix E. Participant List

N=Attended Natural Systems Workshop (February 24, 2010 in Portland; or April 13, 2010 in Albany)

C= Attended Community Systems Workshop (April 7, 2010 in Oregon City; April 9, 2010 in Cornelius; April 15, 2010 in Gresham; or June 4, 2010 in Albany)

Name	Agency	Workshop
Steve Adams	Climate Leadership Initiative	N
Nathan Adelman	USDA Natural Resources Conservation Service	C
Jordannah Baker	Portland State University	C
Susan Barnes	Oregon Department of Fish and Wildlife, Northwest Region	N
Margot Barnett	Oregon State University Extension Service	C
Chris Bates	Community Development	C
Peter Beedlow	Environmental Protection Agency, Global Change Research Program	N
Carol Bellows	American Society of Landscape Architecture	N
Kathryn Blau	Northwest Service Academy, AmeriCorps	C
Dan Blue	City of Gresham	C
Gary Bock	Vancouver Watersheds Council	N
Ali Bonakdar	Corvallis Area Metropolitan Planning Organization	C
Genny Bond	City of Hillsboro Planning Department	C
Nancy Bond	Portland Public Schools	C
Liz Braman	Clackamas County Office of Sustainability	C
Peter Brandom	City of Hillsboro	C
Mindy Brooks	City of Portland Bureau of Planning & Sustainability	N
Anna Buckley	Oregon Department of State Lands	N
Lori Ann Burd	Bark	N
Greg Burne	City of Albany	N
Burns, Tonia	North Clackamas Parks and Recreation District	C
Taber Burton	Benton Soil and Water Conservation District	C, N
Mary Bushman	City of Portland, Bureau of Environmental Services	N
Cyd Cannizzaro	City of Beaverton	C
Josh Caplan	ICF	N
Lisa Carr	Portland State University	C
Ken Carver	Washington County Public Health	C
Ronda Chapman-Duer	Washington County	C
Karen Chase	Oregon Housing and Community Services	C
Betsy Clapp	Multnomah County Health Department	C
Beth Cohen	Metro	C
Coral Conant	City of Gresham	C
Dave Conklin	Oregon State University	N
Theresa Conley	Oregon Cascades West Council of Governments	C, N
Char Corkran	Consultant	N
Nicole Cousino	City of Gresham	C
Michele Crim	City of Portland Bureau of Planning and Sustainability	C, N
Stephen Cruise	Washington County Operations	C
Sara Culp	City of Portland, Bureau of Environmental Services	N
Jan Dabrowski	Marylhurst University	C
Steve Dahl	Clackamas County	C
Dan Daly	Metro Sustainability Center	N
Tiffany Danielson	Portland State University	C
Greg Dardis	Portland State University	C
Tara Davis	Calapooia Watershed Council	N
Kathie Dello	Oregon Climate Change Research Institute	N
Sergio Dias	Sergio Dias Consulting	C

Bob Doppelt	Climate Leadership Initiative	N, C
Doug Drake	Department of Environmental Quality, Northwest Region	N
John Dummer	Clean Water Services	C
Paul Eckley	City of Gresham, Department of Environmental Services	C
Georgia Edwards	City of Tangent	N
Jason Eisdorfer	Bonneville Power Administration	N
Kim Ellis	Metro, Regional Transportation Planning	C
Jesse Engum	City of Gresham, Department of Environmental Services	C
Lucy Falcy	City of McMinnville	C
David Farmer	Northwest Service Academy, AmeriCorps, City of Gresham	C
Charlie Fautin	Benton County Public Health	N
Meg Fernekees	Oregon Department of Land Conservation and Development	C
Maria Fleischman	Sierra Club	C
Scott France	Clackamas County Community Health Division	C
Glen Friedman	West Linn Sustainability Advisory Board	C
Dena M. Gadomski	United States Geological Survey	N
Ron Garst	Tualatin River Watershed Council; Tualatin Riverkeepers	C
Theresa Gibney	Not identified	C
Rhyan Grech	SOLV	C
Kristin Greene	Cogan Owens Cogan, LLC	C
Thomas Griffith	Not identified	C
Bevan Griffiths Sattenspiel	River Network	C
Amy Grotta	Oregon State University Extension Service	C
Ernie Guerrero	Northwest Service Academy, AmeriCorps, Lower Columbia Center	C
Kim Hack	Clark Public Utilities	N
Ginny Haines	Clackamas County Office of Sustainability	C
Roger Hamilton	Climate Leadership Initiative	N, C
Renee Harber	Clackamas Community College	C
Wes Hare	City of Albany	C
Jonathan Harker	City of Gresham	C
Corie Harlan	Metro Sustainability Center	N
Toby Harris	Washington County	C
Mike Harryman	State of Oregon, Department of Health and Human Services	C
Emily Hauth	City of Portland, Bureau of Environmental Services	C, N
Doug Heiken	Oregon Wild	N
Lori Hennings	Metro Sustainability Center	N
Eric Hesse	TriMet	C
Michael Heumann	State of Oregon, Public Health Division	C
Sheila Holden	Pacific Power	C
Liz Hopkins	Portland Sustainability Institute	C
Mike Houck	Director, Urban Greenspaces Institute	N
Lily House-Peters	Portland State University	N
Chris Hurtig	Washington County Fire	C
Niki Iverson	City of Hillsboro, Joint Water Commission	N
Raymond Jackson	Mid-Willamette Valley Council of Governments	C
Roberta Jortner	City of Portland, Bureau of Planning & Sustainability	N
Aireen Joven	Northwest Service Academy, AmeriCorps, Lower Columbia Center	C
Scott Jury	City of Gresham	C
Ani Kame'enui	Oregon Wild, Healthy Rivers Campaign	N
Betty Kaplan	Sierra Club	C
Katherine Kelley	City of Gresham, Department of Environmental Services	C
Steven D. Kelley	Washington County Department of Land Use and Transportation	C
Peter Kenagy	Kenagy Family Farms	N
Sharon Kennedy	Not identified	C
Steve Kennett	SOLV	C
Kammy Kern-Korot	West Multnomah Soil and Water Conservation District	N

Nuin-Tara Key	Metro Sustainability Center	N
Tom Kloster	Metro, Regional Transportation Planning; American Institute of Certified Planners	C
Mark Knudson	Tualatin Valley Water District	C
Nancy Kraushaar	City of Oregon City	C
Ron Larson	Reed College	C
Stephan A. Lashbrook	City of Wilsonville	C
Alice Lasher	Sandy Fire District; Boring Fire District	C
Dan Layden	City of Portland, Bureau of Transportation	C
Jeff Lesh	North Clackamas Parks and Recreation District	C
Deborah Lev	City of Portland, Parks & Recreation	N
Kaitlin Lovell	City of Portland, Bureau of Environmental Services, Science Fish and Wildlife Program	C, N
Bethany Lund	Three Rivers Land Conservancy	N
Tim Lynch	Multnomah County Sustainability Program	C
Kari Lyons	Multnomah County Health Department	N
Jane MacFarland	Multnomah County Principal	C
Brian Mahoney	State of Oregon, Public Health Division	C
Shannon Martin	Clackamas County	C
Steve Marx	Office of Congressman Wu	C
Melanie McCandless	City of Gresham, Department of Environmental Services	C
Sara McLellan	City of Portland Bureau of Environmental Services, AmeriCorps	N
Seaton McLennon	City of Tangent	N
Michael McMahan	Tualatin River Watershed Council	C
Carmen Merlo	Portland Office of Emergency Management	C
John Mermin	Metro	C
Richard Meyer	City of Cornelius	C
Susan Millhauser	City of Lake Oswego	C
Martha Mitchell	Clackamas Community College	C
Jim Morgan	Oregon Parks and Recreation Department	N
Anita Morzillo	Oregon State University, Department of Forest Ecosystems & Society	N
Lisa Moscinski	Gifford Pinchot Task Force	N
Marguerite Nabeta	State of Oregon Governor's Office	C
Beteher Nedi	Portland State University	C
Anne Nelson	City of Portland, Bureau of Environmental Services	C, N
Avis Newell	Department of Environmental Quality	C
Tom Nygren	Tualatin River Watershed Council; Washington County Small Woodlands Association; Oregon Woodland Cooperative	C
Sara O'Brien	Defenders of Wildlife	N
Jason Okuly	City of Gresham	C
April Olbrich	Tualatin River Watershed Council	C
Andy Olson	State of Oregon, Representative District 15	C
Jeremiah Osborne-Gowey	Conservation Biology Institute	C
Seth Owen	Target Distribution Center	C
Gary Oxman	Multnomah, Clackamas, and Washington Counties	C
Jim Phelps	Samaritan Mental Health, Corvallis Sustainability Commission	C
Eben Polk	Clackamas County	N
John Porcello	CSI Water Solutions	N
Kate Porsche	Central Albany Revitalization Agency	C
Laura Porter	Clean Water Services, Watershed Management Department	N
Barbara Progulske	Oregon Department of Human Services	C
Bob Progulske	U.S. Fish and Wildlife Service	C
Claire Puchy	City of Portland, Environmental Services	N
Heidi Rahn	Metro Sustainability Center	N
Jeanne Rice	Mt. Hood National Forest	N
Dianne Riley	Coalition for a Livable Future	N
Phil Roger	Columbia River Inter-Tribal Fish Commission	C, N

Ethan Rosenthal	David Evans & Associates, Inc.	N
Emily Roth	City of Portland, Parks & Recreation	N
Dave Rouse	City of Gresham, Dept of Environmental Services	C
Sara Schooley	Multnomah County Health Department	C
Shelby Schroeder	Northwest Service Academy, AmeriCorps	N
John Sechrest	Corvallis Community Development	C
Kathy Shearin	East Multnomah Soil and Water Conservation District	N
Paul Shirey	City of Milwaukie, Public Works	C
Del Shirley	City of Tangent	C
Sidaro Sin	City of Lake Oswego	C
Jonathan Soll	Metro Sustainability Center	N
Jamie Stamberger	City of Gresham, Department of Environmental Services	C
Eileen Stapp	Clackamas County Office of Sustainability	C
Adam Stebbins	Benton County	N
Mary Steckel	City of Corvallis	C
Jamie Stephenson	Portland State University	C
Henry Stevens	City of Portland, Bureau of Environmental Services	C
Sarah Stevens	Institute for Applied Ecology	N
Bill Stewart	Gladstone School District	C
Elaine Stewart	Metro Sustainability Center	N
Lorna Stickel	City of Portland, Portland Water Bureau	C, N
Trevor Storms	Washington County Fire	C
Candace Stoughton	East Multnomah Soil and Water Conservation District	N
Noelle Studer-Spevak	Portland State University, Campus Sustainability Office	C
Lori Summers	Ridgefield National Wildlife Refuge, NW Service Academy, AmeriCorps	C
Kimberly Swan	Clackamas River Water Providers	C
Nancy Taylor	Oregon Department of Fish and Wildlife	N
Darrel Tedisch	City of Albany	C
Catherine Thomasson	Physicians for Social Responsibility	C
Jennifer Thompson	U.S. Fish and Wildlife Service	N
Andrea Thorpe	Conservation Research Program	N
Douglas Tsoi	Partners for a Sustainable Washington County Community	C
Dyami Valentine	Washington County	C
Greg Verret	Benton County Community Development Department	C
Laura Vierkandt	City of Tualatin, Engineering and Building Department	C
Dan Vizzini	City of Portland, Bureau of Environmental Services	N
Stacy Vynne	Climate Leadership Initiative	N, C
Dave Waffle	City of Cornelius	C
Anne Warner	Metro Sustainability Center (Oregon Zoo)	N
Robert Warren	Bonneville Environmental Foundation	C
Steve Waste	United States Geological Survey	N
Jeff Weber	Oregon Department of Land and Conservation Development	N
Cheryl Welch	Tualatin Valley Water District	N
Sabrina White-Scarver	Oregon Water Resources Department	C
Chelsea White	Bicycle Transportation Alliance	C
Matthew Wiener	North Clackamas Parks and Recreation District	C
Desirée Williams-Rajee	City of Portland, Bureau of Planning and Sustainability	C
Jay Wilson	Clackamas County Emergency Management	C
Christopher Wirth	Multnomah County, Vector and Code Enforcement	C
Brad Withrom-Robinson	Oregon State University	N
Susan Ziolko	Clackamas County, Department of Transportation and Development	C

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