Building Climate Resiliency

in the Lower Willamette Region of Western Oregon

Summary for Decision Makers

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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A Report on Stakeholder Findings and Recommendations

Summary for Decision Makers

The Resource Innovation Group's Climate Leadership Initiative

Written by: Stacy Vynne, Steve Adams, Roger Hamilton, Bob Doppelt

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A program of The Resource Innovation Group
PO Box 51182 ▪ Eugene, OR ▪ 97405
www.theresourceinnovationgroup.org

Introduction

In 2010, the Climate Leadership Initiative (CLI) engaged over 200 experts from the Lower Willamette region of western Oregon in a series of workshops called Climate Futures Forums. Individuals from the following counties participated: Benton, Clackamas, Linn, Marion, Multnomah, Polk, Washington and Yamhill. Forum participant expertise expanded across the following systems: natural, built, economic, human and cultural.

Based on Intergovernmental Panel on Climate Change (IPCC 2007) modeling of two possible future emissions scenarios ("Business as Usual" and a greener scenario) for mid and end of century, the Oregon Climate Change Research Institute (OCCRI) developed downscaled projections of impacts for the Lower Willamette. These projections, coupled with other local research, provided the basis for the CLI Lower Willamette project.

The Climate Futures Forums had the following objectives:

- Assess regional climate change projections;
- Identify likely impacts to systems throughout the region; and
- Recommend strategies to prepare for those impacts.

CLI facilitated participant discussion to integrate strategies across the natural, built, economic, human and cultural systems and ensure that climate change preparedness actions produce complementary benefits the different sectors within the systems as well as reduce conflicting costs.

This document provides policy and decision makers with a summary of findings from CLI's 2010 Lower Willamette project. The full report, which contains a detailed description of the Climate Futures Forums, the modeling process and projections, and the impacts and recommendations, is available at www.theresourceinnovationgroup.org. The complementary modeling projections report from OCCRI is also available.

While this summary and the accompanying report identify a number of consequences from climate change in the Lower Willamette, many opportunities are also presented. 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 summary are only the beginning. Forum participants and stakeholders in the Lower Willamette must begin to 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 the report to initiate dialogue on building resilience to the impacts of climate change in the Lower Willamette.

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.

Overview of Findings and Recommendations

Key Projections

Key projections participants responded to include:

- Overall warming trend, with an increase of 10-15° F in summer under the Business as Usual emissions scenario;
- Changes in precipitation patterns (more rain, more precipitation falling in a shorter amount of time);
- 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.

Key Impacts

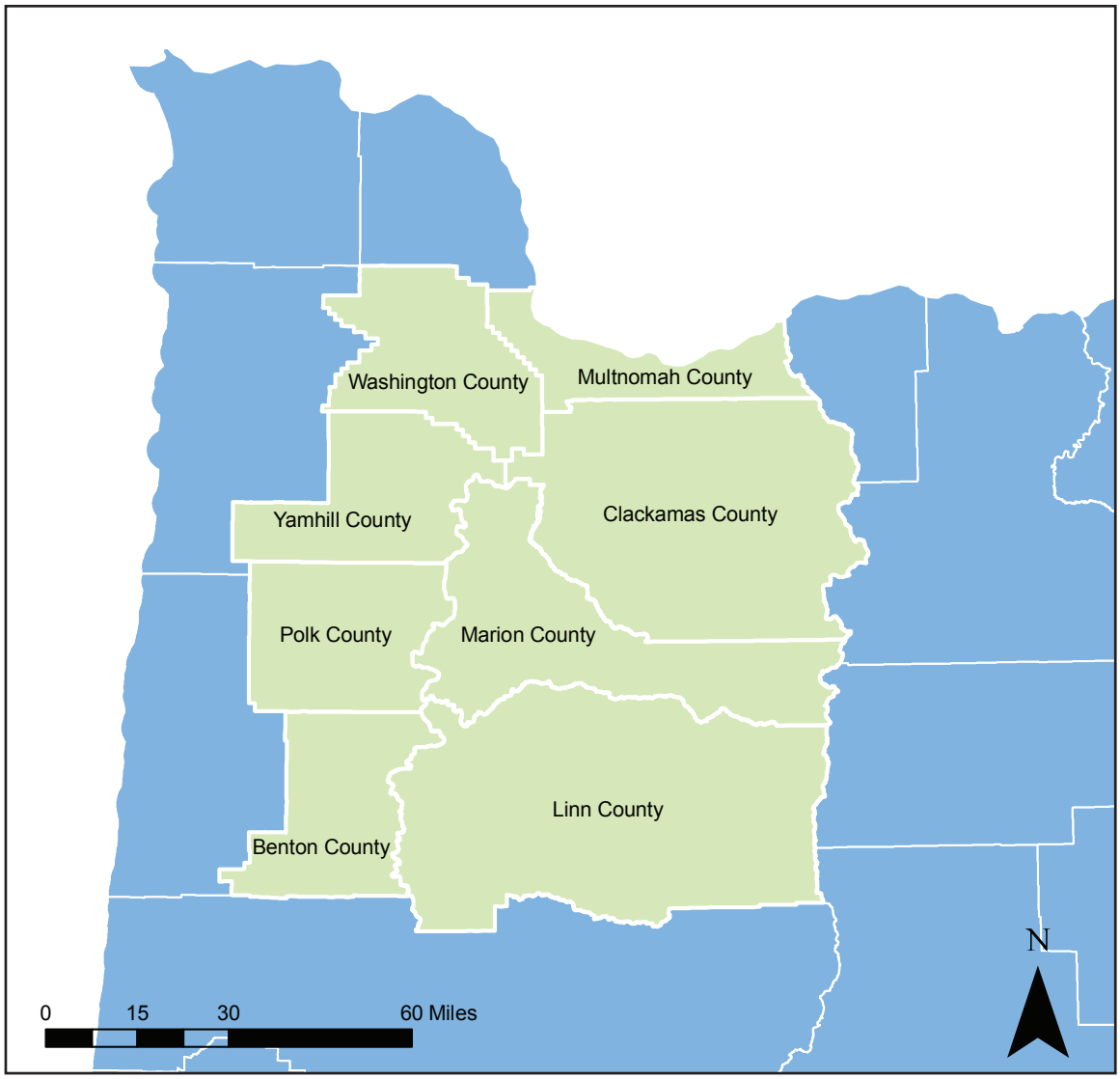
Common themes of impacts identified by participants include:

- 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.



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.

Impacts and Recommendations for Natural Systems

Likely Impacts to Natural Systems

Shifts in stream flow. 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 such as timing and magnitude of flow. 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 flashiness, 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.

Reduced air quality. Climate change amplifies air pollution problems in both rural and urban areas, increasing ground level ozone and particulate matter concentrations. Reduced air quality can disrupt regional ecosystem processes and genetic and population diversity, cause extensive damage to vegetation, and also lead to acidification of ecosystems. This could result in Clean Air Act noncompliance.

Reduced water quality. Increased precipitation events and runoff could lead to erosion and increased nonpoint pollutant loading to streams. Increasing stream temperatures may also lead to decreased water quality from nutrient loading and algae blooms. This could result in Clean Water Act noncompliance.

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. Cold water aquatic species or high alpine terrestrial species are also at greater risk by increasing stress, possibly leading to localized species extinctions and a loss of genetic diversity.

Shifts in quality of habitat and refugia. Wetlands are likely to experience increased drying during the summer months, impacting local amphibian and turtle populations, mammals, native vegetation and birds. Prairie habitat will be threatened with further fragmentation risk through shifting precipitation patterns and increased fire, impacting the ability of prairie-dependent species to migrate. Forest species that rely on soil and ground cover may experience habitat loss, as well as species that require extensive habitat (impacting species management under the Endangered Species Act).

Reduction in ecosystem services. Climate change may impact the natural storage, filtration and pollination services provided by the systems of the Lower Willamette.

Shifts 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.

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 would lead to greater negative climate impacts on urban forests, parks, waterways, fish, wildlife, and vegetation.

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. Species that must travel long distances to escape heat or find water are susceptible to changes in climate.

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). Invasives may be more adapted to soil disturbances associated with fire and extreme events, as well as to warmer climate. Species that thrive in a variety of habitats and on a variety of food sources (i.e. generalist) may not be impacted severely with climate change.

Shift in migration patterns and habitat range. Generalist butterflies are expanding their ranges under current climate changes whereas specialist

butterfly species have been moving northward or are being squeezed out of their ranges. For birds, potential changes include species no longer present in Oregon during the summer, 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.

Changes in intra-species interactions and life history timing. With changes in vegetation, symbiotic relationships between benthics (bottom dwelling), aquatics, and terrestrial species will change, likely to the detriment of many native species. Key timing for life history requirements may become out of sync for some species, such as food availability not matching ingrained migration timing.

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. Scenic areas considered to be part of Oregon's identity might also be impacted (e.g. the glaciers of Mount Hood).

Recommendations for Resilient Natural Systems

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 extreme events. 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. Zoning and building codes can also be used to reduce development impacts on floodplains. Levee and other flood control management efforts should be integrated with natural systems protection to achieve win-win solutions in adapting to climate change.

Increase the complexity of streams. Stream complexity restoration is an effective strategy for ensuring coldwater availability and reducing stream flashiness. Recruitment of large wood to stream systems supports this, but may require a shift in Oregon Forest Practices to encourage interplanting of evergreens in Riparian Management Areas. The Oregon Water Resources Department, Department of Land Conservation and 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 stream policies and restoration projects to identify opportunities for improvement.

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 conservation organizations, should prioritize protection and expansion of high quality urban and rural habitat with greater resilience to climate change. 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.

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 (please see the full report for a more detailed description of landscape approach). ODFW, in coordination with the USFWS, should consider how invasives, as well as Threatened, Endangered and Sensitive (TES) species are identified and managed under a climate change future.

Revise species management. To increase effectiveness and avoid duplication of species management programs and policies, greater communication and collaboration is needed between researchers and land managers. Federal, state, and local species management agencies should increase coordination efforts. 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.

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. The benefits of beavers will need to be weighed with some of the negative impacts of beaver dams, which can thraten private structures and public infrastructure. Stormwater management facilities will need to plan for beavers, and enact road crossings.

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.

Incorporate climate change preparation strategies into watershed management plans. If not already doing so, 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.

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 regime. Natural fire regimes should be restored to build the resilience of ecosystems to climate impacts, as fires maintain diverse assemblages of vertebrate species and forest types.

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.

Increase and refocus monitoring efforts. Monitoring will need to be more adaptive and integrated with management regimes as a result of shifting climate conditions.

Natural Systems			
Recommendation	**Who**	**Co-Benefits/Costs**	**Mitigation Benefits**
Protect and restore floodplains, connect to rivers	FEMA, local government, private landowners	Reduce damage to infrastructure, increase water storage	
Increase stream complexity	WRD, DLCD, local governments, SWCD, DOF, DFW, irrigation districts and watershed councils, OWEB	May require removal of infrastructure and limit development, supports commercially and culturally valuable species, may reduce health risks	
Protect high quality, restore lower quality habitat	Regional jurisdictions, state agencies, nongovernmental conservation organizations, lottery funds	May limit development, provides ecosystem services, may boost property values, improves air and water quality, supports recovery of culturally important species	Yes, if sequestration
Use landscape approach	Conservation organizations, watershed councils, private landowners, and state and federal agencies	May limit some development	
Revise species management	ODFW, USFWS, watershed councils, and landowners		
Restore beavers	ODFW, USFWS, watershed councils, storm water managers, and landowners	May cause damage or restructuring of water infrastructure, benefits to other species and stream complexity	
Reassess allocation of water rights	WRD	Reduce strain on water infrastructure	Yes, if conserves water
Incorporate climate change preparation strategies into watershed management plans	watershed councils and local governments		
Increase riparian vegetation	watershed councils, landowners	Improve air quality	Yes
Restore natural fire regime	Oregon Department of Forestry, federal and state land manager	Reduce catastrophic fire damage to infrastructure, may impact timber production, supports recovery of culturally important species	
Reduce impervious surfaces	Local governments	Reduce flashflooding events, support species and ecosystem recovery, improves water quality for human use, may limit new development	Yes
Increase and refocus monitoring	conservation organizations, watershed councils, state and federal governmental agencies	Supports recovery of culturally important species as well as commercially valuable crops	

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

Likely Impacts to Built Systems

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 due to extreme events 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. As water utilities face longer summer-demand seasons from their customers, plus 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 buckle due to increased temperatures, fire, or flood. This could cause interruptions in emergency response, as well as decrease worker productivity. With increased storms and runoff there may be large sediment increases in streams from blowouts of forest roads. If climate refugees move to the region as anticipated, the carrying capacity of roads may reach its limit and maintenance and repair may need to be done more frequently

Bridge failure: Structural soundness of these bridges may be compromised with climate impacts, particularly from "flashier" floods following heavy precipitation events.

Air and rail disruptions: Sea level rise may impact rail lines as many miles of railroad are along tidal rivers and streams. Rail lines are also susceptible to icing from winter storms, as well as significant temperature increases. The Portland International Airport (PDX) may experience increasing flight delays or cancellations as a result of extreme weather events.

Impacts to utility transmission and meeting energy demand: Electricity demand will be impacted by changes in future temperature. Less energy may be needed in winter with milder temperatures, while warmer temperatures may increase demand in summer. Power outages may occur on very hot days when peak demand exceeds capacity. Population growth may further exacerbate energy demand and reduce availability. Further, transmission lines may be at risk due to climate change events such as fires or excessive heating during extreme temperatures and high use.

Interruptions in communications infrastructure. Above-ground communication infrastructure (internet, phone, television, etc) is at risk to high temperatures, flooding, fires, and extreme storm events such as wind and precipitation. Interruptions may put communities at greater risk during extreme events due to lack of information from emergency service providers.

Impacts to buildings. Homes, essential service infrastructure, and businesses located in floodplains are at risk to damage from floods. With projections showing wildfire likely to increase in frequency, intensity, and distribution, homes in the wildland-urban interface are likely to be damaged.

Recommendations for Resilient Built Systems

Update and improve water and sewer infrastructure: Water and sewer infrastructure must be designed to cope with bigger and more frequent storm events. In addition, updates to infrastructure by local utilities, state and local governments should consider projections for future population growth, including the likely influx of climate refugees. Storm water management should incorporate 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, grey water reuse and stronger water conservation policies should be deployed. In addition, water pricing may need to be considered in order to deal with shortages and provide capital investment for system upgrades. To diversify sources, providers can integrate groundwater as a supplemental supply source and conjunctive water management such as Aquifer Storage and Recovery (ASR).

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.

Improve and safeguard transportation infrastructure. ODOT should explore new paving technologies for transportation infrastructure that reduce the impacts of increased temperatures. Communities will need to plan for mixed-use zones, such as employment clusters and mass transit located near condensed residential areas, as well as integrated land use, transportation, and development codes. Cities will require improved mass public transit, such as with high-speed rail. New transportation infrastructure development will need to consider future floodplain conditions and rerouting of major roads to prevent flood damage. Some airports will also need to consider relocation of runways under future projections for flooding, particularly at the Portland International Airport.

Improve energy efficiency, promote renewables, and protect building infrastructure: Energy efficiency education and outreach programs must grow to reduce the strain on hydropower systems and the potential for black/brownouts. City energy codes need vigorous enforcement while encouraging more LEED certifications. Government buildings should act as an example by improving the energy efficiency of their buildings and purchasing renewables (wind, solar, etc) for the energy used.

Identify back-up communication sources. City and county emergency service providers, in collaboration with communications companies, should identify alterative sources of communication during times of emergency events

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 floodprone areas; 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.

Promote compact housing and protect the urban growth boundary. Limiting future growth and promoting compact housing 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.

Built Systems			
Recommendation	**Who**	**Co-Benefits**	**Mitigation Benefits**
Update and improve water and sewer infrastructure	Local government, utility providers	Prevents contamination of drinking water and ecosystems	Yes, if improves efficiency, lowers energy use
Identify critical infrastructure in floodplains and relocation needs.	State and local jurisdictions	Reduces risk to human health	
Improve and safeguard transportation infrastructure	Amtrak, ODOT, Portland International Airport, and the Federal Railroad Administration	Improves reliability of food delivery and economic stability	
Improve energy efficiency of buildings	Business owners, government, community organizations	Reduces utility costs, improves air and water quality, improves worker productivity, provides urban habitat	Yes
Identify back-up communication sources	Government (local and state), communication service providers	Improves reliability of emergency services during events	
Update land use codes to prevent damage to infrastructure	Department of Land Conservation and Development, local jurisdictions	Protects natural systems, improves water quality	
Promote compact housing and protect the urban growth boundary	Local jurisdictions	Strengthens local businesses, protects agricultural and timber land, reduces strain on emergency services, protects ecosystems, may reduce urban habitat	Yes

Likely Impacts to Economic Systems

Vulnerability of small businesses: Compared to larger businesses, small businesses may face greater challenges in recovering from climate change events such as a flood or fire. Their limited supply and demand chain may be at risk from interruptions to transportation, resources, and infrastructure.

Changes in food prices and agricultural crops. Agriculture and food processing will likely incur higher expenses for managing drought, extreme precipitation events, higher temperatures, and increases in disease outbreaks. 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 or disease. Locally grown food may be impacted by an increase in the frequency of extreme weather events, such as heat, flood, or cold. On the other hand, opportunities may emerge in the Willamette for crops tolerant of warmer climates.

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. An increase in temperature may alter the types of wine grapes grown, quality of grapes, and profitability of the region.

Shifts in timber species and productivity. Climate change may alter the species of commercially viable trees that are able to grow in the region. Trees such as coastal and Douglas firs yield larger profits than other species. Projections show that climate change will favor the warmer species such as ponderosa pine and hardwoods.

Shifts in tourism and recreation. Climate change may impact recreational activities including wine tours, hot air ballooning, river rafting, camping, agri-tourism, among others. Reduced snowpack will impact the skiing industry; however, longer summers may allow for more summer recreational activities such as camping, water sports, and fishing (likely for different fish species).

Interruptions to freight transportation. Freight transportation is vulnerable to flooding and landslides: some roads are in floodplains and at the same time are old and deteriorating. Rail is also essential to the movement of freight. Rail lines in the Lower Willamette are vulnerable to icing during winter storms, high temperatures, and flooding; disruptions in service due to these weather events lead to economic losses.

Increasing insurance rates. Insurance rates may rise as risks for floods and wildfires increase. Homes and businesses located in flood and fire prone areas may be impacted.

Impacts to health care:

Access: Current healthcare infrastructure in the Lower is robust, but climate change may reduce access and availability to healthcare. Emergency management services may be stressed with increased populations, reducing the ability of the healthcare system to efficiently respond.

Insurance: As extreme events exacerbate the spread of disease, diminish air quality, and reduce the health resiliency of the population, health insurers and public programs such as Medicare and Medicaid will likely see increases in claims.

Cost: A number of risks associated with climate change are expected to increase the cost of healthcare in Oregon, including costs related to new diseases, increased respiratory ailments, increased incidence of water- and food-borne diseases, and decline in nutrition and sanitation.

Unintended consequences: While healthcare costs accumulate under changing climate conditions, secondary costs will also affect the Lower Willamette including reductions in workforce productivity, particularly for vulnerable individuals and outdoor workers.

Recommendations for Resilient Economic Systems

Diversify and promote risk management. Economic diversification (functionality, size and scale) will support the economy to 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.

Research and invest in climate tolerant crops. Growers may want to consider diversifying 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, 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.

Plan for shifts in transportation of freight. City, state and regional planners should identify roads most vulnerable to landslides, flooding, and fire, and have a preparedness plan available of the safest and most cost-effective alternate routes for freight travel.

Meet insurance requirements. Insurance prices will continue to rise as risks increase due to climate change events such floods and fires. Laws and building codes must be modified in order to discourage building on floodplains or in close proximity to the wildland-urban interface.

Prepare health care

Education: Increasing opportunities and incentives for individuals to join the primary care field will help prepare for an influx in population and associated health needs. 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: Insurers, governments and local health providers should incorporate climate change preparedness into their long-term planning and needs assessments.

Preventative healthcare: Policymakers, educational institutions, and health providers should emphasize preventative healthcare strategies to manage future healthcare cost and access.

Economic Systems			
Recommendation	**Who**	**Co-Benefits**	**Mitigation Benefits**
Diversify and promote risk management	Regional economic development agencies, Chambers of Commerce, State economic development agencies, individual businesses	Strengthens local economy, increase job opportunities	
Research and invest in climate tolerant crops	OSU–Extension and the State Department of Agriculture, growers	Promotes diversity of species, may reduce impact on soils and water needs, maintains nutritional value of food	Possibly, if less water and fertilizer needed
Shift industrial forest management practices	ODF, Weyerhaeuser and other timber companies	May reduce development in some areas, may promote diversity of tree species, improve air quality	Yes
Plan for shifts in transportation of freight	City, state and regional planners, ODOT	Reduced impact on infrastructure, maintains local economy during events, ensures food and supply delivery	
Meet insurance requirements	Emergency managers, local jurisdictions, insurance agencies, homeowners, businesses	Reduce impact on floodplains	
Prepare health care for change	Insurance agencies, cities, counties, educational institutions, health providers, individuals		Possibly through prevention strategies.

Likely Impacts to Human Systems

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 more vulnerable to disasters. Severe summer heat and changes in precipitation may leave those without access to air conditioning, limited food and water availability, and with inadequate access to healthcare vulnerable to disease.

Overwhelmed emergency response systems capacity. Projected increases in the frequency and intensity of extreme weather events, outbreaks of vector-borne disease, and extreme heat is likely to place greater stress on existing emergency response systems.

Inadequate individual response capacity. Individual and community 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.

Food and water scarcity: The projected frequency and severity of emergency events along with expected changes in global food supply leave the Lower Willamette vulnerable to food and water scarcity. Emergency food systems, particularly in rural areas, are already widely utilized under non-emergency situations, and the need for emergency food is increasing.

Stressed social services: 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.

Public safety concerns: Hotter summers and increasingly extreme events may amplify local crime rates.

Outdated education: A lack of quick adaptability in education systems suggests that curricula may not be responsive to new climate change concepts and job requirements.

Public health concerns:

Reduced air quality: Increased air pollutants (mold, ozone, pollen, haze, etc), in combination with the higher likelihood of forest fires, threaten the respiratory health of the population.

Reduced water quality: Projections for increased flooding and an increased number of extreme heat events threaten drinking water quality.

Increased mental health concerns: The stress of extreme climate events on a population can exacerbate already stressful lifestyles, especially with displacement and/or the loss of a home.

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 have a high likelihood of continuing to do so. Some local experts expect an increased threat of insects that carry disease in the area, such as mosquito-borne diseases like malaria, filariasis, dengue fever, yellow fever, and West Nile virus.
- Water Borne Disease: Disease outbreaks can occur when bacteria, viruses, and protozoa contaminate water. During the summer months, outbreaks of toxic blue-green algae can result in public health threats.
- Food Borne Disease: With both warmer temperatures and increased precipitation, food borne disease outbreaks may become more common. While the Lower Willamette may be impacted less by climate change compared to other regions of the United States, preparedness strategies are important to determine the potential for outbreaks as well as prepare for potential diseases that may arrive in imported food.

Increased heat events: Several consecutive days of temperatures of 90° F or higher, and unusually warm nighttime lows in the 60s and low 70s, can lead to heat illness for populations without access to air conditioning, well insulated homes, or cooling centers.

Reduced access to healthcare: Climate refugees are expected to increase in the Pacific Northwest including the Lower Willamette. With increased population levels, resources and trained healthcare providers will be stretched, as will hospital space, pharmaceuticals, and medicine.

Cumulative impacts: While emergency responders and healthcare providers are able to tend to the needs of the community currently, 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.

Recommendations for Resilient Human Systems

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. 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.

Strengthen local social networks: To alleviate potential stress on the region's social services, local governments and NGO's should work to strengthen local social networks through events and organizations to encourage community members to meet their neighbors and fortify networks of support.

Improve community outreach systems: Public, private and non-profit outreach should ensure the delivery of diverse, culturally sensitive, and multi-lingual resources to the public to convey the public health and economic benefits of adaptation.

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

Increase individual response capacity. Local governments and community-based organizations can work with individuals and social networks to build the preparedness capacity of individuals, therefore reducing the strain on emergency services.

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, opportunities for food preservation, reduce dependence on food imports, and decentralize food sources.

Increase residential water conservation: To minimize water scarcity during emergencies, localities should adopt policies to promote water conservation. Education and incentive programs should be expanded to encourage water saving practices including leak repairs and the installation of high efficiency fixtures.

Decentralize home and community water storage. Localities should ensure access to adequate systems to disseminate emergency water storage information. Localities should reevaluate current regulation on greywater 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 as there are a number of public health and equity issues associated with decentralized systems.

Revise job codes and education certificates system: Oregon's system for updating job codes and certificates should be revised to more quickly adapt to 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: State and local education agencies should develop and incorporate standards for ecological and climate literacy, building from the standards developed by NOAA.

Preparing public health:

Action-oriented education: Local and state officials should educate the public about health impacts resulting from climate change to reduce fear and panic, while building self-sufficiency to reduce public dependence on health services.

Protect water quality: Local and state agencies should focus on water quality protection against events associated with climate change including more stringent pesticide standards will improve water quality and reduce chemical runoff, increased monitoring of water systems particularly at peak weather events, and a reassessment of water systems to ensure they can handle increased amounts of water to reduce the threat of contamination.

Expand mental health services: Local and state health agencies should incorporate mental health trauma needs into emergency response systems so that service providers recognize and treat symptoms early before they are exacerbated.

Air quality notification: Local and state agencies should ensure that communities, particularly vulnerable populations, are effectively notified of poor air quality events.

Disease outbreak monitoring: Local governments must prepare for increased vector-borne, water-borne and food-borne disease by increasing monitoring, testing and public alert systems.

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.

Promote preventative health: Educating individuals on preventative health will create a population more resilient to disease. Encouraging regular doctor visits, exercise, and healthy living is 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.

Human Systems			
Recommendation	**Who**	**Co-Benefits**	**Mitigation Benefits**
Identify and build resiliency of vulnerable populations	State and local health departments, community organizations, social service providers	Reduced energy demand, less building in flood prone areas	Yes
Strengthen local social networks	Cities, neighborhood associations, churches, community-based organizations, etc.	Decrease long term disaster recovery costs	
Improve community outreach systems	Local jurisdictions, community organizations		
Increase capacity of emergency and social service response systems	Local jurisdictions, Red Cross, Salvation Army, schools, private companies (e.g. grocery and hardware stores) and faith-based organizations	Reduce long term disaster costs, reduce flood damage to infrastructure	
Increase individual response capacity	Local jurisdictions, emergency and social service providers	Reduce strain on emergency services	
Enhance local food security	Local jurisdictions, famers markets and local food banks	Builds local economy, may provide habitat for pollinators	Possibly, if reduce food transportation emissions
Increase residential water conservation	Individuals, local jurisdictions, businesses, farmers	Protect natural water bodies, reduce impact on water infrastructure	Yes
Decentralize home and community water storage	Local jurisdiction, Oregon Water Resources Department, individuals, businesses, water providers, public health	Decrease strain on water infrastructure, may have health conflicts	Possibly, if reduce energy use for pumping and treating water
Revise job codes and education certificate system	State, high schools, community colleges and universities, businesses		
Build ecological and climate literacy into the education system	State and federal education departments	Builds support for resiliency initiatives	
Prepare public health	Public health providers, local jurisdictions, neighborhood associations, individuals	Increased activity (reduced obesity, chronic diseases), use of public transportation	Yes, for some preventative measures

Likely Impacts to Cultural Systems

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 especially affected by changes in temperature, precipitation, and aquatic environments.

Deterioration or destruction of historical architecture: Historical structures, buildings, and districts "worthy of cultural preservation" attract significant tourism revenue, provide opportunities for community education, and preserve regional heritage. Fragile building material and structures without foundations and structural support are threatened by increasing extreme weather events.

Conflicts with climate refugees: The region may experience an influx of refugees displaced by global climate change impacts. This could exacerbate cultural tension stemming from competing values and identities, scarce water and other resources, which may further strain social services. Currently, no research exists on likely population growth in the Willamette associated with climate change. 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 to prepare for 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 Resilient Cultural Systems

Protect key resources for tribal communities: Native communities may need to consider diversification of crops and livestock as well as changes in timing of harvest, hunting and gathering. This will support preparation for changes in temperature and precipitation patterns as well as loss of snowpack. Outreach on climate change impacts to tribal communities, particularly to livelihood resources and public health, can improve self-sufficiency and reduce 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. Policymakers can utilize these tools to take advantage of changing social values, while curbing governability issues and cultural tension.

Prepare for increased human population. 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 before climate change-related 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.

Cultural Systems			
Recommendation	**Who**	**Co-Benefits**	**Mitigation Benefits**
Protect key resources for tribal communities	Tribal communities, ODF, ODFW, USFS, USFWS	Improve nutritional health	Yes, if sequestration through planting or restoration
Encourage resource conservation and energy independence in tribal areas	Tribal communities, DOE, renewable energy providers	Reduce strain on utility infrastructure, improve air quality	Yes
Prepare for increased human population	Planners, universities	Reduces strain on infrastructure, builds local economy, reduces development in natural areas, reduces impact on health	Yes, if increase public/alternative transportation and density/walkability in planning
Proactively address current cultural tensions and prepare for new cultures	Local jurisdictions, community organizations		

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A program of The Resource Innovation Group
PO Box 51182 ▪ Eugene, OR ▪ 97405
www.theresourceinnovationgroup.org