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Integrated Strategies for a Vibrant and Sustainable Central Oregon

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EXECUTIVE SUMMARY

This report explores how the communities and natural resources of Crook, Dechutes, and Jefferson Counties of Central Oregon may be affected by projected changes in climate conditions. Most importantly, it identifies approaches to prepare for such changes. Although there is speculation by many residents of the region, best available scientific information demonstrates numerous effects of changing climate including local (earlier snow melt, loss of snow pack, and increasing frequency of high intensity storms) and global (increasing average global temperature and rising sea level) examples. To best take advantage of opportunities and reduce negative impacts, communities of Central Oregon must take steps to prepare for the effects of prospective changes to the climate.

The USDA Forest Service Pacific Northwest Research Station developed projections for the potential future climate of Central Oregon. Geos Institute and Headwaters Economics presented these projections and local socioeconomic trends to local leaders and experts in the region at a workshop. Leaders and experts used these climate projections to identify likely changes to natural (aquatic and terrestrial habitats and species), built (infrastructure), economic (agriculture, forestry, tourism, development, etc.), and human (health, education, and emergency services) systems. Leaders and experts then developed strategies and specific action recommendations to prepare communities and natural resources for those changes.

Future Climate of Crook, Deschutes, and Jefferson Counties

Three global climate models (CSIRO, MIROC, and HadCM) and a vegetation model (MC1) were used to project future temperature, precipitation, vegetation, and wildfire in Central Oregon. All three climate models projected an increase in annual average temperature for both the mid (2.1 to 4.0 °F) and late (5.4 to 8.7 °F) 21^{st} century from the reference period (1961 to 1990). All seasons showed warming, though summer projections show the greatest degree of warming.

Projections for annual average precipitation ranged from a reduction of 7% to an increase of 22 % by late 21^{st} century. All three models agreed that future winters are likely to be somewhat wetter than past winters (increases ranging from 4 to 24%). All other seasons had variable projections for precipitation trends. Increasing temperatures, despite projected increases in winter precipitation, suggest that snow pack levels will continue to decline in the region.

Vegetation model results indicated a shift in growing conditions. Ponderosa pine dominated mixed conifer forests are expected to expand at the expense of Douglas fir dominated mixed conifer and subalpine forests. The extent of wildfire is projected to increase by 11 to 16% by late 21^{st} century.

Recommended Actions for Preparation Across Systems

A number of broad-brush strategies emerged through discussions with Central Oregon leaders and experts. These strategies are particularly valuable to preparing communities and natural resources for changing conditions as they have many benefits to resources and systems beyond their intended target. They include:

Increase water storage, decrease flood risks, increase groundwater storage, and improve surface water quality by restoring wetlands, complex and meandering stream channels, and floodplains. Water managers should optimize water management in existing storage facilities and investigate and employ off-channel water storage facilities where feasible, cost effective, and beneficial to other natural resources.

Conserve water by improving irrigation water delivery and application, reducing water-intensive landscaping in municipal settings, and orienting future developments in locations near available water supplies.

Decrease water demand by employing market-based approaches to water allocation.

Reduce forest fuels through thinning and controlled burns to restore the historic range of forest structure and function, limit health risks from wildfire, and reduce the need for emergency services in the wildland-urban interface zone.

Protect intact habitats with relatively small populations of invasive species like roadless areas and other large public and tribal land tracts. These areas can serve as refuges for terrestrial and aquatic species affected by changing conditions.

Limit urban wildland and floodplain development and **initiate conservation-minded land use planning** by focusing future development near existing emergency service hubs and available water supplies. This will reduce the cost of providing services.

The recommendations made by local leaders and experts represent a sample of potential actions and strategies that could be taken in Central Oregon to prepare for climate change. Heat waves, severe precipitation events, and prolonged drought are all expected to increase in the future. Increasing the resilience of natural resources, the local economy, and local communities to such changes, the potential negative impacts of climate change will be reduced and the quality of life that Central Oregonians enjoy is more likely to be maintained.

WORKSHOP PARTICIPANTS

Geos Institute (Brian Barr, Cindy Deacon Williams, Tonya Graham, Alan Journet, and Marni Koopman) and Headwaters Economics (Ben Alexander) acted primarily as facilitators during this process. The real work was done by the following people, who participated in workshops, contributed ideas, and devoted time and enthusiasm to make the process successful. The body of this report is a reflection of their expertise. We apologize for any oversight on our part if you participated in the process and your name is missing or misspelled.

Rich Affeldt, John Allen, Glen Ardt, Scott Aycock, Rex Barber, Mike Britton, Katy Bryce, Phil Chang, Matt Cyrus, Chris Doty, Amanda Egerston, Andy Eglitis, Roy Epperson, Debbie Fields, Jim Fields, Kate Fitzpatrick, Noelle Fredland, Brett Golden, Peter Gutowsky, Pauline Harie, Megan Hill, Ryan Houston, John Jackson, Susanna Julber, Mike Kasberger, Eric Klann, Tom Kuhn, Nick Lelack, Peter Lickwar, Mike Lunn, Aaron Maxwell, Scott McCaulou, Craig Miller, Marilyn Miller, Mike Morgan, Daniel Newton, Brad Nye, Jennifer O'Reilly, Brenda Pace, Clay Penhollow, James Powell, Betty Roppe, Dan Sherwin, Brian Shetterly, Mike Simpson, Darek Staab, Eric Strobel, Karen Swirsky, Katrina VanDis, Amy Waltz, and Elmer Ward[*]

[*] We apologize for our oversight if we misspelled your name or if you participated in the process and your name is missing from this list.

PURPOSE AND OVERVIEW

Crook, Deschutes, and Jefferson Counties (referred to as "Central Oregon" throughout this report, Figure 1) will face many stressors over the coming decades. The population is expected to grow, water supplies are expected to become more limited, and pressures on natural areas from development are likely to increase. In addition to these pressures, changing climate conditions are likely to cause additional, substantial impacts touching all sectors of the communities in Central Oregon.

The purpose of this ClimateWise® effort is to develop new strategies that will increase the resilience of both human and natural communities to near-term and long-term "stressors" and changes in Central Oregon. Actions taken now can reduce these stressors and improve the exceptional quality of life that residents of this region enjoy, a quality of life that fueled the fast growth from 1995 to 2005. Preparing for change in a cohesive and environmentally sound manner will reduce the vulnerability of Central Oregonians to drought and poor air quality, among other effects of changing climate conditions. It will also help maintain valuable services such as recreation, flood abatement, water supply, and pollination that natural systems provide.

…this report is a reflection of input, values, and opinions from local experts, leaders, and citizens.

This report reflects the collective efforts, insights, and knowledge of many people in Central Oregon, including county and municipal planners, elected officials, land and resource managers, scientists, farmers, business leaders, and concerned citizens. These individuals came together to discuss the potential threats and opportunities of changing climate conditions to the communities and natural resources in Central Oregon and the likely interaction between changing climate conditions and existing stressors. Workshop participants were asked to develop initial "adaptation" strategies to changing climate conditions. These adaptation strategies form the start of activities Central Oregonians can take to reduce community and natural system vulnerability to change. These actions are the first steps towards increasing the ability to recover from climate change impacts, reduce risks, and capitalize on opportunities in a world that is very likely to change from the current circumstances.

While Geos Institute facilitated the exchange of information, this report is a reflection of the input, values, and opinions expressed by the workshop participants.

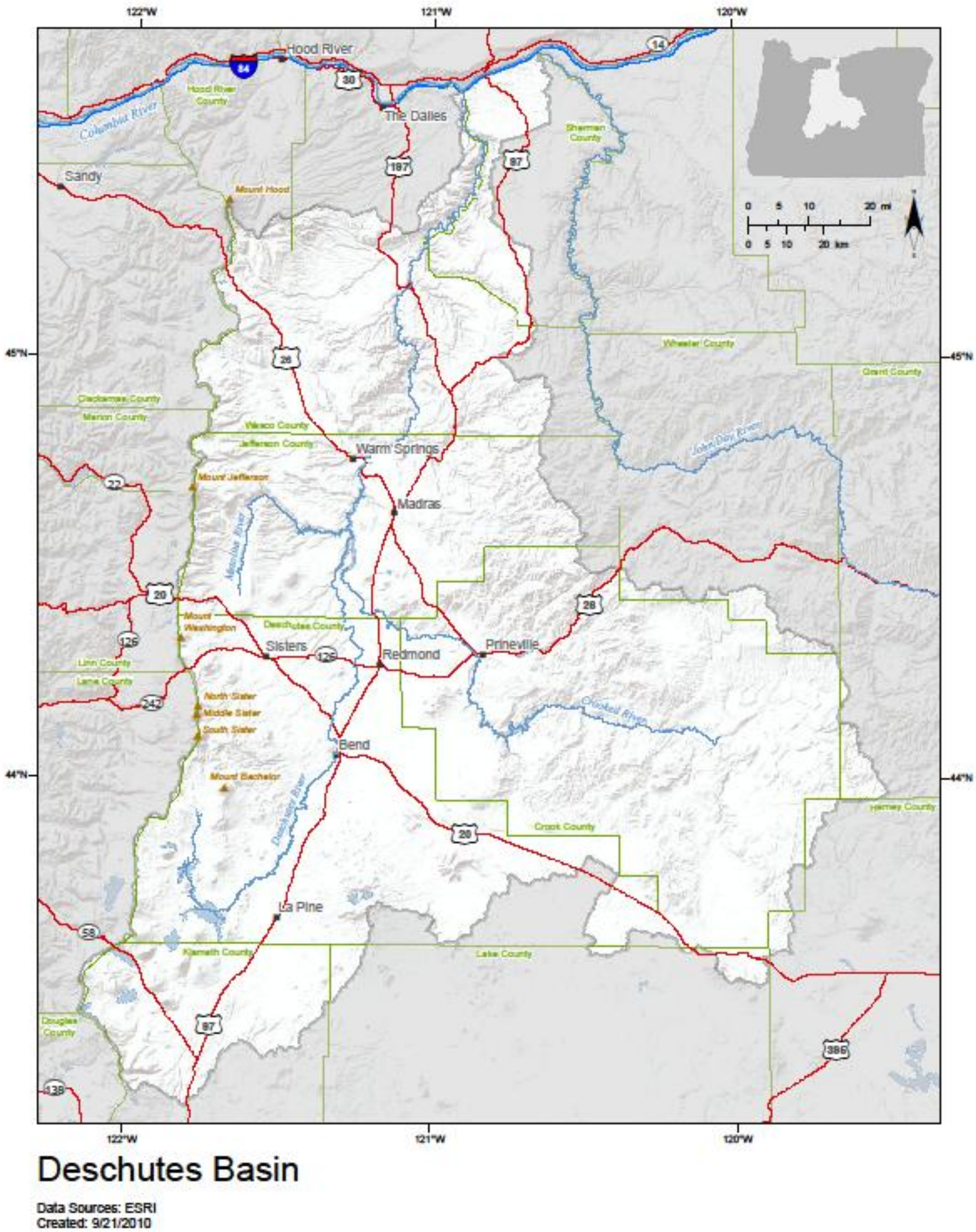


Figure 1. Deschutes Basin, including predominant towns and major road infrastructure.

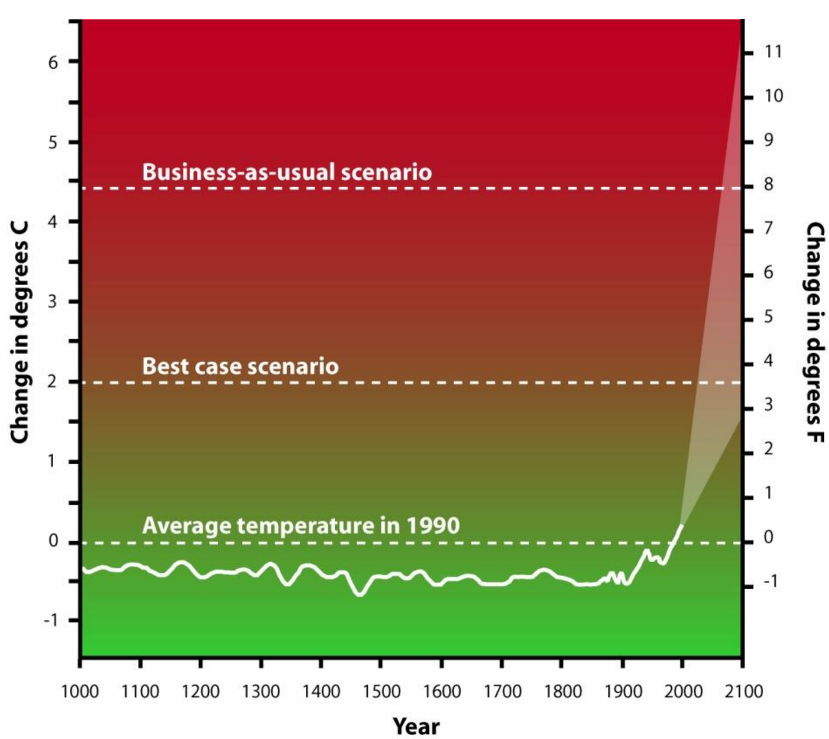
GLOBAL CHANGE

The world's leading climate scientists agree that the Earth's atmosphere and oceans are warming. [1,2] Average global air temperatures have increased 1.4 °F and is expected to increase by as much as 10 °F more by 2100[1] (Figure 2).

Increases in air and water temperature are expected to lead to substantial changes in many of the earth's systems. Storm severity and other natural disturbance events are expected to increase. In fact, severe storm and wildfire frequency have already increased across the western United States[3]. Average sea level has already increased eight inches over the past century with projections to accelerate over the next 100 years.[2,4] These changes are happening, and they are expected to accelerate over the next 40 to 50 years due to greenhouse gas emissions that have already occurred.

Approximately 30% of all species are at risk of extinction from climate chang.[5] Plant and animal populations around the world are already on the move as a result of warming regional temperatures.[6] Because the climate appears to be changing so quickly and dramatically compared to previous warming periods, many species will not be able to move or adapt to the new conditions quickly enough to survive. Other species will lose important food resources or have their reproduction or migration timing disrupted. As these species are affected by changing conditions, ecosystems will be disrupted and many ecosystem services (i.e., pollination, timber production, water filtration) may be compromised.

Figure 2. The last 1,000 years in global mean temperature compared to projected temperature for 2100. Drastic cuts in greenhouse gas emissions may lead to an increase of about 3° F by 2100 while the current emissions trajectory could lead to an increase closer to 8° F and as high as 11° F.[1]



Why make changes if the future is uncertain?

Climate model projections are not certain. There are a number of climate change models and they do not always agree. Moreover, the models require some *estimate* of future greenhouse gas emissions, and this number cannot be known.

Here are four reasons to invest in planning for something that is not certain:

#1 – Planning for continued historic conditions sets us up for failure. Most current planning mechanisms use historical patterns of drought frequency, flood severity, seasonal temperature patterns, etc. to plan for the future. According to thousands of leading, independent scientists, the future is very unlikely to resemble the past. The range of likely future conditions projected by climate models is more likely that a repetition of past patterns.

#2 – We plan for uncertain conditions all the time without a second thought. Why should changing climate conditions be any different? We harvest timber based on models of tree growth. We plan new streets based on projections of population growth and commute patterns. We buy fire insurance when we do not expect to have a house fire. Even if changing climate conditions are unlikely, the costs and risks associated with not planning are so great that the prudent course is to plan proactively.

#3 – Taking action makes the community more resilient and vibrant. Central Oregon is already at risk from long droughts, wildfires, and development of open spaces. Addressing these and other issues soon will maintain the high quality of life that makes Central Oregon such a desirable place to live.

#4 – Communities are pursuing these strategies anyhow. Central Oregon communities are pursuing many of these strategies already. Managing the risks of potentially changing climate conditions is another important reason to complete these activities.

CLIMATE CHANGE IN CENTRAL OREGON

Climate change is a global phenomenon that has the potential for severe local impacts to agriculture, infrastructure, natural resources, culture, human health, and tourism. These impacts are expected to increase the vulnerability of certain populations and sectors of Central Oregon communities. Decision makers in Crook, Deschutes, and Jefferson Counties can increase the resilience of their communities and the resources upon which they depend quickly by identifying and addressing these underlying vulnerabilities.

Climate change model outputs presented in this report were obtained from the USDA Forest Service Pacific Northwest Research Station; these data were analyzed, mapped, and graphed by Geos Institute scientists.[7] We present the results from three global climate models (HadCM, MIROC, and CSIRO) that come from a suite of models reviewed favorably by the International Panel on Climate Change. Temperature and precipitation projections were modeled using the "business as usual" emissions scenario. The model projections were then used to run a vegetation model. This model then projects vegetation life forms (types of trees / shrubs / plants) likely to be favored under projected future climate conditions. The vegetation model also projects wildfire frequency and carbon storage (among other parameters). Mapped model results are presented at a scale of 5-mile grid cells.

Climate change is expected to result in changes to the Central Oregon, including:

- 2-4° F increase in temperature by mid-century and 5-9° F increase by late century
- 50% decline in snowpack, earlier snowmelt, higher and earlier peak runoff
- Declines in stream flow, groundwater recharge, and water availability
- 2-4 times more wildfire at upper elevations
- Declines in populations of native animals and plants and shifts in distributions
- Increases in invasive species
- Possible declines in air quality

Because of emissions already released into the atmosphere, the mid-21st century projections presented in this report are likely to be more accurate. Late-century temperature and precipitation, however, may be quite different from those presented if emissions deviate from the "business as usual" scenario. A companion report (see reference) provides more in-depth coverage of the climate change model assumptions, emissions scenarios, uncertainty, and Central Oregon projections.

Local Climate Change Projections

Temperature – According to the global climate models used in this analysis, the Central Oregon region is expected to become 5.4 to 8.7 °F

Table 1. Future average temperature increases in the Deschutes Basin, based on projections from three global climate models (CSIRO, HadCM, and MIROC). Future projected temperature is shown as change in degrees Fahrenheit, as compared to historic averages (1961-1990).

Season	Historic	2035-45	2075-85
Dec – Feb	30.7 °F	+1.9 to +4.3 °F	+4.9 to +7.7 °F
Mar - May	42.4 °F	+1.8 to +3.8 °F	+3.5 to +7.6 °F
Jun – Aug	60.3 °F	+2.2 to +4.9 °F	+6.8 to +13.2 °F
Sep - Nov	45.6 °F	+2.4 to +4.4 °F	+6.2 to +9.7 °F
Annual	44.7 °F	+2.1 to +4.0 °F	+5.4 to +8.7 °F

warmer by late-century (2075 to 2085), with greater warming in the summer (June through August)and lesser warming in the winter (December through February)and spring (March through May) (Table 1, Figure 2). The models project mid-century (2035 to 2045) temperature increases of 2.1 to 4.0 °F. Model projections for temperature all point to a warmer future, though the degree of warming is variable among the projections.

Precipitation, snowpack, and streamflow – Projections from the three models do not agree on future, annual precipitation patterns. Annual precipitation projections range from changes of -1.8 to +0.1 inches by mid-century and -1.7 to +5.1 inches by late-century. The model projections do agree that winters will be slightly wetter in the future and that spring, summer, and fall (September through November) will be similar to somewhat drier over the near term (Table 2, Figure 3). Model projected precipitation patterns for these seasons in the long-term vary from wetter to drier without agreement.

Precipitation is expected to fall more as rain than snow as winter temperatures rise. This is expected to result in severe reductions in snowpack across the Cascade Mountains, by up to 50 to 60% by mid-century.[8]

Figure 2. Average monthly temperature (°F) in the Deschutes Basin for two 11-year periods (2035 to 2045 and 2075 to 2085) as compared to the 30-year period from 1961 to 1990.

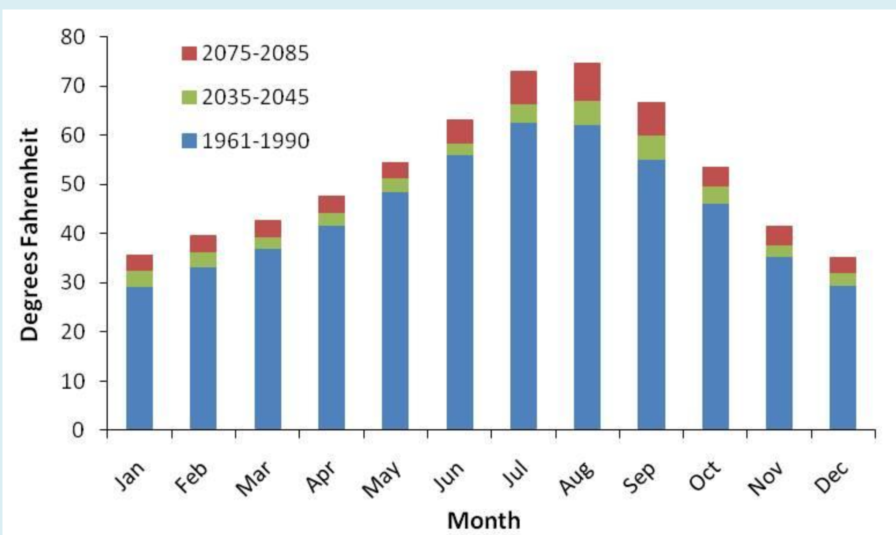


Table 2. Future precipitation (inches) changes in the Deschutes Basin, based on projections from three global climate models (CSIRO, HadCM, and MIROC). Results are presented to show the full range of projections provided by the models as compared to historic averages (1961-1990).

Season	Historic	2035-45	2075-85
Dec – Feb	9.3”	+0.5 to +1.0” (+6 to +10%)	+0.3 to +2.2” (+3 to +24%)
Mar - May	5.3”	-0.5 to -0.3” (-9 to -5 %)	-0.5 to +0.7” (-10 to +13%)
Jun – Aug	2.4”	-0.7 to 0.0” (-29 to 1%)	-1.0 to +0.5” (-42 to +22%)
Sep - Nov	5.8”	-1.3 to 0.0” (-22 to 0%)	-1.0 to +1.7” (-17 to +29%)
Annual	22.8”	-1.8 to +0.1” (-8 to 0%)	-1.7 to +5.1” (-7 to +22%)

Snowpack and precipitation projections illustrate the likely effect on streamflows in the region. Declining snowpack, increasing precipitation in the winter and lesser spring, summer, and fall precipitation over the near-term suggest much higher flows during the winter period. The long-term projection for streamflow is less certain as seasonal precipitation patterns are variable with respect to trend. Winter flows are projected to be greater than they are today and because snowpack is projected to decline, spring, and early summer flows are likely to be lower than current even if precipitation increases during those seasons, though deep groundwater may mediate this response to some degree in some portions of the region, like the high Cascades.[9]

Vegetation change, wildfire, and carbon storage – The USDA Forest Service Pacific Northwest Research Station's MC1 vegetation model project an expansion of conditions suitable for temperate evergreen needleleaf forests (Ponderosa pine forests with lodgepole and Douglas fir as other common species) along the east flank of the Cascades and in the Ochoco Mountains. Conditions suitable for the forests currently found at higher elevations in the region (Maritime evergreen [predominantly Douglas fir and

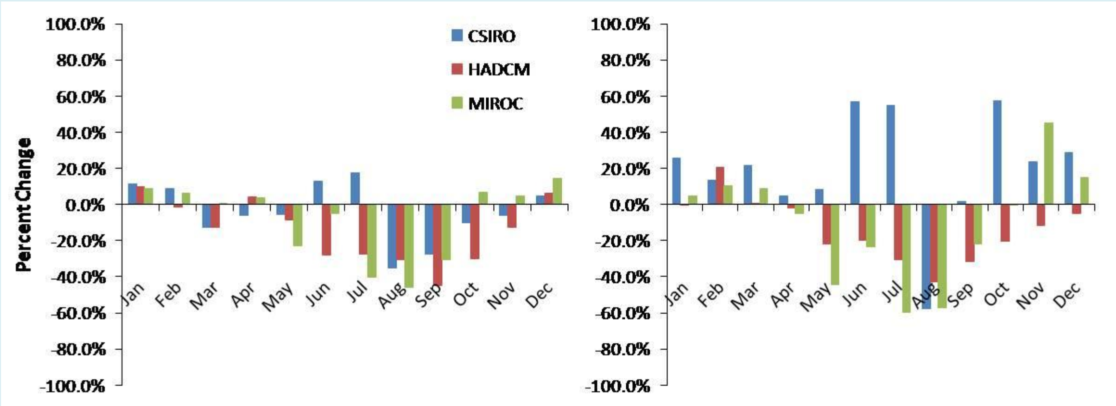


Figure 3. Percent change in average precipitation (inches) by month in the Deschutes Basin for two time periods (2035 to 2.45 and 2.75 to 2.85) as compared to the historical period (1961-1990).

ponderosa pine forests with lodgepole pine] and subalpine forests [mountain hemlock, subalpine fir, silver fir]) are projected to decline.

A climate envelope modeling approach applied to individual tree species projects increased distribution for Douglas fir at high elevations and reduced distribution at lower elevations.[10] Ponderosa pine distribution is projected to be somewhat reduced, especially at lower elevations. White fir distribution is projected to decline in abundance and lodgepole pine, red fir, and western larch are all projected to be absent from the area by late-century.

Both modeling approaches show a change in vegetation, particularly for commercially important species, over the next 100 years.

Despite changed growing conditions, vegetation can take decades or centuries to adjust. Mechanisms promoting vegetation change, particularly at lower elevations, are likely to be fire, invasive species, insects and disease, and possibly seasonal droughts.

The MC1 model projects increases in the average extent of wildfire annually (expressed as the average proportion of each model grid cell burned) from 11 to 16% by 2075 to 2085 compared to the historic period of 1961 to 1990. The model also projects a 38 to 63 % increase in biomass consumed by fire across the Deschutes Basin over the 11-year period from 2075 to 2085. Areas that show increases in biomass consumed by fire include mid- and high-elevation areas along the Cascade and in the Ochoco Mountains.

Two of the three global climate models indicate an increase in carbon storage of roughly 10% by 2075 to 2085. The other model projects a decrease in carbon storage of 20% by late-century.

THE ROLES OF ADAPTATION AND MITIGATION

The impacts outlined in the previous section are expected to increase in severity over Time, and certainly though the next century, depending on emissions. Based on climate modeling results, greenhouse gasses emitted now bind us to 30 to 50 years of increasingly severe impacts.

Two primary approaches to climate change are recognized by climate scientists – adaptation and mitigation. **Adaptation** increases the resilience of communities and resources to near-term climate change impacts. **Mitigation** reduces the long-term severity of climate change by lowering the concentration of greenhouse gases in the atmosphere. Adaptation measures can be effective in the near-term but will ultimately fail without effective mitigation.

"Adaptation" efforts increase the resilience of communities and resources to near-term climate change impacts.

There are many ways that mitigation and adaptation can work together. Restoring floodplains is expected to increase groundwater recharge (adaptation) and allow for the expansion of riparian forests that act as carbon sinks (mitigation).

Adaptation and mitigation efforts can also undermine each other. Adaptation and mitigation strategy development should include explicit goal statements and cross-referencing to identify conflicting (and complementary) approaches.

In addition to integrating climate change mitigation and adaptation, individual strategies for adaptation can be integrated across different sectors. These integrated approaches often result in cost savings and other positive synergies. Using the example from above, restoring floodplains is likely to increase groundwater recharge (benefit to agricultural and domestic water supply) and reduce the risk of flood to vulnerable populations. These same activities can be designed to improve aquatic species habitat and water quality.

To develop strategies that have benefits across many sectors, communication and collaboration is essential. Such collaborations are expected to reduce costs, increase success, and lead to a "team" effort rather than competition for limited funding and resources. Regular communication among such disparate groups as farmers, ranchers, state and federal agencies, Tribes, public health professionals, county planners, social service providers, and land, water, and wildlife managers is vital for developing effective, efficient, and cohesive strategies.

"Mitigation" efforts aim to reduce the long-term severity of climate change by lowering the concentration of greenhouse gases in the atmosphere.

LOCAL VULNERABILITIES, IMPACTS, AND STRATEGIES

Prospective future impacts throughout Jefferson, Deschutes, and Crook Counties will result from the interaction of two components: (1) changes brought on by changing climate conditions, population growth, or other stressors and (2) the vulnerability of local communities, natural resources, and associated systems (e.g., economy, emergency services). With a better understanding of specific changes that can be expected for these counties and the local vulnerabilities, effective strategies to reduce negative impacts can be developed.

The most severe impacts will occur to those individuals and systems that have the greatest **exposure** and **sensitivity** to changing climate conditions and the lowest **adaptive capacity**. Workshop participants used their knowledge of exposure, sensitivity, and adaptive capacity as they relate to local populations, communities, resources, and systems to identify the most compelling risks to the prospective future climate conditions in Central Oregon.

In the later part of the workshop, participants identified the highest ranking risks to changing climate conditions (done through voting by local stakeholders, leaders, and experts), these same individuals identified strategies and specific activities that could be employed to avoid, reduce, or better recover from the impacts likely to result from these risks.

The models used to inform the workshops that lead to this report provide a range of possible future conditions. Actual conditions may differ from those presented here. A precise prediction of future conditions is not necessary to implement sound strategies that reduce local vulnerabilities. All three models used here project drier summers in the region by mid-century. Planning for drier summers is a “no-regrets” strategy because summers are already dry and water supplies are scarce. As the population continues to grow, increased resilience for water supply benefits Central Oregon, regardless of climate change. While climate change may be the impetus for such efforts, the strategies recommended in this report benefit Central Oregon residents, regardless of the precise trajectory of change.

Agriculture, Tourism, Development, and Other Economic Activities

Changing climate conditions pose serious threats, but may provide some opportunities, to agriculture, tourism, and development in Central Oregon. As these are among the most important economic drivers in the area currently, negative impacts to these activities will reverberate throughout the region, affecting local government budgets and the services these governments provide.

Vulnerabilities and Impacts / Opportunities:

Declining snowpack – Reduced snowpack levels and a shorter snowmelt period will affect irrigation (districts that rely on surface water and especially those that lack existing storage reservoirs are particularly vulnerable) and winter recreation (primarily skiing), a major component of the large Central Oregon tourism industry.

Declining surface water availability – Streamflows during late spring, summer, and fall are likely to decline, while demand is likely to increase. This will exacerbate existing competition for water between uses (chiefly irrigation and fisheries with junior water rights holders particularly vulnerable). Moreover, warming temperatures will increase the demand for irrigation water by the agricultural sector and the need for instream flows to improve stream temperatures for salmon and trout. The risks on both sides of this competition are high. Both agriculture and recreational fishing are important components of the regional economy.

Declining community competitiveness – Communities in Central Oregon counties are likely to incur high costs associated with providing sufficient water for domestic and municipal supplies (predominantly ground water in this region) and emergency services responding to more extensive wildfire in wildland urban interface areas and more frequent flooding events (from greater storm intensity). These costs may limit the attractiveness of Central Oregon to industries looking to relocate to the region. Costs for providing domestic and municipal water are already rising and some regions (e.g., Prineville) are currently experiencing groundwater shortages or limitations.

Longer growing seasons / summers – Longer growing seasons, warmer temperatures, and fewer frosts could allow for new agricultural opportunities in the region (e.g., vegetables, fruit). Taking advantage of this opportunity would make Central Oregon agriculture more competitive than it is currently and could also increase local food supplies. Summertime outdoor-related tourism could also increase with warmer temperatures and longer summers.

Stakeholder Recommended Strategies:

Conserve water resources by improving the delivery and application efficiency of irrigation water. County land use planning should reflect patterns of water supply. Technologies and management practices for agricultural and rural water use must be updated and made widely available. Water conservation must start with comprehensive water metering to determine current use patterns by rural and irrigation interests.

Increase ground water recharge with restored wetlands, increased permeability in urban and suburban settings, incorporation of low impact development practices (e.g., bioswales) in developed areas, and increased juniper management in low-elevation woodlands.

Decrease water demand by employing market-based approaches to water resource allocation; this approach would allow for instream leasing and water banking opportunities.

Increase water storage by identifying and pursuing opportunities for off-channel storage, expanding existing storage, and restoring and protecting natural storage areas such as wetlands, meadows, and floodplains. Existing storage may be optimized through coordinated, stakeholder-driven plan development.

Discourage new development in urban-wildland interface and floodplain areas by having residents in these high-risk areas pay a higher proportion of the costs for emergency service protections; this would reduce the costs for providing these services to the rest of the public. Directing new development to areas easily served by existing emergency services could be incentivized through transfer of development rights programs targeted at areas that have high flood and wildfire risk. This could be accomplished with a scaled tax or fee structure using the distance to schooling and emergency service centers.

Develop flexible urban planning to limit stress on government services from potential immigration as climate conditions change in other parts of United States. Flexible urban growth boundaries and growth limitations both require changes in state law but would be useful in addressing rapidly increasing population from immigration to Central Oregon. Housing developments should be explicitly linked to existing or planned infrastructure and services through county or city plans to provide emergency response, proximity to schooling, and efficient transportation networks as communities grow.

Natural Systems

Vulnerabilities and Impacts:
Increasing temperatures and declining water quality – Increasing temperatures and declining summer streamflows will negatively affect native, coldwater aquatic species (e.g., Chinook salmon, steelhead, redband trout, bull trout, amphibians). These species will do poorly in the warm, low dissolved oxygen waters likely to result from the climate change projections.

Summer and fall streamflows are likely to decline (exacerbating water quality concerns listed above). This will increase competition for water between uses (e.g., irrigation and fisheries) and potentially ignite conflict in the region. If population in the region increases, the pressure to deliver greater amounts of water for domestic and municipal water will increase.

Invading, non-native species – Warmer water temperatures and less stable aquatic environments favor non-native, invasive aquatic animals such as zebra mussels, fish diseases, and exotic aquatic predator species found in adjacent river systems. If these species gain a foothold in the Deschutes River system, they could have a dramatic, negative impact on native fish and wildlife populations. Several areas may be less vulnerable to these impacts due to their naturally cool temperatures (e.g., Metolius River, portions of McKay and Whychus Creeks).

Existing and potentially new invasive plant species are expected to quickly colonize habitats as wildfire, off-road vehicle use, grazing, and insect and disease outbreaks occur and native species shift to suitable habitats. Invasive species like medusahead, Mediterranean sage, and cheat grass (among others) are likely to become dominant.

Reduced habitat connectivity – Aquatic habitat connectivity in the Deschutes River Basin is compromised. The likelihood of decreasing stream flows will further reduce this essential habitat element for the migrating native fishes of the area.

Habitat fragmentation – Greater incidence of natural disturbances (e.g., wildfire, insect and disease outbreaks), development, and recreation associated with growing population will further fragment wildlife habitats. Forest, woodland, and shrub steppe habitat fragmentation will affect high elevation species, sensitive species like sage grouse, and wide ranging mammals like elk, pronghorn, and black bear.

Species relationships – Relationships among plants, animals, and environmental conditions may be disrupted. The timing of plant flowering and fruiting, insect emergence, and plankton blooms are all likely to shift to earlier in the year. Migrating fish, birds, and mammals may arrive at the wrong time to take advantage of peak food abundances or appropriate environmental conditions (e.g., water temperature). The disruption of interdependent predator-prey or plant-pollinator life cycles may lead to declining populations of native species.

Stakeholder Recommended Strategies:

Protect and restore key aquatic areas to improve water quality (particularly sedimentation) and provide high quality habitat at all streamflow conditions. Protection and restoration should include flow (hydrology), streamside / wetland vegetation, and in-channel and near channel features like floodplains, debris jams, and pools as well as larger scale features like stream sinuosity. Activities to achieve these objectives include identifying reaches, establishing easements along floodplains and performing physical restoration / precluding development, and re-establishing beaver populations. Particularly important areas include Wychus Creek, McKay Creek, Little Deschutes River, upper and mid-Deschutes River, mid-Crooked River, headwater wetlands, and cold springs.

Conserve water resources and apply saved water to instream uses. Water conservation includes improving the delivery and application efficiency of irrigation water and reducing municipal water use for landscape purposes. Water conservation must start with comprehensive water metering to determine current use patterns in the region. The best way to achieve comprehensive water planning would be to integrate the entities that have water demands (e.g., establishing a flexible framework to manage water stored at Bowman dam on the Crooked River where the pains of dry years is shared between agricultural users, municipal users, and instream interests). Greater instream flows, particularly in late summer and early fall, will improve water quality and increase aquatic habitat connectivity for migrating fish.

Increase water storage by identifying and pursuing opportunities for off-channel storage, expanding existing storage, and restoring and protecting natural storage areas such as wetlands, meadows, and floodplains. Existing water storage may be optimized through coordinated, stakeholder-driven plan development.

Initiate conservation-minded land use planning to incorporate potential risks to habitats from changing climate conditions into community, economic development, and conservation (including transportation, agriculture, and forest / resource management). Planning efforts must cross ownership / management boundaries and include updates to current plans (e.g., county comprehensive plans, city plans, ODFW conservation strategy, Oregon Explorer, Greenprint, Fire Learning Network).

Restore historic range of forest habitat conditions and plant communities to forests, woodlands, and grasslands by restoring and mimicking natural disturbance patterns. This can be accomplished by thinning, controlled burns, and other vegetation management techniques that return native plants to their former abundance and age structures within their habitat types. Numerous healthy plant communities across the region provide the greatest opportunity for alternate species relationships to develop, potentially sustaining "timing sensitive" species.

Forests, Wildfire, and Public Health

The communities of Central Oregon are surrounded by forests. These forests are important to the regional economy and identity, and changing climate conditions increase their susceptibility to a variety of disturbances.

Vulnerabilities and Impacts:

Declining forest resiliency – Forest and sage steppe resiliency is already compromised from past decades of fire suppression and past vegetation management practices. This is particularly true of ponderosa pine forests, dry mixed conifer forests, and sage steppe habitats that have been colonized by western juniper. These forested areas will have difficulty adapting to changes in temperature, precipitation, and soil moisture patterns as shifts occur and these changes will further reduce resiliency in these wildlands.

Demand for emergency services – Wildfires near the wildland urban interface pose a substantial risk to communities, create the demand for substantial amounts of emergency services, and have the potential to take human lives.

Declining air quality and increased respiratory illness – Increasing wildfire potential is likely to affect air quality in Central Oregon. This will cause greater concentrations of airborne particulates in a region that currently has few air quality issues. High concentration of particulates in the air has been shown to lead to higher incidence of respiratory illness.

Increases in invading, non-native species –Existing and potentially new invasive plant species are expected to quickly colonize habitats as wildfire, off-road vehicle use, grazing, and insect and disease outbreaks occur. Invasive species like medusahead, Mediterranean sage, and cheat grass (among others) are likely to become dominant.

Increased incidence of forest pests –Forest pests (e.g., pine bark beetles, moths, pathogens) are likely to increase as trees become stressed by shifting temperatures and precipitation patterns.

Tribal customs – As vegetation shifts, traditional uses of culturally important native plants will be compromised. Many customs, and therefore community identity, are linked to these species, their harvest, and uses. This is likely to impact the diet and lifestyle of Tribal communities.

Stakeholder Recommended Strategies:

Restore historic range of forest habitat conditions and plant communities to forests, woodlands, and grasslands by restoring and mimicking natural disturbance patterns. This can be accomplished by thinning, controlled burns, and other vegetation management techniques that return native plants to their former abundance and age structures within their habitat types. These activities will increase plant vigor and make these habitats and the species residing in them more resilient to climate induced increases in disturbance (e.g., wildfire, disease, and pests).

Protect intact habitats with relatively small populations of invasive species (e.g., large public and Tribal acreages, roadless areas in particular). The most troublesome invading species should be identified and lands assessed to estimate where invasive species problems are most likely to occur. Integrated vegetation management programs (mechanical, biological, and chemical) should be developed to respond to invasions as they occur to prevent being overwhelmed by invaders. These programs should be developed with substantial input from regions that have experience battling these species. The specific issues associated with emerging invasive species must be publicized throughout the region to develop the desire and willingness to pay for the response.

Reduce fuels to limit the extent of high intensity fire and decrease the amount of particulates that are created during wildfires. Fuel reduction can be accomplished through the application of controlled burns, mechanical thinning, and biomass development. While controlled burns have a positive effect on wildlife habitat, they can create air quality impacts (although often at a time where air quality issues are not considered problematic).

Mechanical thinning needs to be planned and implemented carefully to avoid negative effects on wildlife habitat. This activity requires workforce development and stewardship contracting capabilities by land management agencies.

Biomass energy development should be implemented at appropriate scales in high efficiency applications (e.g., both electricity and heat created during the combustion process are used). Biomass fuels should come from thinning done to restore forest stand conditions and plant communities (see above) using forest management criteria already established for the region and to protect wildlands-urban interface to minimize impacts to terrestrial/aquatic habitats and soils.

Infrastructure

To support people's daily lives, safety, travel and participation in Central Oregon's economic and recreational activities, regional governments and service districts provide a variety of infrastructure. Many of them are susceptible to the impacts of a changing climate.

Vulnerabilities and Impacts:
Water supply reliability – Increasing temperatures and the potential for increasing population size in the region will increase demand for domestic water supply. This is particularly true for the summer months, a period surface water availability is likely to be lower than current levels. Existing surface water collection facilities are designed around long winters and prolonged snowmelt. Wetter and rainier winters with lesser snowpack and a shorter snowmelt period will challenge the current domestic water storage facilities in the region. There is likely to be increasing conflict over surface water between municipalities, agriculture, and instream purposes as water rights calls are made and enforced more frequently.

Given the limitations of the existing surface water storage systems and the impending heightened conflict over surface water, there is very likely to be an increasing reliance on groundwater for municipal and domestic water supply. Most towns and communities in Central Oregon already rely heavily on groundwater supplies; these supplies may be compromised as other communities increase groundwater pumping to augment surface water supplies.

Flooding – Generally rainier winters and greater incidence of heavy storm events will increase the number of flooding events along rivers and in urbanized areas in the region. These events will interrupt transportation in many of the region's cities (e.g., there are many underpasses in Bend that will be affected), increase erosion along riverfront agricultural areas, and increase depositions of sediments in slower moving portions of rivers and streams.

Irrigation water delivery – If agricultural crops shift with warmer temperatures and longer growing seasons, irrigation water delivery systems to carry and deliver water to those crops may also need to change. Shifting from pasture and alfalfa to row crops and possibly fruit trees will require dramatic changes in irrigation water delivery.

Stakeholder Recommended Strategies:

Conserve water resources by concentrating development in a manner that minimizes water demand in emerging city and county land use planning. Urban and suburban housing developments and municipal plans should promote xeriscaping over high water use landscaping (e.g., lawns). Rural homeowners should also landscape for low water use. Emerging technologies and management practices for rural and municipal water use must be incentivized and widely available. Water conservation must start with comprehensive water metering to determine current use patterns by municipal and rural users.

Increase water storage and decrease flood risk by restoring and protecting natural water storage areas such as wetlands, meadows, and floodplains, creating off-channel storage facilities, and expanding existing storage. Existing storage operations should be adjusted and optimized through coordinated, stakeholder-driven plan development to better reflect future rain and snowmelt patterns.

Minimize flood-related impacts by restoring wetlands and natural floodplain areas and adopting low impact development techniques (e.g., bioswales) in urban settings. These measures will filter pollutants, trap sediments, and reduce peak flow levels. Culverts and other existing stream restrictions should be systematically inventoried and re-sized for potential future flow levels. Undersized road crossings increase erosion and compromise road use over the short term and road stability over the long term. Municipalities must initiate and implement measures to handle, route, and treat stormwater.

Increase groundwater recharge with restored wetlands, increased landscape permeability, and the use of low impact development practices in urban and suburban settings, and increased juniper management in low-elevation woodlands. Enhancing groundwater recharge reduces flooding risks and sustains higher use of groundwater by communities.

Shift to more efficient irrigation water delivery methods by piping main and lateral canals and increasing use of center pivot, linear, and drip irrigation water application. These changes should occur as crops shift with changing growing conditions.

CHANGES TO GOVERNANCE AND PLANNING

Current local, state, and federal policies and regulations were developed with a stable climate as an underlying assumption. As the challenges of changing conditions emerge, more flexible approaches to governance, decision making, budgeting, and managing will be needed. For example, goals set in Forest Plans on federal lands could become unattainable if conditions change suddenly.

Establishing flexible or adaptive approaches to management is important to meet the challenges of an uncertain future. Changes to planning and governance that allow these approaches should be based on clear, pre-defined decision making processes that are not affected by short-term changes in leadership. Monitoring wildfire conditions could trigger changes to land use policy based on scientifically-determined trigger points. Without clear decision-making processes in place, flexible plans could be used as a political tool rather than an effective management approach.

Increased access to information and stakeholder driven planning was requested by stakeholders. Information on climate change impacts, land use patterns, zoning, water availability and water quality, conservation priority areas and habitats, and etc should be stored in a common location. This information should be shared widely in non-technical language with maps and companion reports. The availability of such information will lead to informed, scientifically-sound land and water management decisions.

Stakeholders expressed a desire to increase collaboration among diverse groups in land management and planning. Pulling together diverse groups to plan where and how land should be managed for specific needs and resources will reduce competition. In particular water issues could be addressed in a collaborative manner to improve groundwater recharge, economic stability of agriculture, efficiency, and natural system resilience. Bringing groups together to tackle tough issues will allow teamwork to replace divisiveness and contention.

Strategies in this report identify a number of policy improvements to address existing barriers to adapting to climate change. These policies should be considered when cities, community service districts, counties, Central Oregon Intergovernmental Council, and agencies are updating their planning documents.

It is clear from the conversations during the workshop that Central Oregon has already made great strides to develop stakeholder-driven alternatives to difficult resource management issues. Moving into a time of uncertain changes, a key to successfully identifying and implementing adaptation activities will be to lean on these experiences and leverage existing relationships to tackle emerging challenges head on.

Table 3. A review of select recommended strategies, their **co-benefits** and *negative effects* across different sectors, and their effect on mitigation efforts.

Recommended strategy	Effect on Natural Systems	Effect on Health and Emergency Preparedness	Effect on Agriculture	Effect on Water Resources and Infrastructure	Effect on Infrastructure and Energy	Effect on Mitigation Efforts
Thin forest ecosystems where ecologically appropriate	Increase forest resiliency and improves wildlife habitat.	Reduce effect of particulates during wildfire limiting pulmonary impacts.		Protect municipal water sources from sediment impacts.	Reduce risk to communities near wildlands. Potential renewable energy source.	Reduce emissions from high severity fire.
Reduce / increase efficiency of water use by communities and agriculture	Allow aquatic and riparian species to retain populations.	Increased instream water quality would limit health impacts from pollutants, reducing surface water treatment costs.	Lead to agricultural crops and practices more tolerant of drought. *Could increase cost of irrigation water.*	Water resources would be more sustainable. *Could increase cost of municipal water.*	Less wear on water infrastructure.	
Protect intact habitats with small populations of invasive species	Increase resilience of native species and ecosystems.	Reduce sprawl into rural areas, which limits emergency response needs.		Higher water quality with sustainably managed uplands.		Intact forests offer high carbon storage opportunities.
Restore and expand wetlands and floodplains	Increase resilience of aquatic and riparian species.	Reduces flood emergency likelihood. Improved water quality would reduce surface water treatment costs.	Increase availability of surface water.	Increase water quality and groundwater infiltration.	Reduce flood impacts on infrastructure.	Wetlands and riparian forests offer high carbon storage opportunities.
Conservation-minded planning	Increase resilience of all ecosystems and species.	Reduces sprawl into risk-prone, which limits emergency response needs.	Opportunities to diversify revenue by using lands for conservation purposes.	Development occurs in places close to available water supplies.	Reduce size of transportation networks and communities' energy demand.	Reduce emissions from electricity generation and motorized transportation.

CONCLUSIONS

Changing climate conditions will stimulate changes in the region's economy, pose risks to human health, transform the rich natural systems of Central Oregon, stress the ability of infrastructure and emergency services to provide for the communities in the area, and impact quality of life. Millions of dollars in costs are likely to accrue if Central Oregon communities do not manage foreseeable risks and prepare for likely changes.[11]

The people and institutions of Central Oregon have the innovation, experience, and capacity necessary to effectively prepare for new risks and changing conditions. Taking steps now to prepare for the likely consequences of the changing climate will help the people, cultures, and ecosystems of the area thrive in the future.

While climate change is projected to cause damage to a variety of systems in the region, it will also create opportunities. As changing conditions provide the impetus for preparation, communities can take the opportunity to increase their self-sufficiency, engage in new enterprises to sustainably revitalize their economy, and develop support networks to better care for vulnerable populations. New industries and agricultural producers can be developed that are more suitable to emerging climate conditions or are more resilient to variability and change.

The strategies and actions described in this report are just a first step in thinking through preparations for responding to changing climate conditions in Central Oregon. Residents of the region should assess these ideas, develop additional strategies and actions, and prioritize them based on likelihood of success, costs, and feasibility. Many of the activities presented here will sound familiar. They have been identified in other planning exercises because they are likely to make populations or resources more resilient. The wide benefits of some of these strategies to multiple resources, systems, or sectors, however, may be surprising. Taking advantage of these co-benefits will help the region save money, increase collaboration and communication among disparate groups, and reduce conflict, save lives, and prevent suffering.

All households, communities, companies, organizations, agencies, and governments in Crook, Deschutes, and Jefferson Counties are encouraged to use the information in this report to develop specific strategies and actions that will build resiliency and resistance to changing climate conditions. While difficult choices will be required, the region has the opportunity to put itself in an advantageous position by preparing early for change. With extensive community involvement, innovative climate preparation planning can be implemented successfully to withstand and take advantage of coming changes, moving Central Oregon toward greater long-term social, economic, and environmental stability.

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