Preparing for Climate Change in the Rogue River Basin of Southwest Oregon


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Stressors, Risks, and Recommendations for Increasing Resilience and Resistance in Human, Built, Economic, and Natural Systems

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Executive Summary

The Rogue River Basin, located in southwest Oregon, consists of a diverse array of communities, economies and ecological systems. The Basin's rich history, beautiful setting, and recreational and employment opportunities, attract visitors and residents to the region year-round. Climate change is likely to produce significant new stresses and alterations to water quantity and quality, fish, wildlife, plant life, forests and fire regimes of the Rogue Basin. The Rogue will not be the only region to experience the effects of climate change. Every region of the West, nation, and the world will be affected. These changes will, however, have important consequences for the economy, infrastructure, and human services on which the people and communities within the Rogue Basin rely on for their quality of life.

In the summer of 2008, the University of Oregon Climate Leadership Initiative, in partnership with The National Center for Conservation Science & Policy and the MAPSS Team at the U.S. Forest Service Pacific Northwest Research Station, initiated a project to assess the likely consequences of climate change for the Rogue River Basin. The project began by downscaling three climate models (CSIRO, MIROC, and Hadley) and incorporating a global vegetation change model (MC1) used by the Intergovernmental Panel on Climate Change. A panel of scientists and land managers then assessed the likely risks posed by changing climate conditions to natural systems and made recommendations for increasing the capacity of ecosystems and species to withstand and adapt to those stressors.
In turn, a panel of policy experts used the information provided by the scientists to assess the likely risks to economic, built, and human systems within the Rogue Basin posed by climate change and recommended ways to increase resistance and resiliency of those systems.

The downscaling of the three climate models and the analysis of the vegetation model led to the following future projections for the Rogue Basin :

Temperature

- Annual average temperatures are likely to increase from 1 to 3° F (0.5 to 1.6° C) by around 2040, and 4 to 8° F (2.2 to 4.4° C) by around 2080.
- Summer temperatures may increase dramatically reaching 7 to 15° F (3.8 to 8.3° C) above baseline by 2080, while winter temperatures may increase 3 to 8°F (1.6 to 3.3° C).

Precipitation and Snowpack

- Total precipitation may remain roughly similar to historical levels but increasingly is likely to fall in the mid-winter months rather than in the spring, summer and fall.
- Rising temperatures will cause snow to turn to rain in lower elevations and decrease average January snowpack significantly, with a corresponding decline in runoff and streamflows. According to one model, snowpack will be reduced 75% from the baseline by 2040, and another 75% from 2040 to an insignificant amount by 2080.

Storms, Flooding, and Drought

- The Basin is likely to experience more severe storm events, variable weather, higher and flashier winter and spring runoff events, and increased flooding.
- Both wet and dry cycles are likely to last longer and be more extreme, leading to both periods of deeper drought and those of more extensive flooding.

Wildfire

- Reduced snowpack and soil moisture along with hotter temperatures and longer fire seasons likely will increase significantly the amount of biomass (vegetation) consumed by wildfire.

Based on these projections, the science panel identified the following likely consequences for aquatic and terrestrial systems and species in the Rogue Basin:

Aquatic Systems and Species

- Increased storm and fire frequency will increase sediment and nutrient loads as well as persistent organic pollutants and other contaminants entering the Rogue River and its tributaries. Along with higher water temperatures these factors will reduce water quality, threatening the recruitment and survival of young native fish.
- Shifts in the timing of stream flows could trigger earlier emergences of aquatic insects and shifts in the timing of adult salmon and steelhead spawning migration, egg incubation and hatch, and smolt outmigration. The result is likely to increase the risk of a disconnection between the timing of fish life stages and the availability of primary food resources.
- Warmer water temperatures and extended low summer base flows extending well past the summer months are likely to decrease dissolved oxygen, produce more disease, and create a greater frequency of conditions lethal to native fish.
- More storms and flooding likely will increase streambank erosion and increase channel downcutting resulting in degraded stream habitat and habitat fragmentation precipitating a reduction in biotic carrying capacity, heightened susceptibility to flood and drought, and a contraction of the stream network.

Terrestrial Systems and Species

- Increasingly drought stressed vegetation, due to higher evaporation rates, will lead to increases in insect outbreaks and disease. Stressed and dying vegetation will produce larger and more frequent wildfires.
- Rapid shifts in climate, compounded by habitat fragmentation, will complicate the opportunity for some native vegetation and wildlife to adjust and disperse, leading to shifting populations.
- Changes in the timing of flowering and insect emergence could disrupt historical relationships between migratory species, and especially long-distance avian migrants, and prefered food availability.
- Amphibians may be especially at risk due to the low mobility of some species and increased drying and habitat conversion expected from climate change.
- High elevation wildlife and plant species may not be able to make the shift to new areas due to a lack of available habitat.
- Disease and disease vectors are expected to increase with warmer temperatures. Individuals under stress from climate change and other stressors will also be more susceptible to disease.

Both Aquatic and Terrestrial Systems

- The changes described above mean increased vulnerability of aquatic and terrestrial species should be expected.
- Expansion in invasive species may also be likely as conditions become more favorable for exotics and less favorable for some natives.

Based on the analysis of the risks to natural systems, the policy panel identified the following risks to built, human and economic systems in the Rogue Basin:

Infrastructure

- Increased disruption and direct damage to transportation systems, buildings, and real estate from more flooding and wildfires; possibly even larger indirect costs due to more rapid depreciation.
- Many roads will likely to be impacted by more frequent storm events, flooding and wildfires, impairing the movement of people during emergencies.

Energy Systems

- Electricity from the Bonneville Power Administration (BPA) hydro system is likely to be constrained in summer months because of reduced snowpack and stream flows just as electrical demand rises due to increased need for air conditioning in the summer and increases in population.
- Power lines are likely to face increased stress due to rising fires and temperatures.

Public Health

- Demands for emergency services are likely to increase as storm events, flooding and wildfires increase, but the funding needed to support them may be difficult to obtain.
- Rising summer temperatures will likely increase the incidence and intensity of heat-related illnesses and vector- and water-borne diseases such as Lyme disease and West Nile virus.
- Rising temperatures and increased smoke from wildfires are likely to increase the incidence of asthma.

Agriculture and Forestry

- Forest products may shift to smaller diameter logs if managed by thinning to reduce drought stress and to supply new biomass energy or alternative forest products.
- Agriculture will face increased competition between in-stream and municipal users for available water supplies while rising temperatures are likely to require the use of more water and/or a shift in crop types and farming practices.

Manufacturing, Retail and Service Sectors

- Manufacturing, retail and service sectors are likely to experience higher fuel and electrical costs due to reduced summer output from the BPA hydroelectrical system, disruption in supply chains and the distribution of goods due to increased storm events, flooding, and fires, and increased workforce health concerns.
- Winter recreation activities such as skiing and snowmobiling will be reduced as snowpack decreases.

The science panel made the following recommendations to prepare aquatic and terrestrial systems for climate change by increasing resilience and resistance:

Aquatic Systems

- Restoration and maintenance of stream complexity and connectivity will improve spawning habitat and allow for movement to new areas as other areas become too warm.
- Restoration and maintenance of critical landscapes such as high elevation riparian areas, floodplains, tributary junctions, north-facing streams, and stream reaches with gravels and topographic complexity.
- Management of fisheries to protect genetic and life history diversity of native species.

Terrestrial Systems

- Protection and restoration of ecosystem structure, function and genetic diversity to allow organisms to withstand and adapt to climate stressors.
- The use of strategic fire should be used to reduce the likelihood of severe fire, as should replanting with a diverse array of native species, and ecologically appropriate fuels reduction efforts.
- Remaining intact habitats should be protected, including old growth, roadless areas and corridor connections for wildlife migration. Protected areas should be expanded longitudinally and latitudinally in order to allow species to shift their ranges.
- Land and stream reaches that provide critical support for ecosystem services should be identified, protected and restored. Ecosystem services are benefits that people gain from functioning ecosystems, including clean water, decomposition of waste and toxins, timber harvest, recreational opportunities, etc.
- Translocations may be necessary when the suitable climate changes too quickly for species to adjust their ranges, or when habitat fragementation prevents their movement.

Both Aquatic and Terrestrial Systems

- Reducing existing stressors, such as habitat fragmentation, erosion from resource extraction and roads, air and water pollution and contamination, the loss of keystone species, introduction of invasive species, and conversion of forests, riparian areas and floodplains to urban and suburban development, would result in substantial benefits to both aquatic and terrestrial species and systems.
- Redirect responsibility for emergency services so that private parties that wish to locate in these high risk areas pay for those services, while also providing funding and tools to help low income and vulnerable populations cover these costs.
- Management should shift to encompass climate-induced changes and contribute to the landscape's ability to buffer greater seasonal, annual, and decadal variability in temperature and precipitation as well as more severe storm events.

The policy panel made the following recommendations to prepare human, built, and economic systems for climate change:

Infrastructure

- Permanent structures should be moved out of high risk floodplains, riparian areas and steep forested canyons if and when they are damaged by floods or fires and new development should be constrained in these critical landscape areas.
- Link public transportation systems as much as possible to facilitate movement of people and equipment in emergency situations.
- Expand road upgrading and maintenance such as the installation of larger culverts and regular culvert clean outs to prevent wash outs during major storms and floods.
- Expand conservation and efficiency programs in commercial and residential buildings to dramatically reduce energy and water use.
- Increase the use of distributed energy such as solar and high-efficiency thermal biomass in order to provide backups in times of energy supply problems and to stabilize costs.
- Re-examine the water allocation system and groundwater use to avoid over-appropriation.

Emergency Management

- Concentrate human populations away from high-risk floodplains and steep canyons to less risky portions of the Basin.
- Redirect emergency service responsibilities so that private parties who choose to locate in high-risk areas pay for those services.
- Link climate preparation with economic development such as job creation through fuels reduction in the urban-wildland interface.

Public Health

- Upgrade and adapt vector control programs to better respond to emerging diseases.
- Strengthen and expand water quality protections from runoff and contaminants.
- Enhance strategies to anticipate new climate-induced health service needs and ensure they are provided to the most vulnerable citizens.

Agriculture and Forestry

- Maintain existing crops as long as possible while also researching new crops and sustainable farming practices in advance of climate-induced demands for change.
- Expand agricultural energy and water conservation and efficiency programs.
- Forest management should incorporate future climate conditions by building resistance and resiliency through greater structural and genetic vegetation diversity.
- Forests managed with longer harvest rotations will sequester more carbon and may acquire credits in a cap and trade market.

Manufacturing, Retail and Service Sectors

- Expand the use of on-site renewable energy systems to provide protection against blackouts and provide stability to energy prices.
- Significantly expand water conservation and efficiency programs and policies in manufacturing and other urban and suburban settings.
- Explore ways to expand the tourism season to include spring and winter as summer seasons become hotter.

A consistent theme heard from the panels was the need for new types of information, resource allocations, and decision-making mechanisms. In short, the panels called for new and expanded forms of governance. Specific recommendations include:

- Incorporate climate change preparation into all current and future public and private plans and policies.
- Reorient management plans and policies to focus on the ‘Future Range of Climate Variability’ rather than the long-held approach of management based on historic patterns.
- Set goals and priorities appropriate for projected future conditions, with alternative plans, goals, and priorities in place for seamless adjustments to changing conditions.
- Utilize ‘scenario planning’ methods to identify and plan for climate futures.
- Expand planning and decision making to at least the Basin scale rather than planning at the forest, county, city or project levels in isolation of other regions or interests.
- Evaluate how policies, programs and projects may affect climate preparation efforts in other sectors or regions of the Basin and constantly identify ways for one activity or project to provide co-benefits for others.
- Expand participation on planning and decision-making teams to include people representing different stakeholder groups or other regions of the Basin that are likely to be affected by climate change.
- Improve and reorient data gathering and monitoring systems to generate timely information on the speed, trajectory, and consequences of climate change.
- Increase public understanding of the likely consequences of climate change and preparation options as well as efficacy of management action.

Global temperatures are rising in large part due to human activities. No matter how fast human-induced greenhouse gas emissions can be reduced, over the coming decades climate change is likely to significantly stress and transform natural systems in the Rogue Basin. These changes will produce considerable modifications in the way the local economy functions, in infrastructure and buildings, in human health, and in the quality of life of the people who live in and enjoy the Rogue River Basin. Numerous initiatives are already underway within the Rogue Basin that can help people prepare for these effects. Upgrading existing and proactively launching the additional climate preparation steps described in this report in an integrated and co-beneficial manner can build resistance and resilience to climate change and help people and communities adapt and thrive in the future.

Table of Contents

Executive Summary	Page iv
Introduction and Background	1
What is Climate Change Preparation and Why is it Needed?	1
The Rogue Basin Project	2
The Emission Scenario and Projected Temperature Increase	3
The Climate Models	4
Limitations to the Climate Models	4
Climate Future in the Rogue Basin	5
Temperature	5
Precipitation, Snowpack, Snowmelt and Stream Flow	5
Changes in Fire and Carbon Sequestration in Vegetation	6
Changes to Vegetation Patterns	6
Risks to Species and Ecosystem Function	9
Risks to Aquatic Species and Systems	9
Risks to Terrestrial Species and Systems	10
Risks to People, Community and the Economy	11
Risks to Infrastructure and the Built Environment	11
Buildings and Real Estate	11
Transportation	12
Water Supply	12
Energy Systems	13
Risks to Economic Systems	14
Agriculture	14
Forestry	15
Manufacturing, Retail and Service Sectors	16
Risks to Public Health and Emergency Services	16
Public Health Services	16
Emergency Services	17
At Risk Areas and Vulnerable Populations	17
Buffered Areas and Populations	18
Summary	18
Recommendations for Increasing Resistance and Resilience	19
The Need for Integrated, Co-Beneficial, Climate Preparation Plans and Policies	19
Preparation for Aquatic Species and Systems	19
Preparation for Terrestrial Species and Systems	21
Preparation Strategies for Infrastructure and the Built Environment	23
Preparation Strategies for Economic Systems	25
Preparation Strategies for Public Health and Emergency Services	26
The Need for New and Expanded Systems of Governance	28
Conclusions	32
Literature Cited	33
Appendix A. Participants in the Natural Systems Workshops	35
Appendix B. Participants in the Human, Built, & Economic Systems Workshop	37
Appendix C. Graphs and Figures	39
Appendix D. Climate Change Impacts – Conflicts and Synergies	41

Introduction and Background

In 2007, the Intergovernmental Panel on Climate Change (IPCC) declared that the evidence is now "unequivocal" that the earth's atmosphere and oceans are warming (IPCC 2007). The IPCC concluded that human activities, including the emission of carbon dioxide, methane and other greenhouse gasses, along with land clearing and development, are responsible for most of the warming. Left unchecked, rising global temperatures and the changes in climatic patterns they cause will affect ecological health and thus undermine economic and social prosperity and security locally and abroad.

This report describes the likely consequences of climate change on natural, human, built, and economic systems in the Rogue River Basin of southwest Oregon. It also describes a suite of strategies and policies for building resistance and resilience to climate change in the Rogue Basin recommended by a panel of scientists and policy experts. The consequences of climate change will not be restricted to the Rogue Basin. Climate change is a global problem and no region in Oregon or elsewhere in the West or the world will be immune from its impacts.

Photo by Steve Whitney

This report is the product of a larger initiative aimed at establishing a common method for developing integrated climate preparation plans and policies. The project is coordinated by the Climate Leadership Initiative in the Institute for Sustainable Environment at the University of Oregon, in partnership with The National Center for Conservation Science & Policy (NCCSP) and the MAPSS Team at the U.S. Forest Service Pacific Northwest Research Station (PNW). In addition to the Rogue Basin, climate preparation assessments will be developed for the Upper Willamette, Klamath and Umatilla Basins. This work will pave the way for collaborative efforts that will increase the resistance and resilience of natural, built, human, and economic sectors to climate change in Oregon and the West.

What is Climate Change Preparation and Why is it Needed?

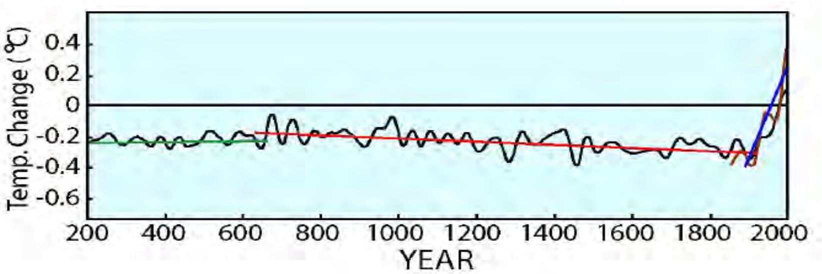


Fig 1. global departures in mean surface temperature over the last two millenia, as compared to 1961-1990 average (adapted from mann and jones 2003).

Global mean surface temperatures have already risen by 1.3º F since the early part of this century (Figure 1). In the Pacific Northwest, average temperatures have risen by 1.5º F. Scientists have spent considerable time teasing out natural from human-related drivers of global warming, and the consensus is that solar variability, volcanic activity and other natural events cannot account for current levels and rates of global warming (IPCC 2007).

Only when the atmospheric concentration of carbon dioxide, which has risen more than 35% since pre-industrial times, methane, which is up 155%, and other greenhouse gasses, are taken into account do climate models replicate observed warming. The bottom line is that global warming is indisputably happening, humans are the primary cause, and this warming will have serious impacts to the world's climate systems.

Although much attention is being appropriately focused on reducing U.S. greenhouse gas emissions by 80% or more to restabilize the climate, it will take fifty years or more for this to occur because of the residence time of emissions already built-up in the atmosphere (IPCC 2007). Efforts to prepare natural, economic, built, and human systems to withstand and adapt to the now unavoidable consequences of climate change therefore must become a priority of government, the private sector, and households. Preparation efforts will, in many cases, complement and enhance actions aimed at reducing greenhouse gas emissions.

This report provides an initial set of guidelines for preparing for climate change in the Rogue Basin. The term "preparation" as used in this context means to proactively build **resistance** and **resilience** within natural, human, built and economic systems to enhance their capacity to withstand and adapt to climate change. Resistance strategies seek to increase the capacity of systems to withstand the negative effects of climate change. Resilience strategies are aimed at building the capacity of systems to recover from the impacts of climate change.

The Rogue Basin Project

This report is intended to provide a starting point for climate preparation efforts in the Rogue Basin. We hope that, over time, all levels of government, the private sector, and households will utilize the information and recommendations as a platform to expand their knowledge and develop continuously improving climate preparation strategies and policies.

The Rogue River Basin of Oregon is a special place. It stretches from the crest of the Cascade Mountains near Crater Lake to the Pacific Ocean in the southwest coast. The Basin incorporates most of Josephine, Jackson and Curry counties, which are home to approximately 302,000 people. Agriculture, forestry, tourism and a diverse array of other commercial sectors support the local economy. Salmon and steelhead fill the rivers, and wildlife is abundant. The Rogue Basin is characterized by its immense natural beauty, which provides spiritual and recreational opportunities for local residents and visitors from around the world.

Climate change is likely to profoundly affect the natural systems of the Rogue Basin. Changes in the structure and function of ecological systems and species will, in turn, affect the economy, communities and quality-of-life of residents. The consequences of climate change in the Rogue Basin were assessed using three models (CSIRO, MIROC, and Hadley) operated under the 'A2' emission scenario assumptions that were developed by the Intergovernmental Panel on Climate Change (IPCC 2007). With assistance from USFS Research Station PNW's MAPSS team, global climate change

Fig 2. Map of Rogue River Basin. Courtesy Richard Nauman

projections were downscaled to the Rogue Basin and mapped for two future time periods, 2035-2045 and 2075-2085. In addition, time series graphs were plotted for some factors, such as wildfire, to show how conditions may change over time.

On the basis of the projections made by downscaling the global climate models (GCMs) and incorporating the vegetation model (MC1), a panel of natural systems experts and other participants (see Appendix A for participant list) assessed the likely impacts of climate change on natural systems (species, ecological communities, and ecosystems). They also identified strategies and policies for increasing ecological resistance and resilience. Finally, they noted better needs for research, data, and monitoring to understand impacts and facilitate ongoing learning and adaptation in rapidly changing conditions over time.

The Emission Scenario and Projected Temperature Increase

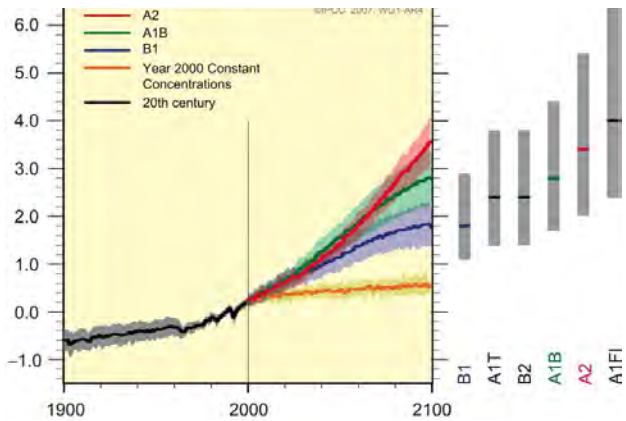


Fig 3. Global surface temperature in the past, and projected 100 years in the future based on multi-model global averages and 6 different emissions scenarios, including A2 (IPCC 2001).

The natural systems assessment served as the basis for a subsequent assessment by a panel of managers and policy experts, (see Appendix B for participant list) who identified the likely risks to human, built, and economic systems posed by the climate and ecological changes. This panel identified strategies and policies for increasing resistance and resilience, as well as information needed to monitor impacts, learn and adjust over time. These workshops form the basis of the recommendations found in this report.

The A2 Intergovernmental Panel on Climate Change (IPCC) scenario used in this project is the “business as usual” emissions path the world is currently following (note that global emissions are now actually higher than the A2 scenario assumes). In this scenario, the IPCC assumes that most countries fail to act individually or collectively to reduce greenhouse gas emissions. Countries preserve self-reliance and national identities, following the lead of the United States, India, and China. The global population continuously increases, reaching a projected 15 billion by the end of the century. The world is much more affluent than today, with a Gross World Product that by 2100 is 26 times the present amount, but economic growth is fragmented and technology change is slow. Emissions caused by land use changes increase, driven by deforestation and converting forests and other lands to agriculture to support population growth, but agricultural productivity gains are low.

On a global scale, surface temperatures increase from just below 1.8º F (1º C) by 2025 to more than 5.4º F (3º C) by 2095 (Figure 3). As ocean waters warm, water expansion from warming alone causes sea levels to rise on average from 0.75 ft (0.23 m) to 1.7 ft (0.51 m); substantial additional rise in sea levels will occur due to polar ice-sheet melting, but ice sheet dynamics are still poorly understood. According to the British Antarctic Survey, sea levels could rise 17-20 ft (5-6m) if the West Antarctic ice sheet collapses (BAS 2004).

To provide a context for the projected increase in global surface temperature, consider Figure 1 (page 1), which shows temperature trends over the last 2000 years. The green line shows global surface temperatures nearly constant for 400 years between 200 AD and 600 AD. The red line shows that global temperatures then declined slowly for 1300 years between 600 AD and 1900 AD. The blue line shows that during the last 100 years, between 1900 AD and 2000 AD, global surface temperatures increased rapidly. This 1.1-1.4º F (0.6-0.8º C) increase in global surface temperature over the past two millenia highlights the novelty of the 1.8-5.4º F (1.0-3.0º C) rise in global temperature anticipated during the coming century.

The Climate Models

The three global climate models used in the Rogue Basin project (CSIRO, MIROC and Hadley) are known as Atmosphere-Ocean General Circulation Models (AOGCM's) and are based on equations describing the atmosphere, land surface, cryosphere (ice and snow), and oceans. Table 1 identifies the factors that are incorporated into the three models.

TABLE 1. MODELING INPUTS FOR EACH OF THE THREE MODELS USED IN THIS PROJECT (IPCC 2007).

Model	CO_2	CH_4	Strat. Ozone	Trop. Ozone	CFCs	Land Use	Aerosols	Solar
CSIRO	Yes	Yes	Yes	Yes	Yes	No	Only SO_4	No
MIROC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hadley	Yes	Yes	Yes	Yes	Yes	Yes	Only SO_4, volcanic	Yes

Limitations to the Climate Models

There are several limitations to the climate models that add uncertainty to forecasting future climate. The more refined and region or site specific a global model becomes, the greater the chance of error. Models also have difficulty with modeling the effects of changes in the amount of solar radiation reflected from the earth's surface back to the atmosphere (albedo effect) and the strength of water vapor in warming the planet. The latter issue is especially important because increased water vapor is linked to rising temperatures and water vapor alone may account for 50% of warming. In general, all three models are better at projecting changes in temperature than in precipitation. In addition, the models were created at globally appropriate scales, and "downscaled" to the Rogue Basin. The downscaling permits the examination of local and regional trends, but retains a global level of uncertainty that potentially clouds the results.

The global climate models forecast increased precipitation at high latitudes and decreased precipitation at desert latitudes. The Rogue River Basin falls directly in the transition between these two major global bands, rendering future forecasts of precipitation highly uncertain. Most importantly, the models forecast increased severity and variability of precipitation events, particularly in the Rogue Basin transition zone between the wet north and the dry subtropics. More severe and variable weather might mean longer and deeper droughts, as well as longer and more severe floods.

-- Dr. Ron Neilson, USFS PNW Research Station

Given the limitations, model projections should not be considered absolute; instead, they should both be considered likely possibilities. It is important to note, however, that growing evidence indicates that the climate change projections made by these and many other climate models are, if anything, underestimating the rate and extent of the changes from global warming.

The three climate models and the vegetation model describe a reasonable range of possible future conditions in the Rogue Basin given projected emission paths and climate changes. Many experts predict an increase in the variability of climate patterns from decade to decade, which the varied outcomes of the models seem to support. This suggests that many, or even all, effects described for the Rogue Basin by the different models could occur at different times in the future. Rather than debating the merits of any particular climate model or outcome, it therefore is in the best interest of the people of the Rogue Basin to plan with the full range of possible future outcomes in mind.

CLIMATE FUTURE IN THE ROGUE BASIN

The three climate models and vegetation model projected changes in temperature, precipitation, snow accumulation and melt, stream flow, vegetation carbon, biomass consumed by fire, and distribution of different vegetation types. Appendix C includes the maps and graphs produced from the models.

Temperature

All three models project a significant increase in annual average temperature in the Rogue River Basin (Figure 4), ranging from 1° to 3° F (0.5 to 1.6° C) by around 2040, and 4° to 8° F (2.2 to 4.4° C) by around 2080, slightly above the global average. Summer temperatures in the Basin are projected to increase dramatically, reaching temperatures 7° to 15° F (3.8 to 8.3° C) above baseline by 2080, while even winter temperatures are likely to rise and reach temperatures 3° to 8° F (1.6 to 3.3° C) warmer than the past century.

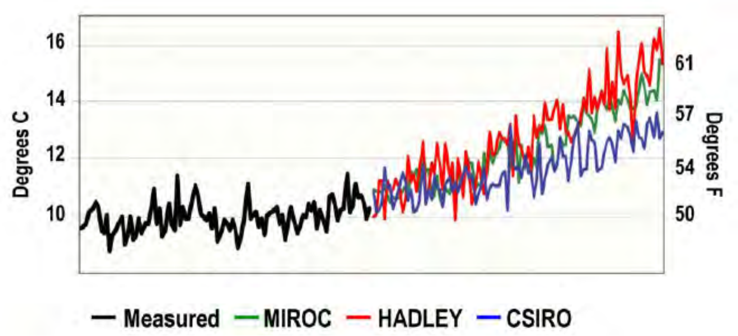


Fig 4. Average annual temperature across rogue basin

Precipitation, Snowpack, Snowmelt and Stream Flow

Two of the three models project that average annual precipitation is unlikely to change significantly during this century, but seasonal precipitation patterns are likely to change. Notable changes include significantly more precipitation during mid to late fall, winter, and early spring than was observed during the past century. The third model, Hadley, projects no significant divergence from current seasonal patterns at any time during the year.

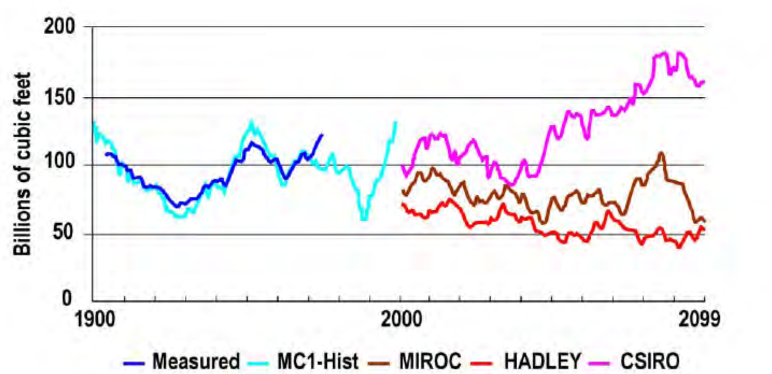


Fig 5. annual stream flow at a single stream gauge (gold rey) in the rogue basin, with an 11 year filter. historical stream flow is shown based on historical data (dark blue) and modeled (light blue). Projected stream flow is given based on three downscaled globalclimate models.

All three models agree that significant changes in annual and seasonal snow accumulation and melt should be expected. Snow accumulation is expected to decline by 25-75% by 2040, and up to 94% by 2080. All models anticipate a significant shift from snow to rain at lower elevations.

The models produced a range of anticipated annual stream flow levels in the Rogue Basin (Figure 5, page 5) that were consistent with the projected changes in annual precipitation. MIROC anticipates gradually declining annual stream flows that are reasonably comparable to baseline; Hadley projects slightly larger declines in annual stream flows that reach levels notably below baseline during the later half of the century; CSIRO projects a continuous increase in annual stream flow in the second half of the century.

Changes in fire and carbon sequestration in vegetation

The global vegetation model was combined with the three climate models and predicted that future conditions would be susceptible to producing two distinct patterns regarding the amount of carbon stored in vegetation and the level of biomass consumed by fire (Figure 6). In general, CSIRO and Hadley both envision increased fires in the first half of the century that will have an impact on the amount of vegetation carbon, followed by a period of declining fire and increased vegetation carbon. MIROC projects increased fires during the first and last thirds of the century, with fewer fires during the middle third of the century resulting in increased vegetation carbon in mid-century.

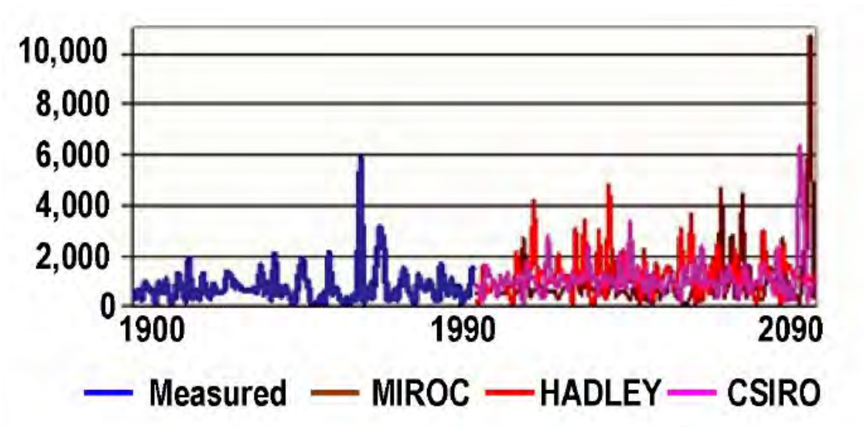


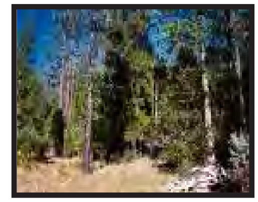
Fig 6. Historic and projected annual biomass consumed by fire in gigatons

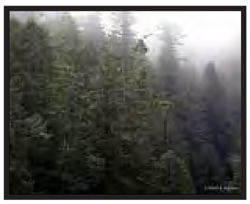
Changes to Vegetation Patterns

Some of the most dramatic changes projected by the models are the new conditions that could produce shifts in the extent and distribution of suitable conditions for four distinct vegetation types: warm maritime evergreen needleleaf, maritime evergreen needleleaf, temperate evergreen needleleaf, and temperate deciduous broadleaf. Descriptions of these four vegetation types are provided below. An additional three vegetation types, which are less common across the Oregon landscape, are also shown in Figure 7 (next page). Note that the models cannot project with certainty the appearance of these vegetation types, but only that suitable conditions for these types may prevail.

Warm Maritime Needleleaf– This forest type is dominated by a mixture of evergreen/deciduous and broadleaf/needleleaf woody species. It often gets no frost in any year, but may on occasion (called subtropical mixed forests in IPCC models). Typical species include diverse mixed pines and hardwoods, with some frost sensitive species such as madrone and evergreen oaks.

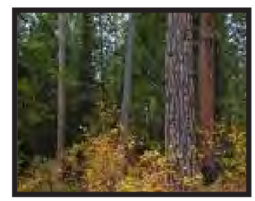
Maritime Evergreen Needleleaf – This forest type is dominated by a mixture of evergreen/deciduous and broadleaf/needleleaf woody species. The difference between summer and winter temperatures is relatively small; it does freeze regularly. Coastal spruce and fir are typical, but with earlier springs there could be an increase in deciduous trees, including oaks.





Temperate Evergreen Needleleaf – This forest type is dominated by a mixture of evergreen/deciduous and broadleaf/needleleaf woody species. The difference between summer and winter temperatures is greater; it does freeze regularly. Douglas fir, true firs, and ponderosa pine savannahs are typical.

Temperate Deciduous Broadleaf – This forest type is dominated by deciduous broadleaf woody species. The difference between summer and winter temperatures is greater and it does freezes regularly. Local species of oaks, maples, ash and other deciduous trees are typical.



By the end of the century two of the models project a dramatic increase in conditions for warm maritime needleleaf and temperate deciduous broadleaf (Figure 7). All three models project significant declines in the conditions for maritime evergreen needleleaf (from the 60% baseline to 5% or less).

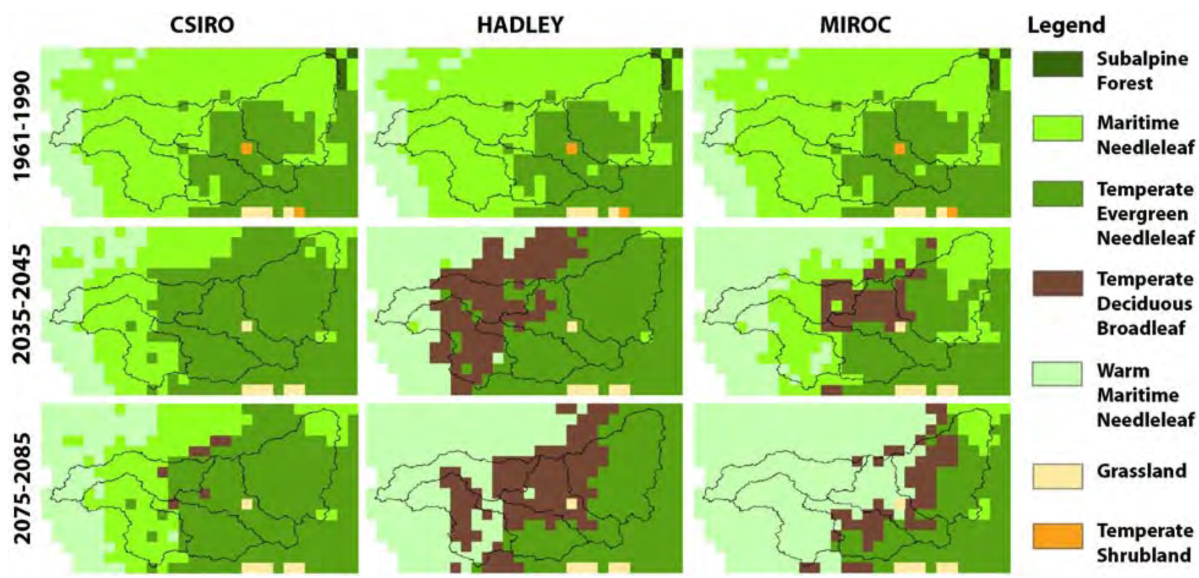


Fig 7. Current and future projected conditions for vegetation distribution across the Rogue Basin, as estimated with the MC1 vegetation model and 3 Global Climate Models.

Risks to Species and Ecosystem Function

The changes projected by the three climate models and MC1 vegetation model suggest significant and unique stresses to the structure and function of ecological systems and species in the Rogue Basin. In June of 2008, panels of aquatic and terrestrial scientists and land managers were convened to consider the projected future climate and identify areas of the Basin most likely to be susceptible to or buffered from climate impacts. Through these assessments, panelists anticipated the risks to species and to ecosystem function posed by climate change.

Risks to Aquatic Species and Systems

- **Increased storm and fire intensity and frequency** - More intense and frequent storms and fires are likely. These events will increase the sediment and nutrient loads, and increase the amount of persistent organic pollutants flowing into the Rogue River and its tributaries, particularly in granitic areas or on steep slopes. These factors, coupled with the impact of higher summer water temperatures, lower dissolved oxygen and increased bacteria and disease, would likely lead to a decline in water quality that is likely to reduce recruitment of young native fishes into the adult population (especially among salmon and steelhead).

- **Changes in timing of snowmelt and stream flow** - As temperatures rise, snowmelt will occur earlier in the year. Warmer temperatures and shifts in stream flow timing could trigger earlier emergences of aquatic insects, and shift the timing of adult spawning migration, egg incubation and hatch, and smolt outmigration. These changes would raise the risk of a disconnect between the timing of salmon and steelhead fry emergence, juvenile rearing, and smolt outmigration and the availability of each life stage's primary and preferred food sources. Such changes in the timing and availability of food sources also may produce unusual intermixing of species.

Photo by Cindy Deacon Williams

- **Increased water temperatures** - Increased and extended summer temperatures coupled with extended periods of lower summer baseflows are likely, leading to decreased dissolved oxygen and increased incidence of bacteria and disease. These conditions also are likely to cause an increase in the frequency of instream conditions lethal to native fishes by the regular establishment of mainstem conditions analogous to those found in the lower Klamath River during the 2002 fish kill. An expansion of the range of non-native invasive species that thrive in warmer waters also is likely. These conditions would be exacerbated further if surface and groundwater withdrawals for municipal and agricultural purposes are increased due to hotter and drier weather conditions.

- **Decreased habitat complexity** - Increased late fall, winter, and spring precipitation occurring during more intense storm events is likely to reduce channel complexity by downcutting to bedrock, eliminating riparian vegetation, causing streambank erosion, and reducing connectivity between stream systems and floodplains/riparian wetlands. The loss of habitat complexity likely would lead to a reduction in the capacity of streams to support biodiversity, exacerbate flood and drought impacts, compound the effects of increased air temperature, contribute to a contraction and drying of headwater stream networks, and increase the likelihood of quickly emerging floods.

- **Increased stream vulnerability** - Some stream reaches are likely to be more vulnerable to climate impacts than others. Areas identified as most susceptible to the negative effects of climate change include: headwater streams that will experience an expansion of the portion that flows only intermittently, high Cascade spring systems that are highly susceptible to expanded seasonal dry periods and extended droughts, reaches in the western portion of the Rogue Basin where past land management has increased the landscape's susceptibility to disturbance, south and west facing headwaters prone to warming and drying, bedrock reaches that don't have hyporheic (i.e., subsurface) flows and are more vulnerable to thermal heating, reaches within particularly steep topography that may erode more and be more susceptible to drought, and low gradient bedrock reaches that will be prone to warming and low flows.

- **Buffered streams** - In contrast, a number of areas were identified as both particularly resistant to the detrimental pressures of climate change and resilient in the face of the disturbances that increasingly will cause impacts. These include: reaches with gravel and biologically rich groundwater (hyporheic flows), areas with intact floodplains and a limited human footprint, and tributary junctions. Specific examples of areas at least partially buffered from climate change impacts and therefore likely to provide "salmon refuges" include deep, steep places along the California border, the Illinois and Applegate rivers, and Elk and Little Butte creeks.

Risks to Terrestrial Species and Systems

- **Increased fire** - Increased wildfire and longer fire seasons, greater biomass burned, and higher elevation fires likely will affect terrestrial vegetation and wildlife and cause sudden shifts in ecological communities. Fire likely will be the main driver of vegetation change. The diversity of vegetation types after intense fires will likely be significantly different from pre-fire conditions. Invasive or non-native species may replace native species. Mature forest species, including Marbled Murrelet, Northern Spotted Owl, Tailed Frog, Pacific Giant Salamander, and Fisher, are likely to be especially affected as fire frequency increases.

- **Shifts in vegetation cover** - Coniferous forest species are likely to decrease while deciduous (especially oak) forest, grassland, and shrubland species may remain stable or increase in response to climate change. Chaparral, grasslands, and scrublands are likely to increase in prominence if, as projected, the Rogue Basin becomes increasingly hotter and drier. Drought-tolerant species that may benefit include Oak, Madrone, Silktassel, and Mountain Mahogany.

- **Invasive species influx** - Increased abundance and distribution of both native and exotic invasive species may be expected due to declines in native species and increasingly favorable conditions for invasive species. Native species may see declines in available habitat and would have little time to disperse to new areas due to the fast rate of projected climate change, thereby leaving ecosystems ripe for invasions. Species with small ranges (such as endemics) and rare habitat communities likely will have difficultly adapting due to the fast rate of expected change.

- **Increased disease** - Disease and disease vectors are expected to increase due to more favorable conditions, including warmer temperatures, drought stress, and changes in vegetation. For example, increases in oak distribution and changes in climate variables could lead to outbreaks of Sudden Oak Death Syndrome.

- **High elevation species decline** - High elevation wildlife likely will become rare as their habitat warms and vegetation turnover occurs. Species that depend on high elevation wetlands and meadows, such as the water vole and American Pipit, would not be expected to survive in the area. Other species at risk include Clark's Nutcracker, Evening Grosbeak, Townsend's Solitaire, Boreal Owl, Pileated Woodpecker, Sooty Grouse (previously Blue Grouse), and Olive-sided Flycatcher. High elevation vegetation, including hemlock and native wildflowers, will also be at risk. Brewer's spruce, an endemic conifer and relic from the ice age, is restricted to high elevation areas and very prone to fire, putting it at risk of decline due to climate change.

- **Amphibian decline** - Some amphibians are expected to decline due to their lack of mobility, affinity for unique microsites, and susceptibility to drought, heat, and habitat change, while others may benefit from warmer temperatures. In addition, increasing temperatures will allow introduced species such as warm water fish, crayfish, and particularly bullfrogs to move higher in the watershed and expand into high elevation refugia.

- **Changes in timing** - Changes in plant growth, flowering, and fruiting times may disrupt traditional relationships for migration, breeding, and flowering. Long-distance avian migrants will be especially at risk of missing the times when food is most abundance which is vital for reproduction because their migrations are timed to the length of the day rather than temperature.

Risks to People, Community, and the Economy

The projected climate stresses on natural systems in the Rogue Basin are likely to have significant consequences for its people, communities and economy. In June 2008, a panel of government officials, business leaders and citizens examined the likely ecological changes and projected the possible consequences on social and economic well-being in the Rogue Basin.

Risks to Infrastructure and the Built Environment

Buildings and Real Estate

Many of the buildings and infrastructure in the Rogue Basin are located in high-risk floodplains and in narrow, steeply sloped forested canyons. The topography of the Basin therefore exacerbates the potential for millions of dollars of direct and indirect damage to buildings and real estate. The direct costs will result from flood events and anticipated increases in wildfire intensity and frequency due to climate change. The indirect costs are likely to be many times larger than the direct impacts, and will result from more rapid depreciation of property from higher temperatures, more intense storms and other climate stresses. (Josephine County has a total value of all taxable property of $6.5 billion and Jackson County has a $15 billion value of taxable property [Josephine County 2005; Jackson County 2008]).

Photo by Cindy Deacon Williams

Oregon ranks third among western states in the number of homes built in forested areas next to public lands, but ranks near the bottom (10th) in the percentage of those homes that are only seasonally occupied (Headwaters Economics 2007). Several of the most severely at-risk counties among western states are in parts of southwestern Oregon that overlap the Southern Cascade mountain range. These counties are at risk in terms of existing risk of wildfire (number of square miles of the wildland/urban interface with homes) and potential future risk (number of square miles of urban/wildland interface that remain undeveloped). Jackson County, with 82 square miles, and Josephine County, with 119.1 square miles, have the greatest number of square miles of developed land in the urban/wildland interface in Oregon.

Transportation

Road and air transportation are vital to the Rogue Basin's diverse economy. Josephine County has 560 miles of maintained roadways and 195 bridges/structures. Jackson County has more than 700 miles of paved roads. Coos and Curry Counties have about 260 miles of paved roads (AOC 2007). The Oregon Department of Transportation maintains approximately 2,300 lane miles in the two county area of the upper Basin (ODOT). In addition, the USDA Forest Service and the Bureau of Land Management manage a significant forest road network in the four county area. The Rogue Valley International-Medford Airport currently services eight hubs. In 2008, four air carriers serviced the airport with approximately 56 arriving and departing flights daily.

Severe flooding caused by storm and rain events as well as increased forest fires are likely to impact roads and impair movement of persons and equipment during storm emergencies. The most susceptible roads will be those bordering rivers and streams, or running through valley bottomlands as well as those in the vicinity of unstable slopes. Air transport may also be affected by increased storms and smoke intrusion from wildfires. In addition, efforts to raise taxes to fund mass transit in response to the need for greenhouse gas reductions may place increased financial pressures on communities, but also may facilitate more concentrated development.

Water Supply

The availability of water is critical for agriculture and municipal purposes in the Rogue Basin. The Rogue River and its tributaries may already be over-appropriated: according to the Jackson County Water Study, a conservative estimate shows a 2963 acre-feet/year surface water deficit by 2050, and the report did not even consider the potential impacts of climate change on water demand, snowpack, run-off, and resultant reservoir storage (Jackson County, 2002). The demand for groundwater is not expected to increase dramatically in the future because of lower rural population growth and increased urbanization (urban areas rely on surface water).

Photo by Cindy Deacon Williams

Flashier winter storm events and flooding, however, and more severe summer droughts are likely. As a result, water scarcity is likely to become more common, especially in summer and fall. These changes will increasingly challenge the physical and institutional capacity for water storage and allocation in the Rogue Basin. Pressure on already limited off-stream water storage will increase, particularly in the summer months.

Increasing competition for limited water supplies will likely amplify rural-urban tensions over the historical legacy of water rights, apportionment and pricing policies.

Ashland is likely to be especially vulnerable because of its dependence on reservoir capacity. More frequent higher intensity rain events are likely to reduce water quality as sediments and chemicals leech from the soil with more runoff. Valley floors will be particularly susceptible to these impacts.

Energy Systems

The electrical power and transmission sectors play important roles in delivering a reliable supply of energy that is vital to support the Rogue Basin's growing population and diverse economy. The power system is likely to face increased stress due to the likelihood of more intense storms, heat waves, and more frequent fires.

The City of Ashland Electric Department has provided power to the community since 1908. Power is purchased from the Bonneville Power Administration (BPA), metered at distribution substations and dispersed for each customer through city-owned feeder and distribution lines, transformers, and meters. BPA's power mix is primarily hydroelectric, with nuclear and other sources mixed in. Pacific Power provides electricity to Medford and Grants Pass. In 2007, 64% of Pacific Power's energy supply came from coal, 8.5% from natural gas, and 9.8% from hydro. The company projects that by 2016, 43.4% will come from coal, 17.4% from gas and about the same percent from hydro (Pacific Power 2007). The Coos-Curry Electric Cooperative purchases its power from BPA and serves more than 14,000 members and 16,500 meters in Coos, Curry and Douglas Counties. It has more than 1,500 miles of line, including 51 miles of transmission lines between Gold Beach and Brookings.

The Columbia River hydroelectric system, as well as local hydroelectricity systems, will face significant challenges in coming years due to increasing seasonal variability of water. Summer power capacity will likely be reduced as streamflows are reduced and reservoirs depleted during summer droughts due to reduced snowpack and earlier snowmelt. At the same time, the demands for electricity will likely increase as rising temperatures expand the use of air conditioning. The City of Ashland may be especially vulnerable to these effects because it purchases power from BPA, which is dominated by hydroelectricity.

Wildfires are also likely to affect hydroelectric supply due to increased sediment deposition into rivers and streams that reduces reservoir capacity. Fires may also reduce the supply of forest and agricultural residues that is needed to fuel biomass-based energy production. Both increased storm activity and wildfires may impair high voltage electrical transmission lines and distribution systems. In addition, high air temperatures decrease the efficiency of electrical distribution wires.

Demographic changes such as rising numbers of people moving to the Rogue Basin, as well as economic changes, such as possible growth of plug-in-hybrid vehicles that leads to increased electricity needs, would place even greater stress on local energy systems.

Risks to Economic Systems

The economy of the Rogue Basin, manufacturing, agriculture, forestry, or tourism, is highly dependent on stored water for hydropower generation, irrigation, and municipal water supply during hot and dry periods. With warmer temperatures and more extended dry periods predicted by the climate scenarios, this dependency is likely to lead to water shortages. The economy also depends on transportation networks that facilitate incoming supplies and the outgoing distribution of goods and services. These systems are likely to be adversely affected by increased storm events and wildfires.

The economic base in Jackson County is varied and growing, and government is the largest employer. Health care constitutes the largest single employment group in the private sector, and retail (including mail-order businesses) is the second largest employer, followed by tourism, agriculture, manufacturing, and timber. In Josephine County, health care and social assistance, manufacturing, and retail are the largest of twenty major economic sectors. Visitor accommodation and food services, manufacturing, retail, and health care and social assistance are the largest of twenty major sectors in Curry County. In this section the focus is primarily on the impacts of projected climate change on agriculture, forestry, manufacturing, retail and tourism.

Agriculture

Agriculture has always played an important role in the economy of the Rogue River Basin. High value fruits, including wine grapes and other crops, form the backbone of the agricultural economy in the upper Basin. The industry employs about 2500 people directly and 9000 indirectly through value added processing, agriculture related goods and services, and Josephine, Jackson and Curry Counties produce about $141 million in farm and ranch sales (Oregon Department of Agriculture/National Agriculture Statistics Service 2007). Rising land prices, however, caused by accelerating population and economic growth have placed increased stress on local producers. Climate change will add additional stresses.

Disruptions in the timing and quantity of flows will reduce already over-appropriated surface water supply. In addition, ground water will be affected by drought. Even with 30,000 acre feet already imported from Klamath County, senior water right holders may face limited water supply.

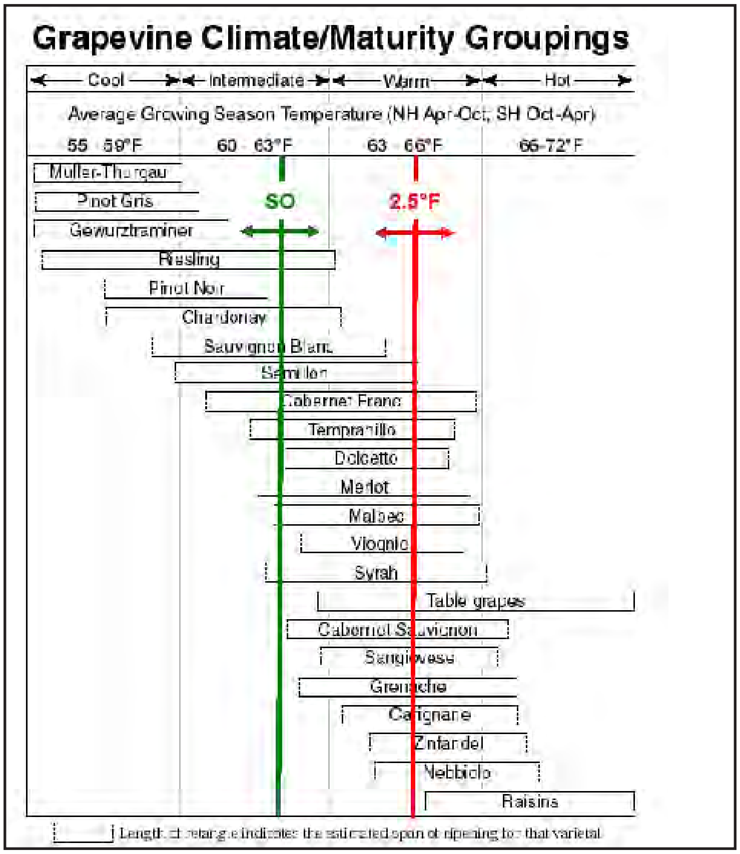


Fig 8. Predicted changes in grape growing season for Willamette Valley, Eastern Oregon and Southern Oregon. (Jones 2007)

Higher temperatures likely will reduce the viability of pears and wine grapes, particularly in Jackson County's pinot noir vineyards in the Illinois Valley. Higher temperatures also generally will stress many crops, although increased atmospheric CO_2 may have positive effects on water use efficiency in plants, thereby increasing plant productivity. Reduced availability of water will limit use of hydro cooling. Warmer and wetter spring months may lead to conditions for pear blight. Greg Jones, Southern Oregon University geography professor and private vintner, has commented that climate influences the style of wine that a region can produce. Each variety is generally grown in specific regions and narrow climatic zones for optimum quality and production, according to Jones. Wine varieties in their optimum zones have consistent sugar level, ripe flavors, and balanced taste. Warmer and longer growing seasons, while reducing frost damage, will alter ripening profiles and increase sugar levels resulting in excessive alcohol content. Warmer temperatures will also change plant disease and pest timing and severity, with uncertain results. Reduction in soil fertility and erosion are also anticipated. Viable zones in southwest Oregon will likely shift toward the coast, northward, and upward in elevation. Wine grape production may largely disappear in the Rogue Valley region by 2100 except in a narrow zone along the coast. How a moderate 2.5° F warming may cause a shift in varieties suitable for the Rogue Basin is illustrated in Figure 8 . For example, high value Pinot Noir and Chardonnay varieties will be replaced by lower value Merlots and Grenaches (Jones 2007).

Pollinators may be affected by climate change induced disease. Higher numbers of insects may lead to increases in pesticide use and reduced water quality. Large and small growers may both be vulnerable. Large growers with monocultures will be more susceptible to disease; growers that rely on single crops are likely to be more at risk financially than growers with diverse array of crops. Growers may need to shift to different crops, and new varieties and types of crops will need to be planted. Production may need to be shifted to cooler, higher elevations. This would require changes in land-use patterns and regulation. A shift to putting more cattle and sheep on public lands in response to drought may impair water quality in upland streams. Horse farms are likely to face reduced pasturage options and higher feed costs due to rising costs for water.

Forestry

Forestry has historically been an important driver of the economy in the Rogue River Basin. Today, the forestry industry in the Rogue River Basin employs approximately 29% of all of the forest sector jobs for Oregon. In southern Oregon, 3,370 people are employed in timber tract operations, forest nurseries, gathering of timber products, and logging, and approximately 21,400 people work in forest related manufacturing (OED).

Reduced snowpack, rising temperatures and the occurrence of drought will likely decrease soil moisture, weaken trees and increase disease. These forces will make forests more susceptible to wildfires, which will likely cause forestry product production to decline. A longer wildfire season may further narrow the window for harvesting trees.

Social pressure to rely on forests for carbon sequestration is likely to exacerbate these stresses. The likelihood of increased frequency and intensity of wildfire may place supply limits and higher costs on the production of biomass energy. The current shift to small diameter logs requires markets, mills and other infrastructure, and a transportation and electric infrastructure. These features are already limited and may be further restricted by climate change impacts.

Manufacturing, Retail and Service Sectors

In the past decades Jackson and Josephine counties have diversified their economies. The principle industries today include the manufacturing of durable goods, retail trade, and health services. Coastal communities are less diverse, with the economy relying heavily on natural resource industries such as commercial fishing, agriculture, lumber and wood products, as well as tourism and sport fishing.

It is likely that fuel costs will rise because of policies that require greenhouse gas reductions and that electricity costs will be higher because of reduced summer hydroelectric supply. These factors may affect many facets of the manufacturing, retail, and service economies. In addition, the climate impacts on transportation and the more restrictive use of water are likely to affect these sectors. Water supply reductions will require the balancing of municipal and agriculture water demands and will particularly affect municipalities that sell water, such as Ashland. Josephine County is vulnerable to reductions in water supply because it has only two municipal water systems and a large number of groundwater wells.

Hotter summer temperatures, increased allergens, and poor air quality (due to rising temperatures and smoke intrusion from wildfire) are likely to adversely affect the health of the local workforce. These factors may also impair conditions now favorable to attracting retired persons. Greenhouse gas reduction measures, however, that lead to cleaner vehicles, more mass transit, and the use of renewable energy could have positive impacts on public health in the Rogue Basin.

The optimal tourist season may shift as extreme temperatures make summers less attractive to people, while milder fall, winter and spring weather may prove more appealing. Reduced snow pack will shorten winter recreation seasons for skiing and snowboarding. Increased fire, smoke, and stream sediment may, over time, reduce the attractiveness of camping and recreational fishing. Declines in wildlife populations and intact habitats could cause declines in tourism, hunting, and other recreational activities. These changes would affect the entire recreational service sector and their suppliers.

Risks to Public Health and Emergency Services

Public Health Services

Rising temperatures, particularly in the summer, will likely produce higher incidences of heat-related illnesses such as heat stroke and exhaustion. Lack of air conditioning, a circumstance found today in a significant proportion of homes, will increasingly play a role in the incidence of heat-related illness in the Basin. The elderly, infirm, and poor are likely to be most at risk because they may lack funds to pay for air conditioning or health care, and because increased warming and air pollution may exacerbate pre-existing diseases and illnesses.

Amplified heat will also lead to more respiratory illnesses from higher ozone levels and increased pollens and allergens; the occurrence of asthma is also likely to grow. Asthma is already considerably more prevalent in Oregon than the U.S. average. The estimated percentage of the population affected by asthma between 2002 and 2005 was 7.1 - 9.9% in Jackson County; in Josephine County 8.1 - 13.5%; in Coos County 6.8 - 11.1%; and in Curry County 5.4 - 12.2% of the population was affected (Oregon Asthma Surveillance Report 2007).

Vector and water-borne diseases also are likely to increase. Warmer waters will bring elevated numbers of mosquitoes that may carry diseases such as Lyme disease, West Nile virus and malaria, which was endemic in the Rogue Basin in the 19th century. Infection most frequently occurs between May and November, with peak incidence in June and July.

Lyme disease is a multisystem inflammatory disease caused by the bite of the western black-legged tick. The Center for Disease Control (CDC) states that Lyme disease is grossly under-diagnosed by at least 10 fold. In 2006 Oregon experienced nineteen human cases with seventeen (89%) occurring west of the Cascades. In 2006 Jackson County had the second highest incident rate in the state at 2.5-6.2 per 1000, Josephine County had 0.3-0.96 per 1000, and Coos and Curry County's had between 0 and 0.29 per 1000 incidences (Oregon DHS 2006). Ticks occur primarily in oak woodlands and chapparal settings; therefore with the vegetation projections showing increases in these forest ecosystems, occurance of ticks is also likel to spread.

West Nile virus (WNV) is carried by mosquitoes and can infect humans, horses, and birds. Across the state, twenty-seven humans, over seventy animals ranging from birds to horses, and thirty-two mosquito ponds were diagnosed or identified in 2007 as being infected by WNV (Oregon DHS 2007). Warmer water temperatures are likely to increase the months of the year that will support high adult mosquito populations. WNV may therefore become more common in Oregon. Alternatively, declines in potential breeding sites due to increased drought and evaporation could keep the incidence of WNV from increasing.

The increased frequency and severity of forest fires pose a public safety hazard and also degrade air quality. The two extremes of flooding and drought will degrade water quality for municipal water supplies and ground water. These factors may affect water quality for human consumption

Emergency Services

Increased storm intensity, flooding and wildfire are likely to place greater demands on emergency service providers in the Rogue Basin. A major demographic shift is likely to exacerbate these pressures as drought, fire, flooding and other extreme weather events encourage people to move from rural to urban areas to be closer to emergency services and service sector jobs.

Emergency service and public health providers, already facing shrinking financial support because of declines in timber revenues tax bases, will also see increasing demands for funding and resources. If the impacts are not headline grabbing disasters, but chronically frequent smaller events, additional funding may be difficult to obtain.

At Risk Areas and and Vulnerable Populations

The populations most vulnerable to flooding will be those living in portions of inland valley bottoms (e.g., portions of Ashland, Medford, Central Point, Grants Pass, Applegate area, and Cave Junction within the floodplain) and in steep canyons in forested areas where flooding is likely to be most severe. The most vulnerable to increased air pollution will be those living in the Bear Creek Valley. Low income populations in rural areas are often the most susceptible to wildfires and flooding and have the most difficult time recovering after such events due to lack of healthcare and property insurance.

Greenhouse gas reduction policies that lead to higher fuel prices will limit the mobility of low-income rural residents and further contribute to the vulnerability of rural populations.

Buffered Areas and Populations

Some segments of the population will be less vulnerable to the impacts of climate change. High-income persons are likely to carry adequate health, fire, and flood insurance and be better informed about strategies to cope with stressors. Individuals, families, and communities that are self-sufficient in food, energy, and water will be more resilient. Populations in larger urban areas, while vulnerable to flooding in the Rogue Basin, also may have access to quality city services. Generally, those communities that are well connected to each other through reliable transportation and communications systems and that have strong social bonds will be most buffered from climate change impacts.

Summary

The consequences of climate change for built, economic and human systems in the Rogue River Basin are likely to be significant: if no action is taken, damages could amount to millions of dollars in direct costs. The indirect costs, along with reduced quality-of-life, may be 5-10 times larger than this direct costs. Preparation can help lessen these impacts, while also reducing the direct production of greenhouse gas emissions and increase the capacity of forests and agriculture to sequester carbon and thus help restabilize the climate. It should be noted that the Rogue Basin will not be alone in experiencing the consequences of climate change. Every region of the West, nation and world will be affected.

Photo by City of Ashland

Recommendations For Increasing Resistance And Resilience Through Integrated Co-Beneficial Climate Preparation Plans and Policies

Preparing for the consequences of climate change should become a priority for every government, business, and households of the Rogue Basin. Preparation actions should start with consideration of likely future conditions in both ongoing and future planning processes, projects, and policies. The goal should be to proactively build resilience or resistance in an integrated manner so that natural, economic, built and human systems can withstand and adapt to climate stressors. Resistance building strategies increase the capacity of systems to withstand the negative effects of climate change. Resilience building strategies develop the capacity of systems to adapt to and recover from climate change impacts.

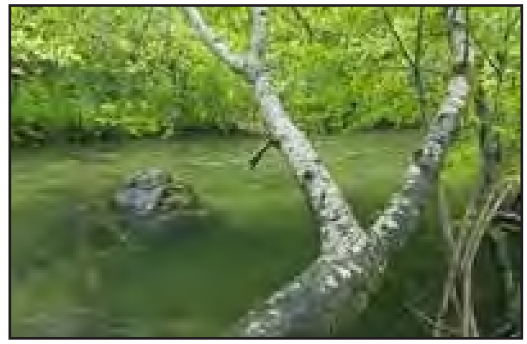


Photo by Kevin Schafer

The Need for Integrated, Co-Beneficial, Climate Preparation Plans and Policies

Integrating preparation plans and policies means that efforts to prepare one system or sector for climate change should enhance, and not undermine, preparation effort in other areas. To achieve this preparation plans and policies should be carefully coordinated with, and be designed so that they provide co-benefits for, other preparation efforts. Instead, integrated preparation plans and policies should be coordinated with, and provide co-benefits for, other preparation efforts. Well-meaning efforts to build resistance to likely future water shortages, for example, can very easily undermine long term water supplies and ecological health. Decisions to build more dams to increase water storage block fish passage and prevent water from recharging floodplain hyporheic zones, thus increasing the consequences of climate stresses on the humans and aquatic organisms that rely on healthy floodplains. In addition, constrained floodplains are less capable of buffering flood events. Tree removal conducted with the goal of increasing streamflow is likely to degrade the water holding capacity of watersheds and increase sedimentation, thus reducing, rathern than increasing, water supply.

Great care should be taken to ensure that all current management plans and policies, as well as climate preparation strategies are well-coordinated, ecologically sound, and provide co-benefits for other sectors within the Rogue Basin.

Preparation for Aquatic Species and Systems

A number of strategies could be employed to build resistance and resilience within aquatic species and ecosystems to prepare for climate change in the Rogue Basin. The overall goal should be to focus management activities on protecting, and where needed, restoring the functional and structural characteristics and organisms that represent critical underpinnings for the overall system. Many of the recommended actions represent best management and conservation practices that become even more important under climate change. Other recommendations are new and result from the special focus on the likely consequences of climate change. Implementation of these actions should be a high priority in the immediate future and across broad scales.

The expert panelists identified the following as the most important and effective approaches:

- **Reduce current stressors** – Existing stressors, such as livestock grazing along riparian areas, logging of old growth forests and riparian areas that reduce stream side shading, floodplain development, and road building that contributes to chronic inputs of sediments to streams, are likely to compound climate change impacts. Many existing management practices aimed at reducing current stresses on aquatic systems also generate the additional benefit of minimizing ecological stress induced by climate change. Protection and restoration of floodplains (including the connections between streams, riparian areas and floodplains), for example, will help increase underground water storage, reduce the effects of sudden floods, and ameliorate the impact of drought. These steps will help prevent scouring of streams, while also reducing the impacts of floods on humans and maintaining stream flows for longer time periods. Restoration and protection of tributary junctions, north-facing streams, and reaches with gravel and high topographic complexity will also provide multiple benefits and should be a priority. These areas of aquatic systems are most able to resist climate induced disturbance events that could cause ecosystems to unravel, and will become increasingly important as headwater stream networks contract due to reduced snowpack. Many existing management practices should be used to protect these areas, such as establishing or expanding protective zones and restricting development.

- **Restore channel complexity and connectivity** – The restoration and maintenance of stream channel complexity and connectivity should become a priority. Complex channel habitats, often created by stream flows working on large woody debris, are better able to support healthy native fish populations and limit the establishment and spread of invasive species. Removing up- and downstream passage barriers, including dams that were constructed for specific purposes and diversion structures as well as accidental passage barriers resulting from poorly designed road crossings and culverts, allows native fish to seek out suitable habitat and access it as needed on a yearly, seasonal, and daily basis. Efforts to restore complexity and connectivity often can be the most efficient means of increasing resilience and resistance in aquatic systems and should be prioritized.

- **Restore key biodiversity hot spots** – The restoration and protection of high elevation riparian areas and biodiversity "hot spots" will be vital (e.g., locations where species richness or endemicity is especially high), especially in the near and mid-term. Species with restricted ranges such as endemic mollusks and some salamanders and unique habitat requirements are likely to be the most vulnerable to extinction in the face of climate-induced changes, and therefore need our immediate conservation attention. By maintaining recruitment rates and genetic diversity, we will increase the likelihood that vulnerable species will be able to survive climate-related changes.

- **Protect genetic diversity** – Greater variety of genetic and life history diversity among fish and aquatic organisms will increase the likelihood for species to adapt to and survive future climate stresses. Fisheries management efforts therefore should prioritize the protection of the genetic and life history diversity of native fishes. Special effort should be given to strengthening "weak" stocks so as to increase the likelihood that their genetic diversity and novel life history components are present during the coming century. Fish hatcheries that reduce diversity should be closed. Higher levels of complexity in stock assemblages have proven more capable of sustaining viable populations in the face of increased environmental stress.

- **Manage runoff –** Urban, septic, and road (urban, highway, and forest) runoff should be managed so it does not increase the burden on aquatic organisms, and humans, due to likely climate-induced water quality problems. Runoff from these sources already adds significant sediment, persistent organic pollutants, and pharmaceuticals to aquatic systems in the Rogue Basin. If and when storm events increase, greater effort will be needed to ensure that surface runoff does not move even more contaminants in greater "flushes" from surrounding uplands into the Basin's rivers, streams, lakes, and wetlands. In addition, efforts should be made to reduce the quantity of contaminants in the environment that are susceptible to being flushed into the Basin's waters. Wetlands protection should be enforced and 'green' urban planning strongly encouraged.

- **Protect groundwater –** Ground water sources and recharge areas should be identified and protected. Ground and surface withdrawals should be limited to ensure adequate instream flows are maintained. Water rights law may need to be adjusted to account for the longer periods of drought and low flows expected from climate change. The reintroduction of beavers in appropriate locations within the Basin, especially in compatible high elevation wetlands, may help increase natural water storage.

Preparation for Terrestrial Species and Systems

Terrestrial species of plants and wildlife could benefit from a variety of actions that would increase their resistance and resilience to climate change in the Rogue Basin. Similar to aquatic systems, the immediacy of necessary action and broad scale application was emphasized. Our expert panelists recommended the following steps:

- **Reduce current stressors** – Climate change is likely to exacerbate existing stresses on terrestrial systems and species. The less stress a system or organism faces, the more likely it is that they can withstand or adapt to the impacts posed by climate change. Current stressors that could be reduced, with substantial benefits to wildlife, include habitat fragmentation, poorly planned and located road construction, unsustainable timber harvest, air and water pollution and contamination, the loss of keystone species, introduction of invasive species, and the conversion of forests, riparian areas and floodplains to urban and suburban development.

Photo by Josh Williams

- **Maintain forest resistance and resilience through strategic use of fire and fuels reduction** – Natural forest function and structure allows for increased resistance and adaptation to climate impacts, whereas large-scale uncharacteristically severe fire is likely to act as a catalyst for ecosystem change. Efforts to increase forest function, diversity, and resistance to catastrophic fire through, for example, the use of strategic fire, replanting with diverse native species, and strategically planned and carefully executed fuel reduction will be important. "Strategic fire" could include the use of prescribed burning to maintain habitats that were historically fire dependent or tactical management of wildland fires (e.g., developing a policy for fire suppression that takes into consideration habitat types and risks such as proximity to residential areas and endangered species). The panel noted that the use of strategic fire is difficult in some areas (e.g., the urban-wildland interface) making fuels reduction pragmatic and necessary in these areas.

- **Protect remaining intact ecosystems** – The remaining intact habitats within the Rogue Basin are likely to be most able to withstand and adapt to likely climate impacts. They are also likely to serve as a much needed source of shelter and food for native wildlife, as well as a source of native colonizers that will repopulate areas undergoing ecological turnover. Remaining old growth forests and roadless areas should therefore be a conservation priority because of their greater resilience to disturbance. Land management plans should also seek to conserve forest connectivity to allow species to migrate in response to climate change impacts. Connectivity allowing for upslope and northward movement should be given priority.

Photo by Ken Crocker

- **Maintain connectivity** – The maintenance of existing riparian forest connectivity, especially along north-south corridors, should be a priority. This means avoiding large gaps in riparian corridors because connected systems will provide much needed resilience in drier, warmer conditions and facilitate species migration in response to changing climate conditions. In the same vein, the panel recommended that habitat connectivity along elevational gradients and ridge tops be maintained, as these areas will facilitate shifts in migration and species distribution in response to changing climatic conditions.

- **Protect ecosystem services** – Ecosystem services are benefits that people gain from functioning ecosystems, such as the provision of ample supplies of clean water and clean air, decomposition of waste and toxins, plant pollination and natural flood control. Land and stream reaches that provide critical support for ecosystem services should be identified, protected and restored. For example, some floodplains hold important biologically rich groundwater beneath them (called hyporheic zones) that are critical to supporting surface flows as well as biodiversity. The protection of these and other areas that are essential to the provision of ecosystem services in the Rogue Basin will be even more essential as climate change generates increased stress on these systems. In addition, beaver populations should be maintained and increased in many reaches because the work they do in aquatic systems helps support high- to mid-elevation water storage and slower release during snowmelt, in addition to providing biologically rich habitat for songbirds and other species of plants and animals.

- **Maintain biological diversity** – Biological diversity, including both species and genetic diversity, allows for greater ecological function over long time scales, thereby increasing ecosystem resistance and resilience to climate change. Management plans should explicitly incorporate the conservation of biological diversity. Some experts suggested seed banks as one way to contribute to this effort. When developing species conservation plans, the probability of long-term success in the face of climate change stressors should be considered. The panel of experts suggested a triage approach to species management may be necessary, thereby giving higher priority to species with a greater likelihood of survival in a warming climate.

- **Translocation** – Only local and unique terrestrial species, or those that fulfill a vital functional role, should be considered for translocations. Many species will be unable to disperse fast enough to track their suitable climate or will be prevented from dispersing due to habitat fragmentation.

Because translocations may spread disease and produce other unknown ecological effects, they should be considered a last resort. Decisions should be thoroughly vetted within the scientific community in order to prevent undesirable impacts.

- **Adjust timber harvest strategies** – Timber harvest plans should incorporate likely climate impacts regarding the potential for, and uncertainties in, future regrowth, productivity and fire. Because of the likely increase in fire, major shifts in vegetation types, and other climate stresses the forests of the Rogue Basin are likely to experience, timber harvest strategies should undergo a fundamental shift to explicitly prioritize maintaining species diversity, genetic diversity and ecological integrity.

- **Adjust land use planning policy** – Increased habitat fragmentation and the conversion of open space, forest (especially older forest), and floodplains to hard surfaces and homesites will make it more difficult for natural systems and species to withstand and adapt to climate impacts. Local, state and federal government agencies in the Rogue Basin should include considerations of climate change impacts when making land use planning decisions. The panel felt that further development in the urban-wildland interface outside of urban growth areas, and the expansion of agriculture in a number of areas, would likely make climate preparedness more difficult in the future. Changes in land use policies will be necessary to prevent loss of habitat, life and other impacts to communities during extreme events such as floods, drought, and fire.

- **Increase data collection, monitoring, flexibility and scientific integrity of land, water, and wildlife management** – Few land management agencies currently have systems in place that allow them to gather and evaluate appropriate data and make decisions quickly in response to rapidly changing climate conditions. A sound monitoring system for both native and invasive species, with alternative management actions mapped out, will be vital in order for changes in populations to be detected quickly enough that management can adapt. New types of monitoring, assessment and decision making systems (based on a scenario planning approach) should be developed to allow for timely detection of, and response to, climate change trends.

For both aquatic and terrestrial species, the protection and maintenance of biodiversity "hot spots" (e.g., locations where species richness or endemicity is especially high), especially in the near and mid-term will be vital. Species with restricted ranges, such as endemic mollusks and some salamanders, and unique habitat requirements are likely to be the most vulnerable to extinction in the face of climate-induced changes, and therefore need our immediate conservation attention. By maintaining recruitment rates and genetic diversity, we will increase the likelihood that vulnerable species will be able to survive climate-related changes.

Preparation Strategies for Infrastructure and the Built Environment

Many elements of the built environment and infrastructure in the Rogue River Basin will require climate preparation strategies. The panel focused specifically on recommendations for transportation, water supply, and energy systems and provided suggestions for preparing general infrastructure.

- **Transportation** –Runoff and flooding are likely to produce major stresses on roads and other aspects of the transportation system. Preparation strategies should focus on upgrading culverts so they can pass larger amounts of water and instituting a regular maintenance program to clean culverts to prevent debris clogs. Arterial routes should draw special attention because they are likely to provide vital sources of access when slides, flooding, or fire block other routes. Across the Basin transportation routes should be connected with public transportation nodes and hubs as much as possible to allow people and vital equipment to move about in emergencies. To facilitate efforts to concentrate people and development in low risk areas, density targets should be tied to transportation funding and a shift in priorities should focus financial resources on public transportation rather than on further extension of transport networks focused on single vehicles. Public outreach should educate members of the community about transportation and climate issues.

- **Water supply –** Water conservation and efficiency policies should be strengthened and funded. In agricultural areas, policies, incentives, and mandates should support a shift to drip irrigation and other systems that minimize water demand. Agricultural canals should be piped. In urban areas, policies, incentives, and mandates should support xeroscaping, a shift from lawns to gardens, and a reduction in household water use. Construction of bioswales (and other approaches that decrease impermeable surfaces and/or minimizing development induced changes in the hydrograph) and the use of "grey" water should be widely instituted. Riparian and floodplain buffers should be amplified, perhaps coordinated with increased use of conservation easements, to increase the natural "sponge" capacity of the landscape. Water conservation and efficiency outreach efforts should be expanded.


Photo by Cindy Deacon Williams

- **Energy systems –** New policies should support upgraded and expanded energy conservation and efficiency efforts with the goal of dramatically reducing energy demand by increasing retrofits in existing buildings and energy efficiency in new construction. Expanded use of energy audits and incentives could be used to facilitate this process. Incentives to residential and commercial users aimed at increasing the use of renewable energy such as wind, biomass and solar power, improved home insulation, and the purchase of energy star appliances should be extended and expanded. Policy makers should also clarify the policy authorizing net-metering (the ability of residential and commercial energy producers to sell power back to the grid).

- **Buildings, structures and real estate –** To cover the upfront costs of incorporating green elements (e.g., bioswales, riparian setbacks, etc.) in project design, the development of a basin-specific "green development" revolving fund should be considered that provides low-interest construction loans to developers. FEMA flood maps should be revisited and adjustments made as necessary given the likelihood of increased flooding due to future climate conditions. Policies should be adopted to keep new permanent structures out of the floodplain and high fire risk interface areas, and to relocate permanent structures already located in those areas to safer areas if and when they are damaged by flood or fire.

Preparation Strategies for Economic Systems

The panelists offered recommendations for preparing agriculture, forestry, manufacturing, and service sectors for the impacts of climate change.

- **Agriculture** – The agriculture sector will likely do well to maintain production of existing crops as long as possible, while also initiating research into new crops and markets prior to the time when the need to transition to new crops is required due to changing climate conditions. Introduction of more drought tolerant crops is likely to be key. Of course, knowing when the transition will be mandatory will be difficult, so efforts should begin immediately.

  Farmers will benefit from land and water use policies that protect agricultural land from urban/rural sprawl and encourage efficient water use (e.g., efficient irrigation practices and low water demand crop selection). Policymakers should consider policies that expand sustainable agricultural practices, especially those that reduce pesticide and water use, erosion and stream sedimentation (e.g., no-till farming), and develop incentives to support development and maintenance of a local food supply. The former will increase the resiliency of soils and streams to climate stresses. The later step provides a buffer against climate-induced disruptions in food production outside of the Rogue Basin.

  The existing water rights system should be reexamined, groundwater resources and well capacity assessed, and existing permits and licenses reevaluated to avoid over-appropriation. Current policies and allocations were based on historic conditions that are certain to be very different as the Rogue Basin experiences the consequences of climate change. Adjustments to water laws and allocation systems are certain to be needed. It will be essential to establish a rational, integrated allocation of ground and surface water resources that is consistent with climate change predictions. Farmers may also benefit economically by focusing their lands on carbon sequestration.

- **Forestry** – The local industry already has increasinglyshifted to small diameter logs, and milling is now substantially done out of the area. This transition is likely to continue, with forestry becoming an ever less significant contributor to the Basin's economy. Research efforts should focus on evaluating how predicted climate-induced changes in vegetative patterns will impact this ongoing transition. Forestry management practices should be adjusted to ensure that they encompass climate-induced changes and enhance, rather than degrade, the landscape's ability to provide a buffer against the greater seasonal, annual, and decadal variability in temperature and precipitation as well as against the increased likelihood of severe storm and fire events. With the likelihood of increasing frequency and intensity of forest fires, post-fire logging activities should be carefully examined for impacts on carbon release and ecological disturbance. Policies should integrate fuel reduction efforts with small-scale biomass energy production, and research should focus on resolving practical problems related to the use of cellulosic ethanol. Biomass energy production also contributes to climate change mitigation as, unlike fossil fuels, it is carbon neutral over the life cycle of the vegetation consumed in the production of energy. However, harvest for biomass fuel supply, or as a component of any other thinning practice, should be implemented only if ecological and species integrity of aquatic environments and terrestrial landscapes is maintained.

- **Manufacturing** – Manufacturers in the Rogue Basin will have to develop strategies to protect their energy supplies, reduce their dependence on water, and increase their resilience to possible disruptions in transportation. They may also need to consider ways to protect to their energy supplies, to reduce their dependence on water, increase their resilience to projected disruptions in transportation, and consider ways to protect their workforce from possible health and stress effects of climate change. Instituting aggressive energy, water and materials conservation and efficiency strategies would make firms less susceptible to rising costs for energy and materials. The installation of on-site energy production such as solar photovoltaic or high-efficiency thermal biomass systems can provide valuable backups in times of blackouts or other disruptions in energy supplies while also acting as a counterforce to rising energy prices. The use of solar hot water systems can substantially cut energy consumption for the heating of hot water. These steps would also promote the growth of renewable energy jobs in the Rogue Basin. Shortening and developing redundant supply chains can help protect manufacturers from disruptions in material and transportation. Firms that take proactive steps to ameliorate the likely health threats that climate change poses for their employees are likely to experience decreased absenteeism and increased commitment and productivity.

- **Tourism** – Although there may be seasonal shifts in the tourism industry due to a warming climate, the industry as a whole is likely continue to do well if it adjusts to changing climate conditions. The industry might, for example, consider expanding spring, winter and fall activities to accommodate for likely increases in tourism during the milder seasons as climate change unfolds.

Preparation Strategies for Public Health and Emergency Services

Panelists recommended a number of strategies to prepare human systems for the impacts of climate change. Resistance strategies would reduce the exposure of human populations to disasters (e.g., reducing the number of interface area homes and/or increasing the establishment of defensible space around interface homes). Resilience strategies would build the capacity of emergency services to respond to increased needs (e.g., expanding wildland fire fighting capacity).

- **Concentrate human populations in less risky portions of the landscape** – As risk of flood and wildfire increases, the demand for emergency services will grow and likely stretch beyond capacity unless significant shifts are made in human habitation patterns. Land use planning and zoning should focus on reducing community susceptibility to climate risks by preventing new development in high-risk floodplains, steep forested canyons, and portions of the urban-wildland interface. Reconstruction of buildings that are damaged after floods or fires should be discouraged, for example by making government disaster relief, flood and fire insurance contingent on relocation to less susceptible areas. To ensure social equity, these policies should be coupled with special funding and tools to assist low income and vulnerable populations make the changes. Policies that fully incorporate the likely consequences of climate change into energy pricing could also be used as an incentive to reduce urban sprawl.

- **Redirect emergency services resources and responsibilities** – The costs of fire and flood protection and relief will continue to rise and unless new funding sources are identified they will rapidly exceed the monetary resources available for these purposes.

Therefore, a pragmatic assessment dictates that governments should consider shifting responsibility for emergency services in areas at high-risk of wildland fire or flooding to the private land and homeowners who choose to locate in such areas. This approach would need to be complemented by special funding and assistance to assist low income and vulnerable populations take on these responsibilities. Although local fire agencies currently provide rural fire protection, it is conceivable they will not be able to maintain the financial and personnel resources to support these services in the face of climate change impacts. Such a change in policy will need to be reflected in updated emergency management plans, and must be accompanied by significant outreach efforts to educate existing and new residents, especially rural residents, about their responsibilities and the limits of governmental obligations. Existing outreach programs directed at educating the public on the details of how to establish a defensible space to reduce the risk of loss during wildland fire provide a good illustration of the kinds of education tools available. However, these outreach efforts need to be broadened and expanded.

- **Orient forest and floodplain management policies on reducing susceptibility** – Existing patterns of human habitation in the urban-wildland interface and in floodplains are well established, and will take time to change - even with aggressive policies aimed at consolidating human populations onto less risky portions of the landscape. Forest and floodplain management must therefore be focused on reducing susceptibility to wildland fire and flood on those at-risk portions of the landscape that are currently inhabited. For example, policies that support the incorporation of bioswales and use of other approaches to minimize surface water runoff from new urban developments and the retrofitting of such mechanisms into existing developments would reduce the susceptibility to flooding. Targeting fuels reduction efforts to lands along the urban/wildland interface currently dotted with significant numbers of rural homes would have a similar moderating impact on demand for emergency services during wildland fires.

Photo from City of Grants Pass

- **Link climate preparation and economic development** – It will be important to make a direct link between the vulnerability of communities and economic opportunities related to climate preparation. Emphasis should be placed on creating jobs that reduce the vulnerability of local residents. Opportunities to forge a link between greenhouse gas reduction projects and climate preparation also exist. For example, strategic fuels reductions program in the urban/wildland interface can provide fuel for small-scale biomass energy production. Federal tax money would be helpful to start-up small-scale renewable energy facilities, especially if program policies provided guidelines that facilitated stewardship forestry practices that assisted with preparation efforts.

- **Intensify and adapt vector control for diseases** – Risks from vector-borne diseases stemming from mosquitoes and ticks are likely to increase as temperatures rise and bigger storms and flooding occurs. Although the vector control programs in most of the counties in the Rogue River Basin appear adequate to address these concerns, attention will need to be paid to ensure these programs retain the flexibility needed to address a climate change future.

- **Strengthen and expand water quality protections** – As climate change extends the period of low "summer" base flows, it will become increasingly important to prevent the contamination of shallow wells and to protect surface water quality. Contamination from mining and nonpoint sources (including urban and agricultural runoff) will have greater detrimental impacts as storm event and hydrologic runoff patterns change and less water is available in-stream to dilute pollution.

- **Develop strategies to anticipate new, climate change induced health service needs and provide them to vulnerable populations** – As summer temperatures rise, the incidence of heat related illness is likely to increase. The need for cooling centers for extremely hot days should be planned for, and the logistical challenges of making centers available to those in need anticipated (e.g., developing a system for transporting the elderly to the centers). In addition, asthma and other pollution related diseases are likely to rise and plans should be made to respond to these needs.

The Need for New and Expanded Systems of Governance

A consistent theme that emerged from the panels was the need for new information, resource allocation and decision making mechanisms that are better suited for future climate conditions. These are the core factors of governance. How they are handled determines how power and authority are distributed, i.e. they determine what issues or interests receive priority. Boards, commissions and legislative bodies are merely the 'containers' in which governance occurs. It is the type and ways in which information is gathered and distributed, resources are allocated, and decisions are made that actually determine how governance systems function. This section outlines the recommendations made by the panels for new and expanded systems of governance.

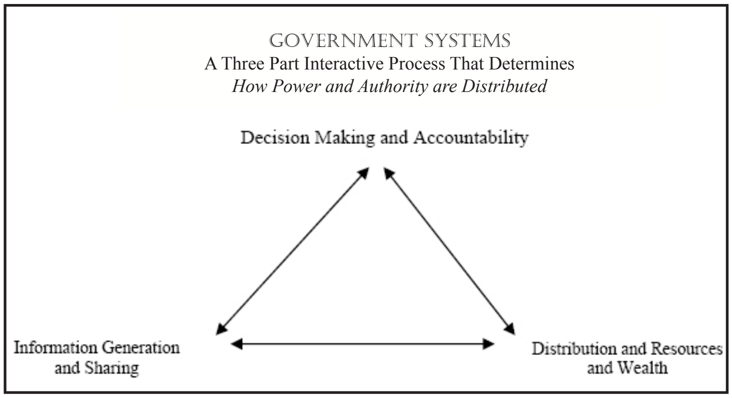


Fig 9. From doppelt 2003

- **Incorporate climate preparation into all public and private plans and policies** - A primary reason for new forms of governance in the Rogue River Basin is the need for ongoing and future planning and decision making to take climate change into account. Decisions made by the people of the Rogue Basin today will have profound implications for future economic, social and ecological well-being. Incorporating climate change into decision making now will require that new types of information be gathered (e.g., effects of climate on organisms or transportation infrastructure), that resources be allocated to different types of programs and policies (e.g., to those that build resistance and resilience in each sector), and that an expanded group of stakeholders (e.g., landowners downstream of proposed dams or revetments- structures placed on banks or cliffs in such a way as to absorb the energy of incoming water) and interests (e.g., future generations) be included or considered in policy development.

The panelists recommended that decision makers throughout the Rogue Basin formally and explicitly incorporate projected climate impacts into ongoing and future assessments, plans and policies. As part of this effort, governments should consider an inventory of their current policy and funding priorities to determine if they incorporate, enhance, or undermine climate change preparation efforts. Policies and budgets should be reprioritized as needed.

For example, the panelists recommended that Oregon's land-use planning "Big Look" process formally take into account climate change predictions. Disaster relief funds should be reoriented to relocate people from fire and flood disaster prone areas. Every public agency should complete energy audits and greenhouse gas inventories and implement appropriate energy conservation and efficiency measures. Mass transit and runoff retention should be incorporated into new developments and public transportation and reduction in the size of the human footprint on the land should be prioritized. Many other types of reprioritization will be needed.

- **Manage for 'Future Range of Variability'** – When incorporating climate change into ongoing and future programs and policies, decision-makers will need to shift their management perspective to focus on "future range of climate variability" rather than continuing the long-held approach of formulating management plans based on patterns observed in the past ("historic range of variability"). Climate model projections in the Rogue Basin indicate that the ecological, social and economic conditions of the past are no longer reasonable indicators of future conditions. This reality requires that decision-makers with responsibility for natural, economic, built and human systems adopt a future oriented perspective. As stated previously, planning for likely future conditions will require different types of information, changes in monitoring protocols, new funding and personnel allocation, and new decision making mechanisms.

Managing for the 'Future Range of Variability' will require flexibility in setting goals and priorities because conditions are likely to continuously change. A true 'systems' approach to goal and priority setting will be needed that is based on careful assessments of how shifts in one aspect of the natural or human environment is likely to affect other aspects. This approach to management is likely to enhance the capacity of every system to withstand and adapt to changing climate conditions.

- **Use Scenario Planning** – One of the most helpful tools when planning for the future range of variability is "scenario planning." Although the downscaling of climate models provides a reasonable projection of the range of conditions likely in a future climate, it is not possible to know exactly how climate change will play out in the Rogue Basin. To resolve this inherent uncertainty regarding the details, decision makers will benefit by developing a suite of possible future scenarios, analyzing potential vulnerabilities, identifying the gaps that exist in the capacity of existing programs and policies to respond to those vulnerabilities, and then developing strategies and policies to increase resistance and resilience of local systems under most or all of those future conditions. Figure 10 (next page) outlines the steps in a scenario planning process.

The Rogue Basin project described in this report used a scenario building process. As previously stated, three different IPCC climate models and a global vegetation model were used to describe scenarios of how climate change would likely affect the Rogue Basin. The panels then assessed the effects of each of the scenarios and identified actions and policies that would help prepare natural, economic, human and built systems for climate change. Scenario building is a common practice used within the business community. Information about the process can be obtained from the web and in many books.

Steps in a Vulnerability / Opportunity Assessment

1) Develop/utilize climate impact scenarios
2) Assess risks to existing systems
3) Assess existing systems against climate scenarios
4) Estimate the gaps between existing capacity and what will be needed under different climate scenarios
5) Identify and assess strategies for closing gaps
6) Choose strategy and implement

Fig. 10. From curbing and preparing for climate change: handbook for rural governments in the pacific northwest, UO climate leadership initiative, 2007.

- **Expand goal setting and decision making to the landscape level** – When planning for the future range of variability, goal setting and decision making will be enhanced by shifting to the landscape level with a future climate focus. Changing climate conditions mean that individual projects that on first glance appear to have little consequence beyond the specific location in which they take place may in fact have significant affects on ecological, human, economic and built systems elsewhere in the Rogue Basin.

  This new reality means that management goals, policies and projects should no longer be planned or implemented in isolation of their effects on the entire landscape. A core element of decision making should be to ask how every plan or project would affect other aspects of natural, built, economic and human systems in the Rogue. Landscape level climate-oriented ecological management means that federal land management plans should be updated to account for likely climate futures. Many watershed plans have been prepared and landscape level analyses currently are being conducted. These should also be updated to include likely future climate conditions.

  Forest thinning projects, for example, aimed at restoring resistance and resilience to fire in the terrestrial component of the ecosystem should be integrated with efforts to restore resistance and resilience to fire in therestoration efforts aimed at the aquatic environment.Thinning plans should be made with a thorough understanding of how climate change is expected to impact the forest, soils, water quality and quantity, fisheries, and other factors. Similar considerations should be incorporated for planning and policy making in the human, built, and economic sectors. Most important, the implications across and between all four sectors must be explicitly and comprehensively built into planning and policymaking.

  The scientific panel also acknowledged that the traditional segregation between the management of public and private lands, and between forested, agricultural and urban areas, will need to shift to a more integrated approach if natural systems and functions vital to society such as the provision of clean water are to withstand and adapt to climate impacts. A more integrated approach will help identify potential barriers to the implementation of preparation activities. Landscape-level planning and management are also likely to foster the identification of opportunities for leveraging efforts through involvement with multiple partnerships.

- **Continually seek co-beneficial actions** – The analysis found that if landscape level planning and decision making occurs many actions aimed at increasing the resistance and resilience of one system in the Rogue Basin can offer co-benefits for other systems. By using this approach a self-reinforcing system will be established that continually enhances natural, built, economic and human systems. Appendix D offers examples of how climate preparation activities in one sector can provide benefits in other sectors.

- **Expand participation on planning and decision making teams** – One of the most important considerations when expanding planning to the landscape level is who or what interests should be involved with decision making. Because climate change expands the realm of the issues and people that may be affected by projects and policies, planning teams will often benefit by expanding participation.

  For example, aquatic scientists should be included in planning and decision making regarding forest thinning projects because although they may occur in the uplands, forest thinning in a climate-affected forest may have significant implications for aquatic species and systems. Similarly, infrastructure projects implemented upstream in the Rogue Basin may have significant implications for natural systems, public safety or public health downstream. Unintended negative consequences can often be avoided by expanding the range of expertise of people who are involved in planning and decision making.

  In addition, all counties in Oregon have natural hazard plans for preventing loss of life, and reducing injuries and property damage during extreme weather events. The hazard mitigation plans for each county provide data on threats as well as preparation planning, strategies, and techniques. The plans are developed collaboratively, in conjunction with various partners throughout the county. For instance, the Jackson County wildfire protection plan was developed with input from BLM, fire departments, transportation and development departments, soil and water conservation districts, national forest departments, and planning departments. When developing climate preparation plans and policies, there should be collaboration with the Partners for Disaster Resistance and Resilience: Oregon Showcase State Initiative, a coordinating body that leverages human and financial resources for risk reduction throughout Oregon. Many other types of collaboration are possible.

  A more coordinated and integrated participatory approach to planning and decision making may require new or expanded institutions of governance. Watershed councils, for example, which include multiple stakeholders, are an example of new governance mechanisms that could be built upon and vested with authority to coordinate and integrate ecological climate futures planning at the landscape level. Other new governance institutions are possible as well.

- **Improve and reorient information gathering and monitoring systems** – In order to generate the information needed to successfully withstand and adapt to climate change, monitoring systems must be reoriented and strengthened to measure and generate useful information in a timely manner on the speed and trajectory of climate change impacts and the effectiveness of resistance and resilience strategies. The responses of people, infrastructure, economies, and natural systems to climate change will be inherently chaotic and uncertain. Many changes will occur more rapidly than anticipated and surprise events are likely. Improved monitoring of the types, extent, and effects of those changes will be vital to the development and implementation of agile, responsive preparation plans and policies.

The natural systems panelists, for example, said it is important to develop a greater understanding of the relationship between climate projections and fire impacts by developing a finer resolution analysis of fire responses in forests. The panel also identified a need for a finer resolution analysis of the intensity and frequency of high stream flow events and the impact of such events on ecosystem integrity, stream function, and survival of the various life history stages of our native fishes. In addition, the panelists recognized a need to develop a clearer understanding and awareness of the response of mobile, invasive, native and non-native species to climate change. These species are pioneers that will herald the onset of landscape scale shifts in biological communities. Climate induced changes in fire and flood behavior and invasive species responses clearly also are of critical importance to preparation planning for human communities.

The economic, built, and human systems panelists stated that improved monitoring and data gathering about storm intensity and precipitation, seasonal water availability, energy supply (locally and across the western electrical grid), public health risks and other issues will be important to building increasingly effective resistance and resilience strategies.

- **Increase public understanding** – One of the most important steps decision makers in the Rogue River Basin can take to develop the new governance mechanisms required to successfully withstand and adapt to climate change is to educate citizens. To accomplish this sound knowledge and understanding among the public about climate impacts and preparation will be essential. Extensive, long-term climate education and outreach programs should be instituted within all levels of government, the private sector, educational institutions, and community groups in the Rogue River Basin. Residents must come to understand the likely risks of climate change and what can be done to minimize and prepare for them.

Conclusions

Global temperatures are rising in large part due to human activities. No matter how fast human-produced greenhouse gas emissions can be reduced during the coming years, climate change is likely to transform the natural systems of the Rogue River Basin, as it will in all other regions, nations, and across the planet. These shifts will stimulate considerable change in how the local economy functions, the capacity of the built environment to support local communities, in human health, and in the overall quality of life of the people who live in and cherish the Rogue River Basin. Numerous planning and policy initiatives exist in the Rogue Basin that can help increase climate resistance and resiliency. The people and institutions of the region have the capacity to make the adjustments needed to effectively prepare for climate change. Proactive steps to upgrade and expand preparation efforts for natural, economic, built and human systems for the likely future consequences of climate change can help the people and communities of the Rogue Basin adapt and thrive in the future.

This report should serve as a beginning, not an ending point, for the development of climate preparation programs and policies in the Rogue River Basin. It is our hope that organizations such as The Rogue Valley Council of Governments, municipal and county governments, federal and state agencies, as well as private firms and households will use this report as a platform for more extensive investigation into effective means to prepare the Rogue Basin for climate change.

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APPENDIX A. List of Participants in the Rogue River Basin Climate Future Forum Natural Systems Workshops.

Name	Affiliation
John Alexander	Klamath Bird Observatory
Pat Boleyn	Lane Community College
Rick Brown	Defenders of Wildlife
Paula Burgess	Wild Salmon Center
Ben Carrier	National Center for Conservation Science and Policy
Dominick DellaSala	National Center for Conservation Science and Policy
Bob Doppelt	Climate Leadership Initiative, University of Oregon
Ray Drapek	US Forest Service/Pacific Northwest Research Station
Chris Frissell	Pacific Rivers Council
Tonya Graham	National Center for Conservation Science and Policy
Sam Gregory	Oregon State University
Roger Hamilton	Climate Leadership Initiative, University of Oregon
Paul Hosten	US Bureau of Land Management
Aida Jolosheva	Climate Leadership Initiative, University of Oregon
Marni Koopman	RMRS/NCCSP
Aaron Maxwell	Southern Oregon University
Ron Neilson	US Forest Service/ Pacific Northwest Rearch Station
Dennis Odion	Odion Consulting
Michael Parker	Southern Oregon University
Dave Perry	Oregon State University
Pepper Trail	US Fish and Wildlife Service
Dan Van Dyke	Oregon Department of Fish and Wildlife
Rob Walton	NOAA Fisheries
Cindy Deacon Williams	National Center for Conservation Science and Policy
Jack Williams	Trout Unlimited

APPENDIX B. List of Participants in the Rogue River Basin Climate Futures Forum Human, Build and Economic Systems Workshops

Name	Affiliation
Craig Anderson	Jackson County Planning Department
Lynn Barnhardt	Jackson County
Bruce Bartow	Jackson County Emergency Board
Neil Benson	Jackson County Fire Plan
Andres Briggs	Oregon State Parks
Ben Carriers	National Center Conservation Science and Policy
Chris Chamgers	Ashland Fire and Rescue
Mike Curry	Jackson County Emergency Management
Bob Doppelt	Climate Leadership Initiative, University of Oregon
Dave Gilmour	Jackson County Commissioner
Don Greene	Jackson County Planning Commission
Kay Harrison	City of Central Point
Bob Jones	Medford Water Commission
Josh LeBombard	Jackson County Development Services
Katie Mackendrick	Climate Leadership Initiative, University of Oregon
Jim McGinnis	Ashland Conservation Commissioner
Charlie Phenix	Retired USFS Fire Manager
John Renz	Oregon DLCD
Morris Saltekoff	Sams Valley Bee Keeper
Ben Truwe	City of Medford
Philip Van Buskirk	OSU Agriculture Extension Administrator
John Vial	Jackson County Road Department
Jude Wait	City of Ashland
John Ward	Bear Creek Watershed Council
Jenny Zeltvay	Josephine County Public Health

APPENDIX C. Graphs and Figures

NOTE: Due to document size limitations, the graphs and figures are available in a separate document.

APPENDIX D. Climate Change Impacts: Conflicts and Synergies. Note: A plus (+) sign after a listed interaction indicates a positive or complementary impact and a minus (-) sign indicates a negative or competing impact.

Recommended Strategy/Policy	Natural Systems (NS)	Human Systems (HS)	Built Systems (BS)	Economic Systems (ES)
NS 1 Protect and restore floodplains and other key stream reaches		Competes with water for irrigated agriculture and hydroelectric power (-) Reduces hazardous stream flooding (+)	Limits development in flood plains (-)	Enhances recreation and tourism (+) Enhances commercial fisheries (+)
NS 2 Restore channel complexity		Reduces hazardous stream flooding (+)		
NS 3 Restore high elevation riparian areas				Enhances recreation and tourism (+)
NS 4 Protect genetic diversity				Helps maintain ecosystem services (+)
NS 5 Manage runoff		Improves municipal water quality (+)	Reduces water treatment costs (+)	
NS 6 Protect groundwater				Enhances water storage and supply for all purposes (+)
NS 7 Reduce current stressors to natural systems		Steady supplies of clean water for humans (+) Clean air, plant pollination, flood control (+)		Limits development in forests and flood plains (-)
NS 8 Maintain forest health through strategic use of fire		Potential health hazard (-)	Limits development on forest land (-)	Enhances forest productivity (+)
NS 9 Protect remaining intact ecosystems				Limits development in forests and flood plains (-)
NS 10 Maintain existing riparian forest connectivity				Limits development in forests and flood plains (-) Enhances recreation and tourism (+)
NS 11 Protect ecosystem services		Steady supplies of clean water for humans (+) Clean air, plant pollination, flood control (+)	Flood control (+)	Limits development in forests and flood plains (-) Flood control (+)
NS 12 Maintain biological diversity				Helps maintain ecosystem services (+)
NS 13 Translocation of local and unique terrestrial species				Costly (-)
NS 14 Adjust timber harvest strategies				Short-run reduction in timber harvests as adjustments take place (-) Long term adaptability of timber industry to climate change (+)
NS 15 Change land use planning policy			Limits development in forests and flood plains (-)	

Recommended Strategy/Policy	Natural Systems (NS)	Human Systems (HS)	Built Systems (BS)	Economic Systems (ES)
HS1 Concentrate human populations onto less risky portions of the landscape	Protects riparian areas (+)		Reduced damage to residential and commercial buildings (+) Limits development in forests and flood plains (-)	Good for future economy (+)
HS 2 Redirect emergency services resources and responsibilities				More efficiency use of resources and good for future economy (+)
HS 3 Orient forest and floodplain management policies on reducing susceptibility	Protects riparian areas and reduces stream sediments (+)		Prevents future destruction to residential and commercial buildings (+) Limits development in forests and flood plains (-)	
HS 4 Link climate preparation and economic development				Good for future economy (+)
HS 5 Intensify and adapt vector control for diseases				Enhances viability and resilience of work force and economy (+)
HS 6 Strengthen and expand water quality protections	Protects and enhances integrity of species and ecosystems (+)			Enhances recreation and tourism (+)
HS 7 Develop strategies to anticipate new, climate change induced health service needs and provide them to vulnerable populations				Enhances viability and resilience of work force and economy (+)
BS 1 Revisit transportation strategies, for instance expand road culverts, reduce forest roads, and enhance storm run-off protection	Protects rivers from sedimentation and forests from mudslides (+)	Protects municipal water quality (+)		Reduces insurance costs (+)
BS 2 Protect energy systems and water supply	Reduces greenhouse gas impacts (+)	Improves air quality (+)		Reduces business costs and reduces wealth export (+)
BS 3 Relocation of structures built in high risk areas	Reduced impact on natural systems (+)	Short term inconvenience (-)		Good for future economy (+)
ES 1. Maintain production of existing forestry products as long as possible, while also initiating research into new crops	May harm forest ecosystems (-)			
ES 2 Embrace land and water use policies that protect agricultural land from urban/rural sprawl and encourage efficient water use		Protects municipal water quality and agricultural land (+)		
ES 3 Development and adoption of policies that expand sustainable agricultural practices	Reduces impact on water and land ecosystems (+)			
ES 4 Remove federal subsidies for large-scale monocultures	Enhances ecosystem diversity and function (+)			

Recommended Strategy/Policy	Natural Systems (NS)	Human Systems (HS)	Built Systems (BS)	Economic Systems (ES)
ES 5 Develop incentives to support development and maintenance of a local food supply				
ES 6 Reexamine existing water rights system, groundwater resources and well capacity, and reevaluate existing permits and licenses to eliminate over-appropriation.	Enhances ecosystem function and integrity (+)			
ES 7 Continue shift to small diameter logs				
ES 8 Encompass climate-induced changes and enhance the landscapes ability to provide a buffer against the greater seasonal, annual, and decadal variability in temperature and precipitation as well as against the increased likelihood of severe storm events.	Reduces stress on species and ecosystems (+)			
ES 9 Expand research and production of biomass and cellulosic ethanol	May harm ecosystems and species (-)			
ES 10 Develop strategies to protect manufacturing energy supplies, reduce dependence on water, increase resiliency to projected disruptions in transportation, and consider ways to protect workforce from possible health and stress effects	May harm ecosystems and species (-)			
ES 11 Develop aggressive energy, water and materials conservation and efficiency strategies	Enhances water quantity and quality for species and ecosystems (+)	Enhances water quality for human health and consumption (+)	Firms less susceptible to energy and material shortages while also substantially reducing costs (+)	
ES 12 Installation of on-site energy production	May harm ecosystems and species (-)		Increase resilience to blackouts and other disruptions in energy supplies while also acting as a counterforce to rising energy prices (+)	
ES 13 Consider expanding spring, winter and fall activities to accommodate for likely increases in tourism during the milder seasons as climate change unfolds	May stress wildlife during mating and rearing seasons (-)			