Preparing for a Changing Climate

Washington State's Integrated Climate Response Strategy

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Figures and Tables

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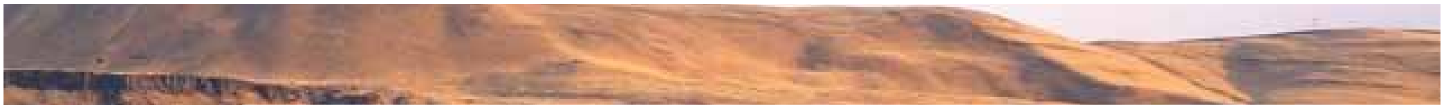
Executive Summary






Executive Summary

Rising levels of carbon dioxide and other heat-trapping gases have warmed the earth and are already causing wide-ranging impacts, from rising sea levels, to melting snow and ice, to more drought and extreme rainfall. Scientists project that these trends will continue and in some cases accelerate, posing significant risks to human health, our forests, agriculture, freshwater supplies, coastlines, and other natural resources that are vital to Washington State's economy, environment, and our way of life.

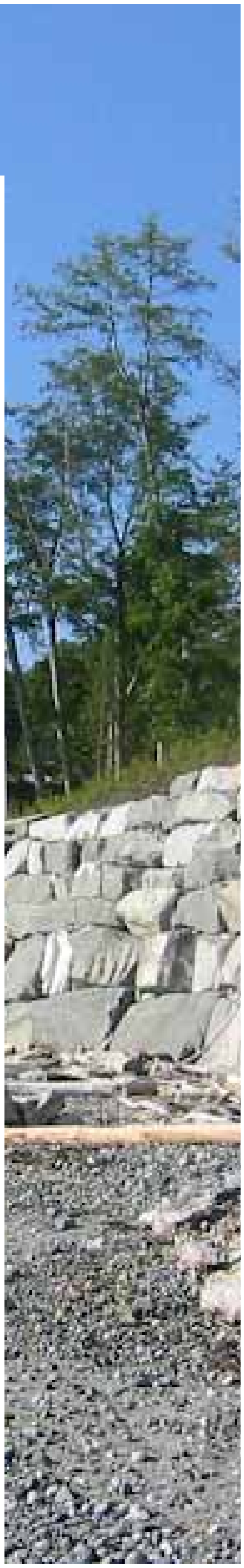
By taking action now to respond and adapt to changing climate conditions, Washington can significantly limit the damage and reduce the long-term costs of the climate-related impacts that are expected to grow in number and intensity in the decades to come. If no action is taken, potential costs to Washington from climate change impacts are projected to reach nearly $10 billion per year by 2020 from increased health costs, storm damage, coastal destruction, rising energy costs, increased wildfires, drought, and other impacts.[1]

The Need for Action

Our state and societies around the globe need to reduce greenhouse gas emissions to avoid worsening climate impacts and reduce the risk of creating changes beyond our ability to respond and adapt. Washington State is addressing this challenge and has adopted policies to reduce energy use, limit greenhouse gas emissions, and build a clean energy economy. Some changes in climate—and impacts on our state—are unavoidable, even if we reduce greenhouse gas emissions today.

This document, ***Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy***, lays out a framework to protect our communities, natural resources, and economy from the impacts of climate change and build our capacity to adapt to expected climate changes. It describes how existing and new state policies and programs can better prepare Washington to respond to the impacts of climate change. It calls on state agencies to make climate adaptation a standard part of agency planning and to make scientific information about climate change impacts readily accessible to decision makers in the public and private sectors. It also recommends that state agencies strengthen existing efforts and build partnerships to help local and tribal governments, private and public organizations, and individuals reduce their vulnerability to climate change impacts.

[1] Climate Leadership Initiative (2010).



Washington's Changing Climate and Risks

While Washingtonians have experience dealing with natural weather variability, climate change is moving us beyond a range where past experience can provide a reliable guide for what we might expect in the future.

- **Climate change could have severe consequences to human health** and will likely increase the number of people exposed to illness and injuries due to declining air quality and more frequent and severe heat waves, drought, wildfires, and flooding.

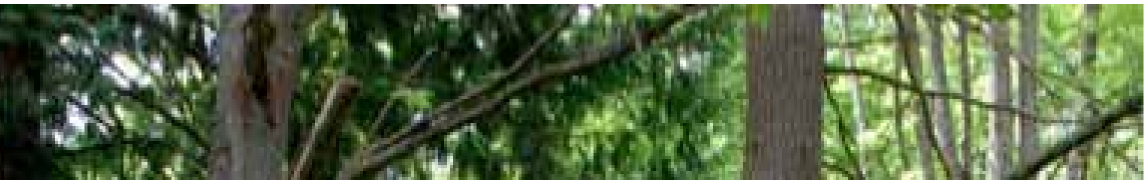
- **Our communities and transportation, energy, and other infrastructure could face increased damage costs and disruptions** from more frequent and severe flooding, wildfires, changes in energy supply and demand, and other climate impacts.

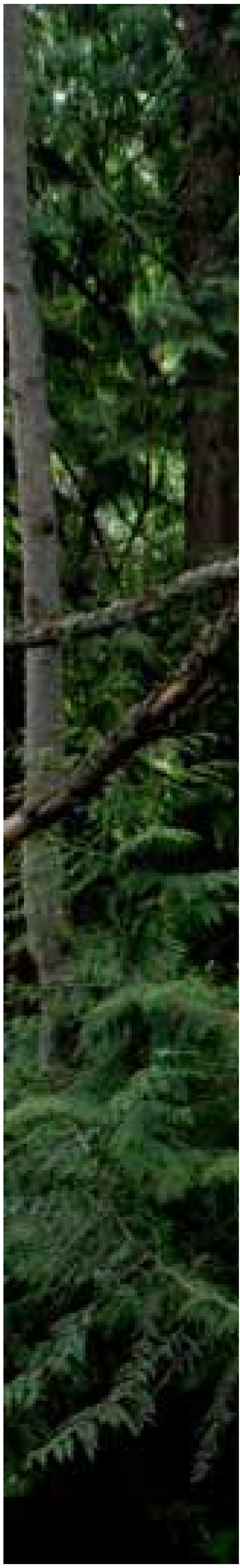
- **Coastal communities and ecosystems could face increased risks from sea level rise and storm surge.** Increasing ocean acidity poses risks to our shellfish industry and could alter the marine food web.

- **The quantity and quality of water available** for communities, irrigation, fish, hydropower generation, recreation, and other uses will be affected by declining snowpack, changes in seasonal streamflow, and increases in summer demand for water.

- **Fish, wildlife, and natural systems** will face increased stress. Climate change will more likely damage and destroy certain types of habitats, increase threats to certain species such as coldwater fish, alter natural patterns such as animal migrations or flower blooms, and alter the presence of pests and invasive species.

- **Washington's farms and forests will be threatened** by increased disease, pests, weeds, and fire, along with reduced summer water supplies. Climate change impacts could affect crop yields and benefit or damage different crops.





To manage the potential risks, safeguard our communities, and protect our assets, we need to understand the vulnerability of natural and human systems, as well as the costs and benefits of action versus inaction, and plan alternatives accordingly.

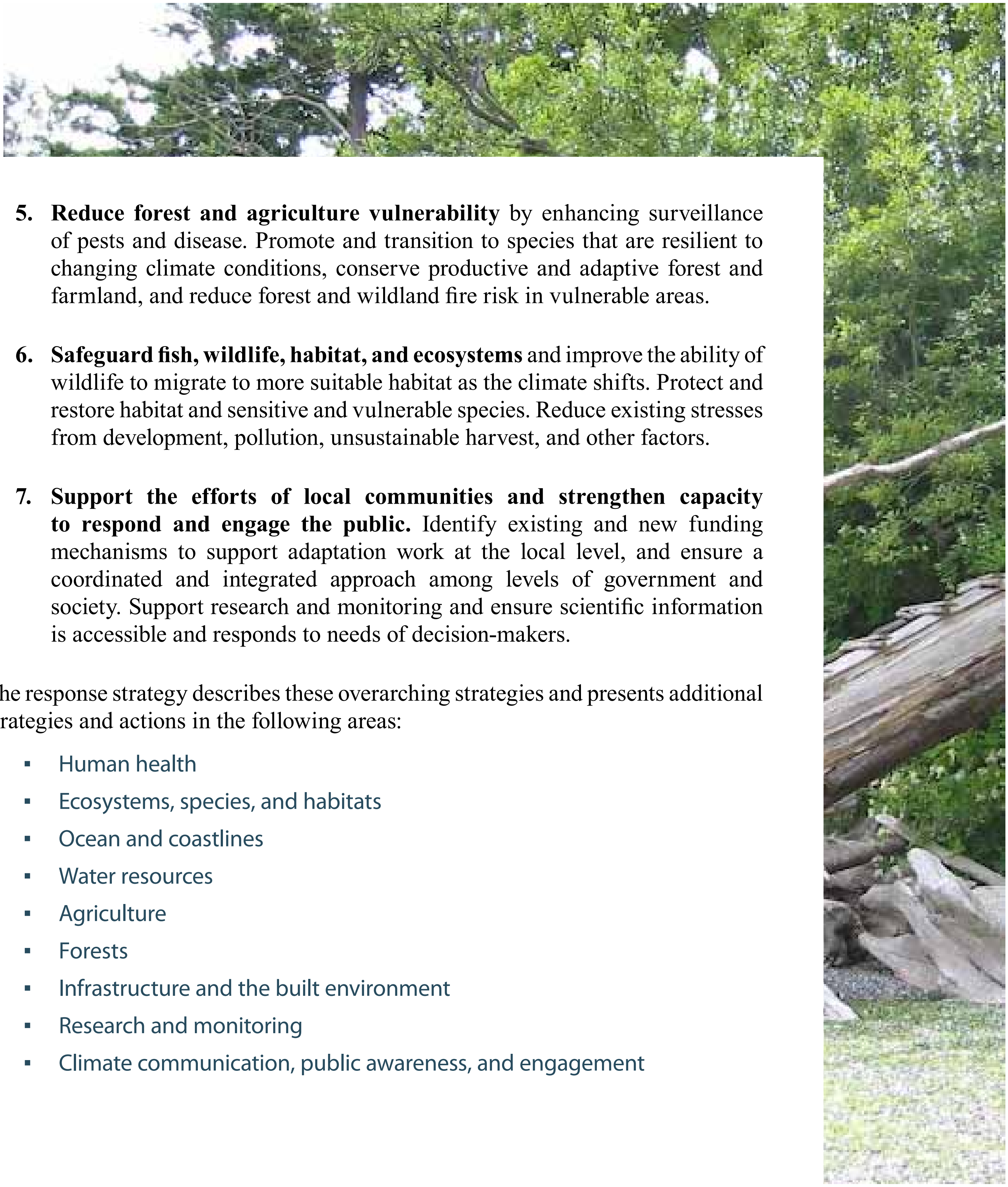
This document identifies seven high-priority, overarching response strategies that can help Washington State adapt to climate change:

1. **Protect people and communities** most vulnerable to climate impacts by increasing state and local public health capacity to monitor, detect, plan, and respond to emerging threats and climate-related emergencies. Also increase awareness of climate risks among the public and health-care providers.

2. **Reduce risk of damage to buildings, transportation systems, and other infrastructure.** Identify vulnerable areas and take proactive steps to reduce risks to infrastructure, avoid climate risks when siting new infrastructure and planning for growth, and enhance capacity to prepare for more frequent and severe flooding, rising sea levels, wildfires, and changes in energy supply and demand.

3. **Reduce risks to ocean and coastlines.** Help communities prepare for rising sea levels and storm surge and protect people and property. Prevent the degradation of habitats and create opportunities for upland habitat creation. Reduce shellfish vulnerability by reducing land-based contributions of carbon and polluted runoff to the marine environment.

4. **Improve water management** by promoting integrated approaches that consider future water supply and address competing water demands for irrigated crops, fish, municipal and domestic water needs, and energy generation. Implement enhanced water conservation and efficiency programs and incorporate climate change realities into agency decision-making.



5. **Reduce forest and agriculture vulnerability** by enhancing surveillance of pests and disease. Promote and transition to species that are resilient to changing climate conditions, conserve productive and adaptive forest and farmland, and reduce forest and wildland fire risk in vulnerable areas.

6. **Safeguard fish, wildlife, habitat, and ecosystems** and improve the ability of wildlife to migrate to more suitable habitat as the climate shifts. Protect and restore habitat and sensitive and vulnerable species. Reduce existing stresses from development, pollution, unsustainable harvest, and other factors.

7. **Support the efforts of local communities and strengthen capacity to respond and engage the public.** Identify existing and new funding mechanisms to support adaptation work at the local level, and ensure a coordinated and integrated approach among levels of government and society. Support research and monitoring and ensure scientific information is accessible and responds to needs of decision-makers.

The response strategy describes these overarching strategies and presents additional strategies and actions in the following areas:

- Human health
- Ecosystems, species, and habitats
- Ocean and coastlines
- Water resources
- Agriculture
- Forests
- Infrastructure and the built environment
- Research and monitoring
- Climate communication, public awareness, and engagement

Moving Forward

This response strategy clearly outlines our path forward to prepare for a changing climate here in Washington State to safeguard the communities, economy, and quality of life that we value—now and for future generations. Implementation of this *Integrated Climate Change Response Strategy* requires the support of state agencies in developing both near-term and long-term actions to move forward and carry out this strategy—in coordination with local governments, federal agencies, tribal governments, research institutions, nongovernmental organizations, businesses, and other stakeholders.

Efforts are already underway in Washington State and across all levels of government and society to address the impacts of climate change. Many options with low or no costs can be implemented today that will significantly improve our prosperity now and in the future. In other cases, the costs of preparing our natural and built environments to cope with the impacts of changing climate will be more substantial. Such costs are far less, however, than costs of inaction.

By taking action now, we can protect Washington's people and natural areas from climate change risks, protect our jobs, ensure our continued economic competitiveness, and help build resilient communities.

1. Introduction

1. Introduction

Rising levels of carbon dioxide and other heat-trapping gases have warmed the earth and are already causing wide-ranging impacts, from rising sea levels to melting snow and ice to more drought and extreme rainfall. Scientists project that these trends will continue and in some cases accelerate, posing significant risks to human health, our forests, agriculture, freshwater supplies, coastlines, and other natural resources that are vital for our economy and the environment.

To avoid significant climate impacts and reduce the risk of creating impacts beyond our ability to respond and adapt, Washington State and societies around the globe need to reduce greenhouse gas emissions. Washington State is addressing this challenge and has adopted a portfolio of policies to reduce energy use, meet statutory greenhouse gas limits, and build a clean energy economy. This approach is summarized in the 2010 report to the Legislature, *Path to a Low-Carbon Economy—An Interim Plan to Address Washington's Greenhouse Gas Emissions*.[2] More work is needed to get the state on track to meet its statutory greenhouse gas limits for 2020 and beyond.

Some changes in climate are unavoidable even if greenhouse gas emissions are reduced. Climate impacts will likely be experienced through incremental changes in temperature and precipitation and through more frequent and destructive disaster events, such as catastrophic floods, wildfires, or coastal storms. In many cases, climate-related impacts will combine with existing stressors to increase harm to people, communities, infrastructure, economic activity, and natural resources. Both incremental changes and catastrophic events will be costly and will have direct implications for the health and welfare of our state. The state can significantly reduce the risks to our communities, economy, and the environment by taking action now to respond and adapt to changing climate conditions.

Guiding principles for Washington's climate change response strategy:

- Use best-available science.
- Build on principles of sustainability.
- Increase our resilience and protect the most vulnerable populations.
- Ensure integrated approaches that maximize mutual benefits and avoid unintended consequences.
- Emphasize collaboration and strengthen partnerships.
- Recognize the impacts of decisions made by other regions and countries.

[2] 2010 Comprehensive Plan, available at http://www.ecy.wa.gov/climatechange/2010CompPlan.htm.

Purpose of Response Strategy

In recognition of Washington's vulnerability to climate change impacts, the Washington State Legislature directed state agencies to develop this **integrated climate change response strategy** to enable state and local agencies, public and private businesses, nongovernmental organizations, and individuals to prepare for, address, and adapt to the impacts of climate change.[3] Governor Gregoire's May 2009 executive order reinforced this requirement, directing the Department of Ecology (Ecology) to collaborate with affected local, state, and federal agencies to develop recommendations, guidelines, and tools to address the impacts of sea level rise and changes in water resources.[4]

This document, *Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy,* satisfies these requirements. It offers recommendations on how existing state policies and programs can better prepare Washington State to respond to the impacts of climate change. It urges state agencies to make adaptation a standard part of agency planning and to make scientific information about climate change impacts accessible to public and private-sector decision makers. It also recommends that state agencies strengthen existing efforts to help local and tribal governments, private and public organizations, and individuals reduce their vulnerability to climate change. The response strategy underscores the need to build strong partnerships to support state, local, and tribal adaptation; coordinate activities across sectors; and engage stakeholders and the public.

Ecology prepared this response strategy in collaboration with the state departments of Agriculture, Commerce, Fish and Wildlife, Health, Natural Resources, and Transportation. A broad range of stakeholders with policy, management, and scientific expertise participated in four advisory groups and developed a set of recommendations for near- and long-term actions to prepare Washington for a changing climate. (See Appendix A for advisory group members and Appendix B for advisory group recommendations.) This response strategy builds on, summarizes, and integrates the recommendations of the four advisory groups. It also draws on the best available science on the impacts of climate change on Washington from the *Washington Climate Change Impacts Assessment* and other key sources, as well as Washington's initial adaptation plan developed in 2008 under Executive Order 07-02.[5]

[3] 2009 legislative mandate set in the State Agency Climate Leadership Act, Senate Bill 5560, codified in RCW 43.21M.010-040.

[4] Executive Order 09-05, http://www.ecy.wa.gov/climatechange/2009EO.htm.

[5] Climate Impacts Group (2009), available at http://cses.washington.edu/cig/res/ia/waccia.shtml#report. Leading the Way: Preparing for the Impacts of Climate Change in Washington, http://www.ecy.wa.gov/pubs/0801008c.pdf.

Response Strategy Outline

Chapter 2 of this response strategy identifies key climate risks and recommends a set of priority strategies to prepare for the impacts of climate change. The chapter outlines steps for agencies to make climate adaptation a standard part of agency planning efforts, programs, services, and operations. It also recommends major policies and programs that state and local governments can use to minimize climate-related risks and build resilience to climate impacts.

Chapter 3 summarizes the observed and projected changes in climate and the key risks for Washington's communities, economy, and the environment.

Chapters 4 through 10 of the response strategy lay out key climate impacts and priority response strategies for seven key sectors:

Chapter 4.	Human Health
Chapter 5.	Ecosystems, Species, and Habitats
Chapter 6.	Ocean and Coastlines
Chapter 7.	Water Resources
Chapter 8.	Agriculture
Chapter 9.	Forests
Chapter 10.	Infrastructure and the Built Environment

Chapters 11 and 12 of the response strategy outline recommendations to advance research and monitoring, raise awareness, engage the public, and build support for meaningful action.

2. Responding to Climate Change

2. Responding to Climate Change

Climate change will affect different regions, ecosystems, and sectors of the state's economy in many different ways, depending on the sensitivity of those systems to climate change, their ability to adapt to changing conditions, and the ability to manage associated risks. While the state and local communities have experience dealing with natural variability, climate change is moving us beyond a range where past experience is a good guide for what we might experience in the future. Climate-influenced conditions and events such as temperatures, sea levels, and storms can no longer be expected to remain within their historical ranges, and these trends are likely to continue well beyond the end of the 21st century.

Our state is already experiencing challenging economic conditions. The risks of not taking action to address climate change impacts now will only compound these economic challenges. In one study, potential costs to Washington from climate change impacts are projected to reach nearly $10 billion per year by 2020 and $16 billion per year by 2040.[6] These totals reflect increased coastal and storm damage costs, increased energy-related costs (reduced hydropower production and increased demand), increased wildfire costs, increased health-related costs, costs associated with reduced water availability, and other impacts.

Key climate-related risks include:

Increased injuries and disease. Increased injuries, sickness, and even deaths are expected from infectious diseases, heat stroke, and respiratory and cardiovascular disease due to higher temperatures, heat waves, declining urban air quality, and smoke from more frequent wildfires. More frequent extreme storms are likely to cause river and coastal flooding, leading to increased injuries and loss of life. These impacts come at a time when local and state funding for public health is rapidly eroding, and health costs are increasing.

Increased damage costs and disruptions to communities, transportation systems, and other infrastructure. Communities, infrastructure, and key economic sectors could all incur significant costs due to climate change. Damage and repair costs are projected to increase for Washington's roads, bridges, ports, rail, power and communication transmission systems, and communities due to extreme storms, flooding, erosion, landslides, sea level rise, and storm surges. Problems have already started. Interstate 5 in Washington's Chehalis Basin has been closed four times since 1990 due to flooding. The December 2007 storm caused approximately $23 million in damage to interstate and state highways in Washington as well as $39 million in damages to city and county roads. The I-5 closure resulted in $47 million in

[6] Climate Leadership Initiative (2010).

lost economic output to the state.[7] In Puget Sound counties, structures valued at approximately $29 billion are located in flood hazard areas, placing them at risk of flood damage. Ports, rail, highways, wastewater treatment plants, and other coastal infrastructure could require costly retrofits or relocation to accommodate rising sea levels and stronger coastal storms.

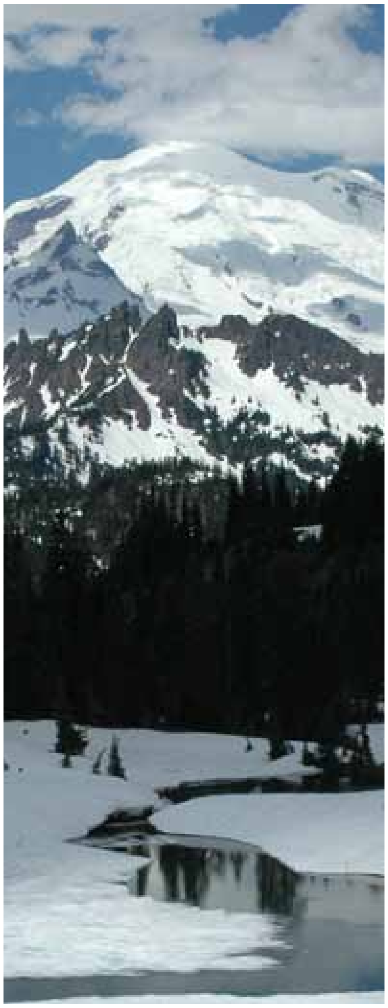
Reduced water supply. Washington's snowpack has historically held more than 6 trillion gallons of water. Increasing temperatures will significantly impact snowpack in the Cascade and Olympic Mountains, leading to reduced streamflows, reduced soil moisture, higher stream temperatures, and concerns for all water users, including agriculture, municipalities, and fish and wildlife. As temperatures rise, water demand increases, as does the potential for conflict among water users. At highest risk are agricultural water users in the Yakima and Columbia basins, along with coldwater fish species such as salmon, steelhead, and bull trout.

Loss of fish, wildlife, and natural systems. Climate change is projected to cause loss of habitat and force many species to move northward or higher in elevation. Species that cannot transition quickly enough will likely perish. Higher summer stream temperatures and reduced flow are projected to increase lethal stream conditions for salmon and other coldwater species. [8]Increased forest fires will destroy important habitat areas, leading to erosion and degraded water quality. Sea level rise is projected to eliminate valuable coastal habitats, and increased acidity in marine waters from carbon dioxide emissions and upland runoff is threatening the aquaculture and shellfish industry. Washington leads the country in production of farmed clams, oysters, and mussels with an annual value of over $107 million.[9] Wildlife recreation in Washington is a $4.5 billion industry responsible for more than 60,000 jobs in the state.[10]

Losses to agriculture and forest industries. Agriculture and forestry industries together contribute $50 billion annually to the state's economy. Increased disease, pests, weeds, and fire, along with reduced summer water supplies, are already affecting Washington's farms and forests. Many operations are experiencing higher costs and lower yields. Pests such as mountain pine beetle, potato tuber moths, and gypsy moths can now proliferate in Washington under warmer conditions. The area burned each year by forest fires in the Columbia River Basin is projected to double or triple by the 2080s. The average production of apples and cherries could decline by approximately $23 million per year by 2020.[11]

[7] Washington State Department of Transportation (2008a and 2008b).
[8] Mantua *et al*. (2010).
[9] Northern Economics, Inc. (2010).
[10] Washington Department of Fish and Wildlife (2011).
[11] Stöckle *et al*. (2010).

Priority Response Strategies



We know enough about future climate to understand the major risks, and many actions can be implemented now, at minimal budgetary cost, to reduce current risks and greatly reduce the need for costly actions in the future. Flexible approaches are needed that respond to risks and also recognize the range of the timing and degree of change as well as how people, wildlife, plants, and other systems will respond to these changes. In many cases, our existing laws and policies are the right vehicles for addressing the climate challenge with minor adjustments. In other cases, new policies will be necessary.

Responding to climate change impacts is typically referred to as “adaptation.” Adaptation refers to taking steps to reduce the vulnerability of human and natural systems, increase the capacity to withstand or cope with changes in climate, and transform the system so that it is more compatible with likely future conditions. Many adaptation strategies are considered “no regrets” strategies because they help address existing stresses on our communities, economy, and environment from flooding, pests and diseases, wildfires, water shortages, and other variables while also reducing climate-related risks. “No regrets” climate adaptation actions can help advance priority goals that are beneficial to Washington State, including sustainable growth, public health, and economic competitiveness.

Seven overarching high-priority climate change response strategies identified for Washington are:

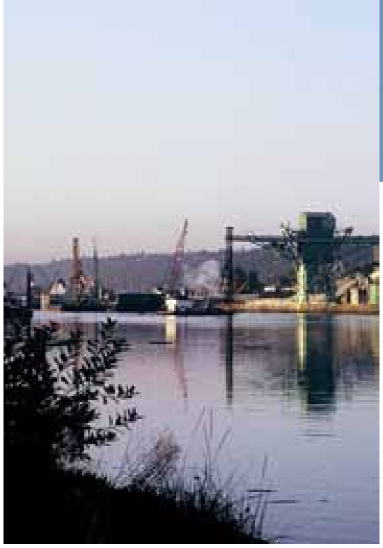
- Protect people and communities.
- Reduce risk of damage to buildings, transportation systems, and other infrastructure.
- Reduce forest and agriculture vulnerability.
- Improve water management.
- Safeguard fish, wildlife, habitat, and ecosystems.
- Reduce risks to ocean and coastlines.
- Support the efforts of local communities and strengthen capacity to respond and engage the public.

The following section describes these strategies in more detail. (See Appendix C for a complete list of strategies and actions.)

1. Protect people and communities from climate change impacts.

Enhance core public health capacity. Core public health capacity will need to be enhanced to increase surveillance, early detection, and response capabilities. Public health agencies should prepare to monitor and respond to diseases and carriers typically found in warmer climates, such as Rocky Mountain spotted fever, tularemia, and Lyme disease. Vulnerable and at-risk communities should be identified, especially for infectious diseases, heat stroke, and respiratory and cardiovascular disease caused by higher temperatures, heat waves, and smoke from more frequent wildfires. Public health agencies should raise awareness of new public health risks from climate change among health providers, health organizations, and the public.

Enhance emergency response capacity to address increasingly extreme floods and fires. State and local emergency response needs are expected to increase in flood- and fire-prone areas of the state. Police, fire and rescue, and wildland firefighting will have to prepare for increased activity, more challenging conditions, and additional costs. Populations that are vulnerable to increased incidence of floods and fires should be identified and educated about the increased risks, options to reduce risks, and appropriate responses in an emergency.



2. Reduce risk of damage to buildings, transportation systems, and other infrastructure.

Reduce flood damage by restoring floodplains and capturing more water. As extreme storms increase, the most effective and least costly approach to managing larger floodwaters is often to enhance floodplains' ability to accommodate flood flows and using "green infrastructure" approaches to manage stormwater. Reconnecting rivers with their floodplains and providing rivers room to flow often reduces downstream flood risks and damage. Natural approaches such as wetlands and soft armoring tend to be more environmentally beneficial than levees, dams, and other "hard" approaches to flood management.

Support local efforts to prepare for coastal flooding and storm surges. Provide information, guidelines, and technical support to coastal counties, cities, and tribes to help them evaluate the risks and vulnerability to sea level rise and coastal flooding in their communities. Roads, bridges, wastewater treatment plants, sewer and stormwater systems, gas and electric transmission systems, communication systems, and other infrastructure could be at risk. Communities should consider options to reduce vulnerabilities without harming ecosystem functions.

Consider climate change impacts when siting new development and infrastructure. Consider future climate change risks when planning for new growth or permitting new structures, even if the location is not currently in FEMA's regulatory floodplain or other critical areas designation. Ensure the building design can accommodate projected impacts and does not increase risks for neighbors.

Plan for relocation if structures are damaged by floods or other impacts. If critical structures are at risk, communities should begin now to identify safer alternative locations for those structures. This will help prevent the typical response to rebuild structures in the same flood-prone location after the disaster.

3. Reduce forest and agriculture vulnerability to climate change impacts.

Enhance surveillance and eradication of pests and disease. Pests and disease can cause significant damage and economic losses, and these problems are projected to increase as the climate warms. Surveillance can identify new outbreaks and promote rapid response that will reduce damage and costs. These efforts should be coordinated among federal, state, tribal, and local agencies.

Promote identification of and transition to plant species that are resilient to new climate conditions. Support research and promote genetic diversity to ensure that agricultural and forest species living in Washington are able to survive under current and future climate conditions and emerging pests and diseases.

Conserve productive and adaptive farmland and forests. Encourage local governments to adopt land use regulations and incentives to minimize conversion of farmland and forests and to support land conservation incentive programs.

Reduce forest and wildland fire risk in highly vulnerable areas. Integrate wildfire management objectives with forest, shrub-steppe and grassland restoration objectives to enhance ecosystem health and resilience from pests, diseases, and invasive species that exacerbate fire risk.

4. Improve water management to address climate-related supply reductions.

Promote integrated water management in vulnerable basins. Projected changes in streamflow and runoff patterns will more likely increase the competition and conflicts among water users. Integrated water management will address existing and future water resources and ecosystem problems affecting fish habitat and agriculture, municipal, and domestic water supplies. This approach supports flexibility and adaptability under changing hydrological conditions. Models for this work include the water management efforts in the Columbia, Yakima, and Walla Walla basins.

Implement enhanced water conservation and efficiency programs. Reduce water demand, especially in water-limited basins, by monitoring water use and aggressively promoting and supporting water conservation and efficiency for agricultural, municipal, and industrial users.

Ensure sufficient cold water in salmon-bearing streams during critical seasons. Increasing stream temperatures can create barriers to migration and can kill coldwater fish such as salmon, steelhead, and bull trout. Shade, increased streamflow, and other measures can keep water temperatures cool and allow rivers to continue supporting coldwater fisheries.

Incorporate climate change realities into agency decision-making. Past hydrological data are an unreliable guide to project future conditions for water management decisions. Water resources managers will need to adapt their management and planning practice to reflect changing water availability. They need to take into account the change in timing and availability of water when planning for additional supplies, deciding whether water users may use their water rights for the amount allowed, and establishing instream flows for fish habitat and ecological purposes.

5. Safeguard fish and wildlife and protect critical ecosystem services that support human and natural systems.

Protect and restore habitat and improve the ability of species to migrate to more suitable habitat as the climate shifts. Identify and protect areas most suitable for current and future habitat as well as the connections between habitats. Land use planning policies, guidance, technical assistance, and incentive programs are effective ways for protecting, restoring, and acquiring habitat areas that provide refuge to species under stress from climate change.

Protect sensitive and vulnerable species and their habitats. Climate change will increase the stress on salmon and other culturally important species that are already sensitive or vulnerable. Climate risks and approaches to recover and protect vulnerable species should be incorporated into management and conservation plans and programs. This planning includes species recovery and management plans, water resources management plans, shoreline management plans, land use plans, and ocean management plans.

Reduce existing stresses on fish, wildlife, plants, and ecosystems. Fish, wildlife, plants, and ecosystems already face an array of existing stresses from human development, habitat loss and degradation, pollution, unsustainable harvest, and invasive species. Reducing existing threats is an important and effective way to help natural systems cope with the additional pressures from a changing climate. For example, reducing stormwater pollution improves water quality and aquatic habitat, increasing the resilience of aquatic species to additional stresses from climate change.

6. Reduce the vulnerability of coastal communities, habitat, and species.

Protect people, property, and infrastructure from coastal hazards and avoid new development in highly vulnerable areas. Rising sea levels, more extreme rainfall, and excessive runoff may increase risks to people, property, and infrastructure from coastal erosion and flooding. Communities should identify vulnerable areas and take steps to reduce threats, while also prioritizing actions that protect habitat and natural areas. Risks to coastal communities should be incorporated into land use and shoreline management plans, and regulatory tools, incentives, and technical assistance should be expanded or developed to incorporate climate risks.

Prevent coastal habitat degradation and destruction and seek opportunities for upland habitat creation as sea levels rise. Rising sea levels will cause a loss of valuable coastal habitats. As coastal flood risk increases, landowners should use natural approaches to reduce flood risks without harming species or habitat. Policies and incentives should be developed at the state or local level to reduce habitat degradation and destruction from hard armoring of coastlines. Incentives and regulatory tools should be modified or developed to guide development away from hazardous coastal areas to prevent costly flooding and to allow coastal ecosystems to be created in newly inundated areas.

Reduce shellfish vulnerability to ocean acidification by reducing land-based contributions of carbon and polluted runoff to the marine environment. Acidification is caused by both atmospheric carbon dioxide and land-based contributions of carbon from sources such as polluted runoff and leaking septic systems. While atmospheric carbon dioxide contributions can only be slowed by reducing carbon emissions, the pace of acidification in some parts of Puget Sound can be reduced by eliminating polluted runoff, leaking septic systems, and other sources of land-based carbon in the waters.

7. Support the efforts of local communities and strengthen capacity to respond and engage the public.

Identify existing and new funding mechanisms to support adaptation work at the local level. In some cases, climate adaptation can be integrated into existing programs with little or no cost or additional resources. In many cases, the cost of making changes and actively managing natural and built environments to cope with the impacts of changing climate may be substantial. However, these costs are far less than costs of inaction. State agencies should leverage existing federal and state funding as well as seek new sources of funding to implement high-priority adaptation projects at the state and local levels.

Develop an institutional structure to improve coordination and support an integrated approach. Successful climate change adaptation cannot be accomplished by a single agency or organization. An effective structure is needed to support cross-agency collaboration, ensure implementation of cross-cutting strategies, and link efforts across all governmental agencies, nongovernmental organizations, and other interests. An improved coordination mechanism is needed to determine and provide state input on research needs and priorities, develop mechanisms to track and monitor progress in implementing the strategies and actions, and ensure new information on climate impacts and effective responses is integrated.

Support information-gathering on climate impacts and ensure scientific information is easily accessible. Understanding of climate impacts and responses is growing rapidly and is continually being expanded. Tracking climate-related trends such as sea level rise, severe storms, and pest and disease invasions can help the state prepare and respond with the least cost and disruption. Tools need to be developed to make this information accessible and useful to the public and to decision makers at all levels.

Engage the public in determining appropriate responses to climate change. The state must provide leadership to ensure that communities, businesses, schools, and the public have accurate information and a forum to consider climate impacts and responses. Agencies should develop consistent messages, provide access to relevant information, and work with partners, stakeholders, and others to identify concerns and prioritize responses.

State Agency Climate Adaptation Planning

State government has an important role in responding to climate impacts. The Washington State Legislature mandated state agencies to lead by example in planning for and responding to the impacts of climate change:

> *State agencies shall strive to incorporate adaptation plans of action as priority activities when planning or designing agency policies and programs. Agencies shall consider: The integrated climate change response strategy when designing, planning, and funding infrastructure projects; and incorporating natural resource adaptation actions and alternative energy sources when designing and planning infrastructure projects.*[12]

This climate change response strategy establishes a framework for state action. The actions identified are broad and do not address who, when, and where to implement actions. Action plans with near- and long-term steps to implement the strategies and the broad actions should be developed by various lead agencies. In many cases, the advisory group reports identify more specific near-term actions that could be included in future action plans.

To advance the goals in the response strategy, the Department of Ecology should work with other key agencies to implement the response strategy and ensure that adaptation is integrated into agency policies, programs, and funding programs. Guidelines and information are needed to:

1. Educate agency leadership and staff on climate impacts and assess how climate change will affect their operations, services, and critical assets managed or owned by the agency, such as highways, forests, agricultural and habitat lands, water resources, and buildings.

2. Evaluate agency operations and programs, including existing enabling legislation, through a "climate lens," to determine what activities need to be adjusted to take into account climate variability and changes. This evaluation should consider such questions as the following:
   - *Is the policy, program, or investment sensitive to current and future changes in climate, such as observed or projected temperature, precipitation, streamflow, sea level, storms, or water quality?*
   - *Will climate impacts alter the effectiveness of the existing plan, policy, program, or project?*
   - *What is the level of risk and vulnerability to climate impacts?*
   - *Are adjustments or modifications needed to account for climate impacts and to help achieve the intended objectives?*

[12] Codified in RCW 43.21M.040.

3. Incorporate climate impacts and response into programs or projects managed by local governments and organizations that receive funding or are regulated by state government, and build local capacity to address climate change.

4. Develop a plan for near- and long-term actions to implement this response strategy.

Barriers Limiting an Effective Response to Climate Change

1. Inadequate information and experience.

- Outdated assumptions that future conditions will vary within historic bounds.
- Limited knowledge and experience in dealing with climate-related risks.
- Limited knowledge of effective response strategies.
- Lack of tools, maps, and guidance for communities to identify risks, assess vulnerability, and account for ranges of variability.
- Limited stakeholder awareness and engagement.

2. Inadequate institutional support for adaptation.

- Short-term perspectives and tendency to focus on near-term risks and benefits.
- Conflicting mandates and incentives.
- Fragmented decision-making and lack of coordination across levels of government and between governments.
- Legal barriers.

3. Lack of resources.

- Insufficient financial resources.
- Lack of human resources.
- Limited information on costs and benefits of climate change response strategies.

4. Public beliefs and attitudes.

- Skepticism about the science of climate change.
- Lack of understanding of the difference between weather and climate.
- Climate science is sometimes described in abstract technical terms that do not resonate.
- Lack of awareness of the near- and long-term risks of climate change and the benefits of acting.

Current Legal Framework for Climate Change Adaptation

We have a broad set of state, local, and federal laws that may be used to reduce risks of climate change on natural and human systems. This section highlights current statutory programs that can provide policymakers a solid foundation to address and reduce the impacts of climate change, though it is not a complete list.

State Comprehensive Emergency Management Plan and the State Hazard Mitigation Plan. RCW 38.52 requires that each political subdivision has a comprehensive emergency management plan that is based on the hazards the community faces. These plans are reviewed at the local level and updated at least every four years. Each of the plans is submitted to the state emergency management division for review to ensure consistency with the State Comprehensive Emergency Management Plan (CEMP). The CEMP, along with the State Hazard Mitigation Plan and its foundation document, the Hazard Inventory and Vulnerability Analysis, are the right vehicles to integrate and address climate risks and hazards.

Growth Management Act. The Growth Management Act's (GMA) policy foundation to control sprawl, protect our infrastructure investments, and conserve and protect our natural environment makes it central to planning for and reducing climate change impacts. Under the GMA, every county, city, and town is required to protect critical areas, including critical aquifer recharge areas, fish and wildlife habitat conservation areas, frequently flooded areas, geologically hazardous areas, and wetlands. Many local jurisdictions have been implementing a range of policies, programs, and regulations aimed at slowing down the impact of climate change on their communities.

Shoreline Management Act and Shoreline Master Programs. The Shoreline Management Act focuses on three basic policy areas: shoreline use, environmental protection, and public access. Local governments and Ecology work in partnership to develop Shoreline Master Programs for managing shorelines and help protect and restore important habitats, keep water clean, protect properties, and provide recreational opportunities to Washingtonians. This program continues to evaluate options to plan for storm surge, coastal flooding, and sea level rise. In 2010, Ecology released voluntary guidance for local governments on how to incorporate sea level rise into Shoreline Master Program updates.

Federal climate adaptation initiatives

In 2009, the Obama Administration convened the Interagency Climate Change Adaptation Task Force to develop recommendations on how federal policies, programs, and planning efforts can better prepare the United States for climate change. The Task Force released a set of recommended actions in support of a national climate change adaptation strategy in 2010, and federal agencies are currently working to implement several cross-cutting national strategies:

- National Action Plan for managing freshwater resources in a changing climate.
- National Ocean Policy Implementation Plan, which includes a series of actions to address resiliency and adaptation to climate change and ocean acidification.
- National Fish, Wildlife & Plants Climate Adaptation Strategy.

More information on federal implementation of the national adaptation strategy is available from:
www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation/evolving-components

Federal agencies are also developing agency-specific plans to strengthen existing adaptation efforts and establish long-term priorities to respond to the challenges and opportunities that climate change poses to their missions, operations, and programs. By June 2012, under Executive Order 13514, agencies will submit their climate adaptation plans to the White House Council on Environmental Quality and the Office of Management and Budget.

For more information, see the Agency Climate Change Adaptation Planning section on CEQ's website:
www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation

For more information and background on the U.S. response to climate change, see the America's Climate Choices reports developed by the National Academy of Sciences:
http://nas-sites.org/americasclimatechoices/

Coastal Zone Management Act. The Coastal Zone Management program is a voluntary state/federal partnership that encourages states to adopt their own management programs to meet the federal goals of protection, restoration, and appropriate development of coastal zone resources. Through the Department of Ecology, Washington State participates in the nationwide Coastal Zone Management (CZM) Program. Washington's CZM Program strives to preserve and protect coastal resources in the state. It sets up estuarine reserves that are jointly managed by the state and federal governments.

Watershed Planning Act. In 1998, the Washington State Legislature enacted a statewide Watershed Planning Program to encourage comprehensive, long-range water resource planning through voluntary collaborative efforts at the watershed level. Because of its statewide scope, high levels of support and participation, and its collaborative nature, the watershed planning program presents a useful vehicle for adaptation to impacts of climate change. Several of the planning groups have discussed the potential impacts of climate variability and change, and some have included these impacts in the technical assessments required for each watershed.

State Environmental Policy Act. The State Environmental Policy Act (SEPA) is intended to ensure that environmental factors are considered during decision-making by state and local agencies to encourage the development of environmentally sound proposals. SEPA requires the identification and evaluation of probable impacts for all elements of the environment and the development of mitigation measures that will reduce adverse environmental impacts.

Floodplain Management Act. The Floodplain Management Act requires the State to plan and prepare for flood hazards to improve public safety and prevent damages to property and infrastructure. Ecology partners with local governments to implement the act.

Clean Water Act and Water Pollution Act. The federal Clean Water Act requires the State to identify sources of pollution in waters that fail to meet state water quality standards (e.g., temperature) and to develop water quality improvement reports (including Total Maximum Daily Loads, or TMDLs) to address those pollutants. TMDLs establish limits on pollutants that can be discharged to the water body and still allow state standards to be met. Washington already has a significant number of water bodies, marine sediments, and groundwater polluted by an array of

pollutants. Regulatory tools—including water quality standards, National Pollution Discharge Elimination System (NPDES) permits, and section 401 water quality certification—as well as non-regulatory tools (such as Water Quality Financial Assistance) exist to clean up polluted waters, control stormwater pollution, prevent point source water pollution, and reduce nonpoint source water pollution.

Forest Insect and Disease Control Act (RCW 76.06). The law's primary goal is to expand and improve forest health problem detection, distribution of information and technical assistance to landowners, as well as coordination between all landowners. The law offers consultation regarding sources of risk to landowners such as insect infestations, diseases, tree overcrowding, and weather damage. The Department of Natural Resources (DNR) is responsible for implementation of the law. DNR monitors forest health to record the extent of insect and disease damage and gain advanced warning of outbreaks by certain pests.

Water resources laws. Several state water laws and programs are aimed at improving water management by seeking out new water supplies for both instream and out-of-stream uses; funding and incentivizing conservation, water use efficiency, reclaimed water, and shallow aquifer recharge; and enhancing water resources data and information.

Laws providing incentives. Several state and federal laws and programs are dedicated to ensuring protection for our state's forests, farmland, and aquatic resources; acquiring land to protect wildlife and ecosystems; and providing incentives for private landowner conservation. Specific examples include but not limited to the following:

- Washington Wildlife and Recreation Program
- Estuary Salmon Restoration Program
- Conservation Reserve Program
- Conservation Reserve Enhancement Program
- Forest Legacy Program
- Farmland Preservation Program
- Wetland Reserve Program
- Grassland Reserve Program

3. Observed Trends and Future Projections

3. Observed Trends and Future Projections

Climate change is pushing temperature and many climate-influenced conditions and events beyond their historical ranges. In Washington State, we are already experiencing trends that are consistent with a warming climate, from warmer temperatures to rising sea levels to melting snow and ice to more drought and extreme rainfall. (See Appendix D for a summary of Pacific Northwest climate change impacts.) Scientists project that these trends will continue and in some cases accelerate, posing significant risks to human health, our forests, agriculture, freshwater supplies, coastlines, and other natural resources that are vital for our economy and the environment.

Nine key indicators and projections of climate change affecting Washington State are discussed in more detail below:

- Increasing carbon dioxide levels.
- Warmer air temperatures.
- Drier summers and reduced snowfall.
- More frequent and severe extreme weather events.
- Rising sea levels.
- More acidic marine waters.
- Warmer water temperatures.
- Increasing frequency and severity of wildfires.
- Increasing frequency and severity of flooding.

Scientific projections of future climate in the Pacific Northwest

The Washington Climate Change Impacts Assessment reported scientific projections of future climate for the Pacific Northwest and assessed the potential consequences for eight key ecological and economic sectors. The assessment projects future climate for the Pacific Northwest using two scenarios of future greenhouse gas (GHG) emissions.

The scenarios provide plausible examples of what might happen given different assumptions about future technology, population growth, economic development, and other factors affecting greenhouse gas emissions. Scenarios can help us understand the likely range of future impacts and our vulnerability to climate change.

The **"A1B"** scenario represents a moderate GHG emissions scenario where global GHG emissions rise sharply until mid-century and slowly decline to the end of the century.

The **"B1"** scenario reflects a low emissions scenario where global GHG emissions rise slowly until mid-century and more rapidly decline to the end of the century.

GHG emissions are currently rising faster than what is projected in the A1B or B1 scenarios. This suggests that if current trends continue, climate impacts could be more severe than what is projected for the two scenarios.

http://cses.washington.edu/cig/res/ia/waccia.shtml#report

1 Increasing carbon dioxide levels

Climate change is caused by increasing levels of carbon dioxide and other greenhouse gases such as methane and nitrous oxide in the earth's atmosphere.

Observed trends: In 2010, atmospheric carbon dioxide levels were 392 parts per million (ppm), an increase of 41 percent over pre-industrial levels of 278 ppm and higher than any level in the past 650,000 years.[13]

Future projections: If current trends continue, carbon dioxide levels are projected to reach 600 to 1,000 parts per million by the year 2100.[14] Increasing levels of carbon dioxide and other greenhouse gases are causing global temperatures to rise and making the world's oceans become more acidic.

2 Warmer air temperatures

The *Washington Climate Change Impacts Assessment* projects potentially significant increases in average annual and seasonal temperatures in the Pacific Northwest.[15] Even at the low end of the projections, the changes in average annual temperature will be substantially higher than average conditions observed in the 20th century. Warming is expected in all seasons, with the greatest warming occurring during the summer months.

Observed trends: In the Pacific Northwest, average annual temperature rose 1.5°F between 1920 and 2003. The warming has been fairly uniform and widespread, with little difference between warming rates at urban and rural weather monitoring stations. Although the warmest single year on record was 1934, according to NASA the 2000s were the warmest decade since reliable modern records have been kept, going back to 1880.[16]

[13] NOAA/ESRL, http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html; IPCC (2007b).
[14] IPCC (2007a).
[15] Climate Impacts Group (2009).
[16] NASA (2010).

Future projections: Average annual temperature in the Northwest is projected to increase (relative to 1970-1999) approximately:

- 2°F by the 2020s (range of 1.1 to 3.4°F).
- 3.2°F by the 2040s (range of 1.6 to 5.2°F).
- 5.3°F by the 2080s (range of 2.8 to 9.7°F).[17]

Natural variability, including El Niño, La Niña, and the Pacific Decadal Oscillation (PDO), will continue to influence average temperatures, bringing colder or warmer than average years—or decades in the case of the PDO—to the Northwest, even as average global and regional temperatures increase over the long term as a result of rising greenhouse gas emissions.

Higher temperatures are expected to cause glacial and snowpack melt, sea level rise, more severe storms, increased wildfires, and increased diseases and pests.

3 Drier summers and reduced snowfall

Summers are expected to be drier, and winters are generally expected to be wetter, although some models project winter drying.[18] Because winter temperatures are projected to rise, Washington is expected to receive less snow and more rain on average in the future. As with temperature, natural variability will affect how we experience climate at any given point in time, producing wetter or drier than average years (or decades), even as climate change affects precipitation trends over the long term. Because of our region's large range of natural variation between wetter and drier years, it may be difficult to see how climate change is altering long-term precipitation trends for several decades.

Observed trends: Trends in annual precipitation in the Pacific Northwest vary depending on the time period, but overall, annual precipitation has increased. For the period 1920-2000, annual precipitation increased approximately 13 percent. Increases during this period were largest in the spring (37 percent), followed by winter (12 percent), summer (9 percent), and autumn (6 percent).[19] Cool-season precipitation also became more variable in the western U.S. from about 1973 to 2003.[20] Average snowpack in Washington's Cascades declined about 25 percent between 1950 and 2006, due in part to natural variability, with the largest decreases occurring at lower elevations.[21]

[17] Mote and Salathé (2010).
[18] Mote and Salathé (2010).
[19] Mote (2003).
[20] Hamlet and Lettenmaier (2007).
[21] Mote *et al*. (2008).

Future projections: For summer months, a majority of models project decreases in precipitation, with the average decline of 14 percent by the 2080s.[22] Some models project reductions of as much as 20 to 40 percent in summer precipitation.[23]

In winter, a majority of models project increases in precipitation, with an average of 8 percent increase by the 2080s under the moderate emissions modeling scenario (A1B). This figure is small relative to variability from year to year.[24] Although some models project modest reductions in fall or winter precipitation, others show very large increases (up to 42 percent).[25] Spring snowpack across the state is projected to decrease 29 percent by the 2020s, 44 percent by the 2040s, and 65 percent by the 2080s (relative to the 1971-2000 average) for the A1B scenario. Projected decreases in snowpack are slightly less for the low emissions modeling scenario (B1): a 27 percent decrease for the 2020s, a 37 percent decrease for the 2040s, and a 53 percent decrease for the 2080s.[26]

Snowmelt provides approximately 70 percent of annual streamflow in the mountainous regions of the western U.S.[27] Increased winter rain (as opposed to snow) and shifts to earlier spring snowmelt—both due to warmer winter temperatures—result in higher streamflows in winter and early spring. Late spring and summer streamflows are reduced in snow-dominated and transient watersheds (which receive a mixture of rain and snow).[28]

Lower summer streamflows could have major implications for fisheries, wildlife, water supply, and agriculture, particularly in drier regions of the state.[29] Although changes in total annual precipitation may be relatively small, reduced summer precipitation and warmer temperatures may lead to decreased soil moisture and higher rates of evapotranspiration. In some areas, these changes will likely lead to increased drought frequency and severity.[30]

[22] Mote and Salathé (2010).
[23] Mote and Salathé (2010).
[24] Mote and Salathé (2010).
[25] Mote and Salathé (2010).
[26] Elsner *et al*. (2010).
[27] Mote *et al*. (2008).
[28] Casola *et al*. (2005).
[29] Elsner *et al*. (2010).
[30] Mote and Salathé (2010).

4 Extreme weather events may increase

Climate change is expected to increase the frequency and intensity of extreme weather events such as floods, coastal storm surges, droughts, and heat waves.

Observed trends: The frequency of heavy downpours (defined as the top 1 percent of rainfall events) has increased by almost 20 percent on average in the U.S. and by about 12 percent in the Pacific Northwest.[31] Nationally, 8 of the top 10 years for extreme one-day precipitation events have occurred since 1990.[32] Record high temperatures have increased compared with low temperatures, and drought conditions have increased in many parts of the western United States.

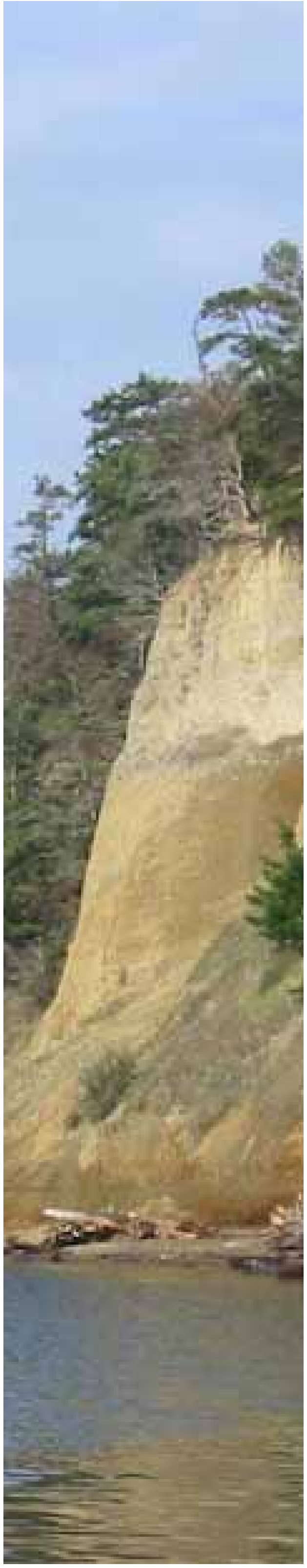
Atmospheric rivers: Narrow regions in the atmosphere that deliver large masses of warm, moist air, transporting large amounts of water vapor across the Pacific Ocean and elsewhere.

Future projections: Climate models project an increased risk for more frequent extreme precipitation in the Northwest by the second half of the 21st century, although the patterns and level of intensity is highly variable.[33] More intense atmospheric rivers along the West Coast of the United States are also possible.[34] Increases of 5 to 10 percent in storm intensity are projected for the North Cascades and northeastern Washington, while increases in other areas of the state are not significant.[35] In the Seattle-Tacoma area, the magnitude of a 24-hour storm is projected to increase 14 to 28 percent during the next 50 years.[36]

Increased extreme heat events are projected for the 2040s, especially in south-central Washington and the western Washington lowlands.[37] Increases in the average annual number of heat events, average event duration, and maximum event duration are projected for the Seattle, Spokane, Tri-Cities, and Yakima regions.[38]

Extreme weather events can cause significant damage to structures and property, depending on the exposure and vulnerability of the specific location. In Puget Sound, development in floodplains heightens the exposure and vulnerability to floods resulting from heavy downpours. Coastal development heightens the exposure and vulnerability to coastal storm surges and sea level rise.

[31] U.S. Global Change Research Program (2009).
[32] U.S. EPA (2010).
[33] Salathé (2006); Rosenburg *et al*. (2010). Tebaldi *et al.* (2006).
[34] Dettinger (2011).
[35] Salathé *et al*. (2010).
[36] Rosenberg *et al*. (2010).
[37] Salathé *et al*. (2010).
[38] Jackson *et al*. (2010).



Heat waves and drought will increase fire risk, reduce summer water supply, and increase water temperatures to lethal levels for coldwater fish species.

5 Sea levels are rising, but the relative effect varies by location

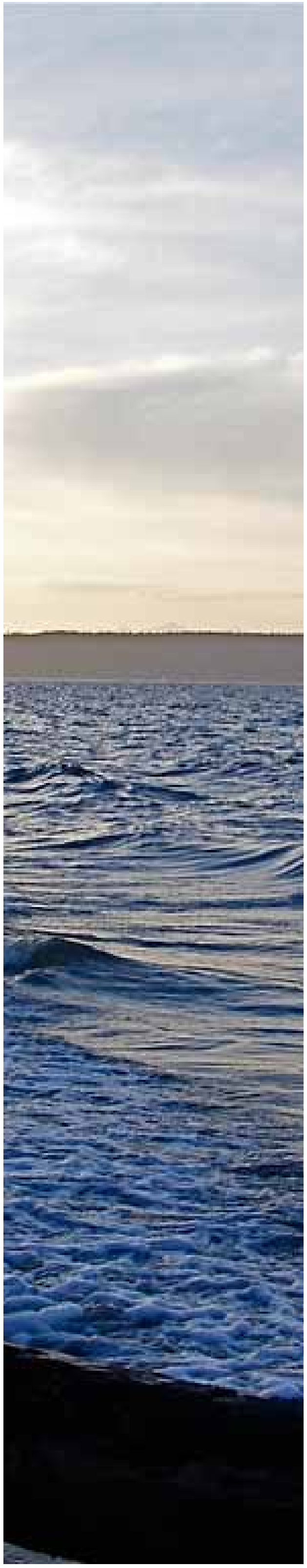
Rising sea levels are primarily caused by two processes: additional water in the ocean from melting of glaciers and land-based ice sheets like Greenland and Antarctica; and thermal expansion of ocean waters due to warmer sea temperatures. Sea level is rising globally, but the relative effect varies by location with changes in land elevation and wind patterns.

Observed trends: Globally, oceans rose approximately 8 inches from 1870-2008, an average of 0.06 inches (1.5 mm) per year. However, the rate of change has accelerated in recent years. Between 1993 and 2008, average sea level rose approximately 0.12 inches (3 mm) per year, which is roughly twice as fast as the long-term trend.[39] In Washington, sea levels are not changing uniformly. Because the edge of the Juan de Fuca oceanic plate is slowly moving under the North American continental plate in western Washington, the Olympic Peninsula is rising at a rate of about 2 millimeters (0.08 inches) a year, while south Puget Sound is subsiding at about the same rate.[40] If these trends continue, relative sea level rise will be greatest in south Puget Sound and least on the northwest tip of the Olympic Peninsula.[41]

Future projections: In the Puget Sound region, the medium estimate for sea level rise is 6 inches by 2050 and 13 inches by 2100. For the central and southern Washington coasts, the medium estimate is an increase of 5 inches by 2050 and 11 inches by 2100. If uplift on the northwest corner of the Olympic Peninsula continues through the 21st century, sea level rise in that area could be lower than other areas of the state. The medium estimate for the northwest Olympic Peninsula is 0 inches by 2050 and an increase of 2 inches by 2100. However, the potential for continued accelerated ice melt from Greenland and Antarctica means that higher sea level estimates are possible for Washington's coastal regions. Increases of up to 3 feet for the northwest Olympic Peninsula, 3.5 feet for the central and southern coast, and 4 feet for Puget Sound by 2100 cannot be ruled out at this time due to large ranges for accelerating rates of ice melt from Greenland and Antarctica.[42]

39 U.S. EPA (2010b).
40 Mote *et al*. (2008).
41 Huppert *et al*. (2009).
42 Mote *et al*. (2008).

Rising sea levels, combined with increased storm surge, will increase the frequency and intensity of coastal flooding. Periodic floods will likely pose a greater and more near-term risk than permanent inundation of low-lying areas from increases in average sea level. Coastal erosion and habitat loss are also projected due to higher sea levels. For much of Puget Sound, 1 foot of sea level rise will likely turn a flood event expected to occur once in 100 years into an event that occurs every 10 years. If sea level rises 2 feet, a flood event expected to occur once in 100 years would turn into an annual event.



6 Marine waters are becoming more acidic

The global oceans have absorbed approximately 30 percent of human-generated carbon emissions since the Industrial Revolution.[43] When dissolved carbon dioxide mixes with seawater it forms carbonic acid. As marine waters have absorbed increasing amounts of carbon dioxide, the carbonic acid has caused ocean pH to decline, making seawater increasingly acidic.

Observed trends: Globally, ocean pH has declined 0.1 units relative to its pre-industrial measure of 8.2.[44] In the Hood Canal area of Puget Sound, observed pH is substantially lower, ranging from 7.39 to 7.56.[45]

Future projections: If carbon emissions continue their current trends, global ocean pH is projected to decline to approximately 7.8 by 2100.[46]

The biological effects of ocean acidification are not well understood and will vary among organisms, with some coping well and others not at all. Marine organisms that use carbonate to build shells or skeletons are expected to be affected by changes in seawater chemistry. The long-term consequences of ocean acidification for marine organisms are unknown, but changes in many ecosystems and the services they provide to society appear likely.[47]

[43] Canadell *et al*. (2007).
[44] IPCC (2007a).
[45] Feely *et al*. (2010).
[46] IPCC (2007a).
[47] National Research Council (2010).

7 Warmer water temperatures

Increased water temperatures are caused by warmer air temperatures and reduced summer water inputs. Water temperatures are increasing in freshwater rivers, lakes, and wetlands as well as in marine waters and nearshore systems such as estuaries.

Observed trends: Annual average water temperature in Lake Washington increased about 1.6°F from 1964 to 1998.[48] In marine systems, average sea surface temperatures have risen globally by 1.1°F since 1950.[49]

Future projections: Average statewide summer stream temperatures are projected to rise about 1.8°F by the 2020s and between 3.6°F and 9°F by the 2080s.[50] In many of Washington's streams and lakes, the duration of periods that cause stress to salmon because of warmer temperatures and migration barriers is projected to at least double and perhaps quadruple by the 2080s.[51] Prolonged elevated water temperatures and thermal stress for salmon are expected particularly in eastern Washington along the Upper Yakima River, the Columbia River at Bonneville Dam, and the Lower Snake River near Tucannon, as well as in western Washington along the Stillaguamish River near Arlington and in the Lake Washington/Lake Union area. Sea surface temperatures near the Washington coast are projected to increase 2.2°F by the 2040s.[52]

Increased water temperatures can be lethal for salmon and other coldwater species. Lakes may also experience a longer stratification period in summer,[53] which could increase eutrophication and lead to oxygen depletion in deep zones during summer, eliminating refuges for coldwater fish species.[54] Warmer ocean temperatures contribute to sea level rise, increased storm intensity, and greater stratification of the water column.[55]

[48] Arhonditsis *et al*. (2004).
[49] Nicholls *et al*. (2007).
[50] Mantua *et al*. (2010).
[51] Mantua *et al*. (2010).
[52] Mote and Salathé (2010).
[53] Euro-Limpacs (2011).
[54] Euro-Limpacs (2011).
[55] Hoegh-Guldberg and Bruno (2010).

8 Wildfires are increasing in frequency and severity

While forest fires occur naturally and provide important ecological benefits for many ecosystems, the frequency and severity of fires is expected to increase due to climate change. Warmer air temperatures, reduced snowpack, and reduced summer precipitation lead to reduced soil moisture and longer dry seasons that prolong the period in which fires could occur.[56]

Observed trends: Over the period 1987-2003, major wildfire frequency in the western U.S. increased fourfold compared to the period 1970-1986. The area of forest burned was six times greater in 1987 to 2003 than during the previous 16-year period from 1970 to 1986.[57]

Future projections: In the Pacific Northwest, wildfires are projected to burn twice as many acres yearly by the 2040s and three times as much forest area by the 2080s (relative to 1916-2006). The probability that more than 2 million acres will burn in a given year is projected to increase from 5 percent currently to 33 percent by the 2080s.[58] In forested ecosystems such as the western and eastern Cascades, Okanogan Highlands, and Blue Mountains, the area burned is projected to increase by a factor of 3.8 by the 2040s, compared to 1980-2006.[59] Regionally, the area burned by wildfire each year on average is projected to increase from about 425,000 acres currently to 800,000 million acres in the 2020s, 1.1 million acres in the 2040s, and 2.0 million acres in the 2080s.[60]

More frequent and severe wildfires will raise the risk of injury or death for firefighters and the public as well as increase the costs of firefighting. Increased property damage and reduced timber yields are also likely, as well as reduced air quality, loss of forested habitat areas for fish and wildlife, and reduced water quality due to erosion and sedimentation of water bodies.

[56] Westerling *et al*. (2006).
[57] Westerling *et al*. (2006).
[58] Littell *et al*. (2009).
[59] Littell *et al*. (2010). Compared to the period 1980 to 2006.
[60] Littell *et al*. (2010).

9 Floods are increasing in frequency and severity

In western Washington, flood risk is generally highest in late fall and winter when precipitation is greatest. In eastern Washington, flood risk is generally highest during the spring snowmelt. An increase in winter rainfall (as opposed to snowfall) as a result of climate change is expected to lead to more winter flooding in rain-dominated and transient (rain/snow mix) watersheds.

Observed trends: Flood risks are increasing primarily in rain-dominated basins and warmer, transient basins in western Washington,[61] which tend to experience average winter temperatures near 32°F. Flood risk in colder snow-dominated basins and cooler transient basins was largely unchanged during the 20th century. Since 1990, Puget Sound has experienced 16 federally declared flood disasters, and Interstate 5 has closed four times due to flooding.[62]

Future projections: As the climate warms, flood frequency is projected to increase in the months of January to March and decrease in April to May.[63] Flood frequency is projected to increase progressively from the 2020s through the 2080s, with the largest increases predicted for mixed rain-snow runoff basins located in Puget Sound, the west slopes of the Cascades in southwest Washington, and in the lower elevations on the east side of the Cascades.[64] Rain-dominated basins are projected to experience small changes in flood frequency.

Floods can cause widespread damage to communities and property. Increased frequency and severity of floods will likely lead to greater taxpayer costs for cleanup and rebuilding as well as economic disruption. Floods have caused numerous deaths and put emergency responders at risk during rescue operations.

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61 Hamlet and Lettenmaier (2007).

62 Washington State Department of Transportation (2008b).

63 Vano *et al*. (2010).

64 Mantua *et al*. (2010).

4. Human Health



4. Human Health

Human health is naturally linked to the environment. As such, impacts of climate change will likely create a significant and emerging threat to human health in many ways, both directly and indirectly (see Figure 1). For example:

- Extreme temperatures, more frequent wildfires, and other severe weather events will likely increase the risks of heat-related illness, respiratory disease, and vector-borne diseases.
- Drought, flooding, and storm damage will likely alter drinking water supply and water quality conditions.
- Changes in water, air, food quality and quantity, ecosystems, agriculture, and the economy also indirectly expose humans to climate change impacts.

Vector: An organism or vehicle that carries pathogens from one host to another.

Climate change can affect human health in ways that affect families and the workforce, such as premature death and increased sick days, leaves of absence, health care costs, and insurance claims. These impacts also impair quality of life. The populations at greatest risk include children, the elderly, individuals suffering from respiratory and cardiovascular disease, and economically disadvantaged people.

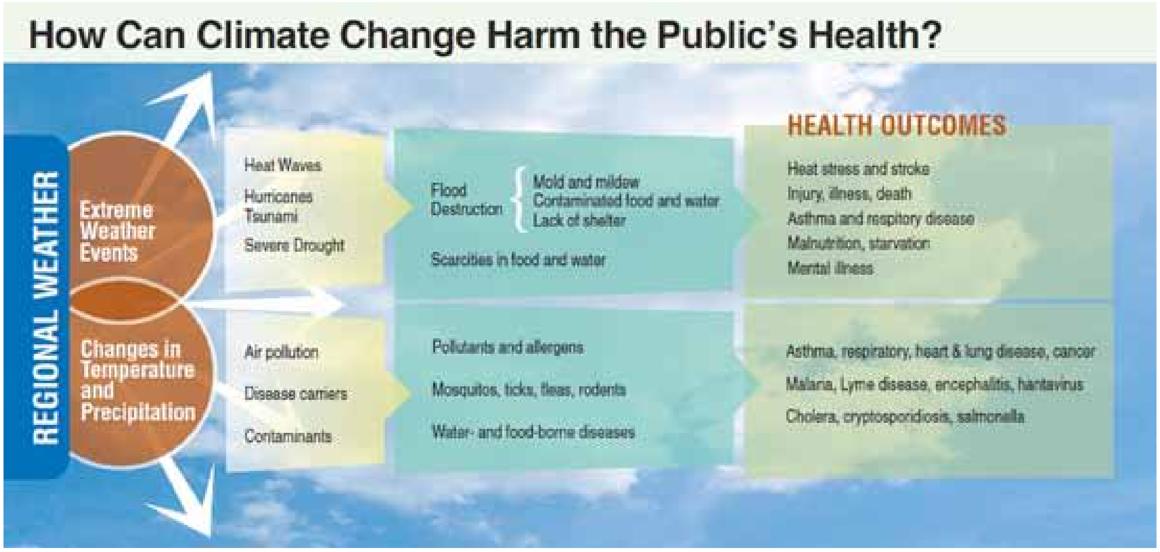


Figure 1. How climate change can harm human health[65]

[65] American Public Health Association citing U.S. Global Change Research Program

Much of the work to address and prepare for climate change effects on human health will happen in local communities and public health agencies, with focus on the adverse effects on vulnerable populations and sensitive communities.

Keeping the people of Washington healthy is of paramount importance. The challenge of adapting to the health impacts of climate change comes at a time when the entire public health system is examining and reshaping its approach to service. Local and state funding for public health is also rapidly eroding. For example, the loss of trained public health professionals ranges from as much as 25 to 40 percent in some jurisdictions.

The following sections describe the scientific understanding of the impacts of climate change on Washington's citizens and outline key strategies to support state and local efforts to protect human health and lower risks to our communities.

Impacts of Climate Change on Human Health

Climate change is expected to affect human health in at least five key ways:

- The risk of illness and death from extreme heat will increase.
- Asthma and respiratory problems will increase due to increasing levels of smog (ground-level ozone) and potential increases in other air pollutants.
- Diseases transmitted by food, water, and insects will increase.
- Illness, injury, and mental health problems from storms will increase.
- Drinking water supplies will change, and water quality could decline.

1 Illness and deaths from heat waves

Climate change is expected to increase the frequency, intensity, and duration of extreme heat events in Washington State. Excessive heat can lead to heat stress, heat stroke, and other health complications such as heart attack, stroke, respiratory illness, and death. Elderly people and people with existing health conditions are especially susceptible to heat-related illness.

Since extreme heat days are uncommon in the Puget Sound region, most homes lack cooling systems. Most people are not well prepared and do not take the necessary precautions. In the Seattle area, the number of heat-related deaths for people age 65 and older is projected to increase. In eastern Washington, increasing numbers of hot days (over 100°F) are expected to cause more heat-related illness, and agricultural workers are particularly exposed.[66]

[66] Jackson *et al*. (2010).

Ground-level ozone, or smog, is an air pollutant with harmful effects. Exposure to smog is linked to premature death, asthma, bronchitis, heart attack, and other cardiopulmonary problems.

2 Air quality and respiratory and cardiovascular disease

Climate change is expected to increase exposure to ground-level ozone and make it more difficult to meet the air quality standards necessary to protect public health.[67] In King County, average summer ozone concentrations are projected to increase 28 percent by the 2050s. In Spokane County, ozone concentrations are projected to increase by 17 percent by the 2050s.[68]

Larger and more frequent wildfires could also significantly affect air quality in Washington and increase concentrations of tiny atmospheric particles, which degrades air quality. Climate change could worsen our current challenges with asthma, increase pollen production, and prolong the pollen season.

Tiny Particles in the Air: Aerosols or Particulates

When you look up at the sky, you are looking at more than just air. Billions of tiny bits of solid and liquid are floating in the atmosphere. Those tiny floating particles are called **aerosols** or **particulates**.

The aerosols that are from air pollution are hazardous to human health. When these small particles go deep into a person's lungs, it can make him or her very ill.

3 Infectious disease

Climate change is expected to increase some diseases transmitted by food, water, and insects. Increasing temperature, precipitation, and extreme weather events can affect the replication, survival, persistence, habitat range, and transmission of disease-causing agents, worsening the following health concerns.

Tick-related disease. Longer, drier summers and changing distribution patterns of animal hosts could increase the distribution range of Dermacentor ticks, which are can carry Rocky Mountain spotted fever, tularemia, and Q fever, as well as cause tick paralysis. Milder winters in western Washington could cause an increase of Ixodes pacificus tick populations, which is the Lyme disease carrier in the western United States.[69]

[67] U.S. Environmental Protection Agency (2009).
[68] Jackson *et al.* (2010)
[69] Personal communication with Elizabeth Dykstra, DOH Public Health Entomologist, 2011.

Mosquito-borne diseases. The introduction of foreign mosquito-borne diseases remains a concern. The recently introduced species Ochlerotatus japonicus is a known carrier of filariasis and has been shown to transmit West Nile virus in the laboratory. Other types of diseases like western equine encephalitis and St. Louis encephalitis have occurred in Washington State and may be sensitive to climate change, though no cases have been reported since 1988.[70]

Waterborne illnesses. Outbreaks of waterborne diseases frequently follow heavy precipitation[71] and flooding.[72] Surface water used for drinking may be at greater risk of contamination.[73]

Harmful Algal Blooms (HABs). HABs are blooms of algae that can produce natural toxins with harmful effects, including illness and death. Humans are exposed to HABs through consumption of fish or shellfish, inhalation, or skin contact with contaminated water. Climate change may be contributing to the conditions that allow these algal blooms to flourish.

Rodent-related disease. Increased forest damages and losses due to beetle infestations and increasing risk of severe forest fires will alter the habitat and distribution of rodent populations. Loss of forest habitat may send more rodents into residential areas, increasing the risk of human exposure to the diseases rodents can carry, such as hantavirus.[74]

Food-borne illnesses. Research shows a significant correlation between food-borne illnesses and ambient temperature. Depending on the type of food-borne illness, for every degree centigrade (ºC) rise in temperature, the risk of food-borne illness can increase 2.5 to 6 percent.[75]

Washingtonians may also face higher risks from diseases originating in other parts of the world.

[70] Washington State Department of Health (2008).
[71] Curriero *et al*. (2001); Thomas *et al*. (2006).
[72] Wade *et al*. (2004).
[73] Rose *et al*. (2000).
[74] Personal communication with Elizabeth Dykstra, DOH Public Health Entomologist, 2011.
[75] Portier et al. (2010).

4 Injury and mental health problems from severe storms

More frequent and severe weather events such as storms and flooding are expected to result in injuries, illness, and deaths. These health problems include carbon monoxide poisoning from people using generators or barbeques indoors for cooking and alternative sources of heat during power outages.

Extreme weather events also result in more short- and long-term emotional trauma and mental health problems, including:

- Post-traumatic stress disorder.
- Depression.
- Sleep difficulties.
- Social avoidance.
- Drug or alcohol abuse.

The severity of the problems that come after an extreme climate event depend on how much support is available, both during and after, to the person affected by the event. During the recovery period, mental health problems and stress-related disorders can come from:

- Geographic displacement.
- Unemployment.
- Loss of property.
- Death or injury of loved ones.

Impacts of climate change on U.S. national security

According to the National Intelligence Council, global climate change will have wide-ranging implications for U.S. national security interests in the coming decades. Climate change could increase instability and conflict in vulnerable regions as a result of:

- Increasing drought and conflicts over water.
- Declining food security.
- Increased health problems.
- Increased displacement from flooding and rising sea levels.

These climate-driven impacts will worsen existing problems, such as poverty, social tensions, environmental degradation, and weakening of national governments.

For more information:

www.dni.gov/nic/special_climate2030.html

5 Drinking water supply and water quality

Climate change may affect the sustainability of water supplies in parts of the state in the coming decades. As temperatures rise, declining snowpack and changes in precipitation will affect streamflow timing and volume. These changes in streamflow could increase the risk of water shortages in many basins and also impair water quality. Sea level rise could cause increased saltwater intrusion into coastal aquifers. Expert opinion suggests that sea level rise will have only a minor effect on coastal aquifers, however, and the amount of freshwater available is not expected to change for coastal areas.

Vulnerable populations will bear the burden

For projected impacts of climate change on human health, the most vulnerable populations are children, the elderly, and people with existing respiratory, cardiovascular, or other chronic diseases.[76] People who work or exercise outdoors are also more exposed to the effects of heat.

Poor and disadvantaged people are particularly at risk from the impacts of climate change. Low-income individuals, people of color, and those that speak English as a second language often experience higher rates of chronic stress and have poorer health outcomes, regardless of the stressor. These individuals also may experience:

- Poorer existing health conditions.
- More barriers to health care.
- Unstable employment.
- Lower-quality housing.

In addition, the poor are more likely to:

- Have little or no access to healthy food.
- Have fewer transportation options.
- Live in neighborhoods with less social and financial capital, higher crime rates, and more safety concerns.

As a result, the impacts of climate change may further reduce the ability and capacity of low-income individuals and communities to adapt and to improve their quality of life.

[76] U.S. EPA (2010a).

Recommended Adaptation Strategies and Actions—Human Health

Much of the work to address and prepare for climate change effects will happen in local communities and public health agencies. The public health community has programs that reach across various populations and locations. Public health leaders have a key role to play in preparing communities to cope with the urgent consequences of climate change.

The following section describes five recommended strategies, along with accompanying actions. These strategies and actions are intended to help Washingtonians understand, respond, and adapt to the impacts of climate change. The strategies are not expected to introduce entirely new fields of work to public health but rather to bolster existing systems. By integrating climate adaptation strategies into the emerging public health system, the strategies:

- Help communities' most vulnerable populations.
- Communicate the health impacts of climate change.
- Enhance public readiness to take actions.
- Prioritize and implement operational changes that allow public agencies and communities to prepare for climate change.

Strategy A-1. Protect the communities that are most vulnerable to impacts of climate change.

Actions:

1. Identify people, communities, regions, infrastructure, and local economies that are most vulnerable to climate impacts. Provide tools that local health departments and communities can use to conduct community-wide assessments. Provide financial and technical support for local communities to develop and implement appropriate adaptation strategies to respond to current and future threats.

2. Enhance the capacity of state and local health organizations and communities to implement preventive actions that reduce public health risks related to climate change. The focus will be on ensuring efficient organizational structure, effective policies and programs, and adequate funding.

3. Work collaboratively with local health departments, community-based organizations, state and local planning organizations, and transportation agencies to:
   - *Improve community planning and design to support and promote healthy built environments and healthy living.*
   - *Expand and protect urban vegetation and open space.*
   - *Prevent construction of new critical infrastructure in vulnerable areas.*

4. Work with state and local agencies and organizations to:
   - *Enhance efforts to develop transportation options and evacuation routes to ensure safety of vulnerable people.*
   - *Develop and publicize shelters and responses to heat and flooding extremes.*
   - *Increase access to health care for at-risk populations.*
   - *Prepare for aftermath of extreme events.*
   - *Enhance preparedness for disease prevention of vector-borne and water-borne diseases following floods and storms.*

Strategy A-2. Enhance surveillance and reporting systems to monitor and support early detection of climate-related risks and swift responses to emerging health threats associated with climate change.

The ongoing and systematic collection of data is critical for monitoring changes in the magnitude of current public health threats and early detection of new or emerging threats. The following are the three areas where surveillance systems are critically important to public health preparation and adaptation:

- Zoonotic disease (diseases transmitted from animals to humans).
- Air quality monitoring.
- Notifiable conditions, a public health surveillance of those conditions that legally require reporting to local and state health departments.

Actions:

1. Maintain, rebuild, and increase overall efficiency of current surveillance systems—at the state level and in local health departments and health care organizations—to monitor and identify outbreaks of climate-related health diseases and illnesses.

2. Continue development of the Department of Health's Environmental Public Health Tracking network, and focus future efforts on expanding data and health indicators linked to climate change and healthy communities.

3. Enhance surveillance and electronic reporting from laboratories to support our ability to detect emerging health issues rapidly and implement timely and effective community responses.

4. Develop meaningful data sets to better understand changes in zoonotic disease patterns and disease vectors, air quality conditions, and harmful algae blooms. This information will assist our future efforts in preparing for and adapting to climate change-related conditions affecting our health.

5. Develop an early warning system to identify and predict when and where a harmful algae bloom or pathogen event may occur in our marine waters. This initiative will focus on:
   - *Characterizing environmental and biological factors that contribute to biotoxin or bacterial events.*
   - *The public health burden associated with these toxic events.*
   - *Potential policy and scientific solutions and/or information and data needs for mitigating human exposure from recreational, occupational, and seafood-related pathways during such events.*
   - *Increase collaboration between the Health and Agriculture departments on zoonotic disease surveillance improvements.*

Strategy A-3. Incorporate climate adaptation strategies into the Department of Health's *Agenda for Change*, with a focus on prevention, early detection, and swift responses to protect people from diseases and other health threats caused by changing climate conditions.[77]

Actions:

1. Identify, prioritize, and incorporate into health planning and regulations climate change mitigation and adaptation strategies. Include actions that promote healthy living and reduce greenhouse gas emissions and toxic pollutants. Collaboration with local governments can help incorporate healthy living strategies into land use planning and regulations, such as compact development that concentrates growth in compact walkable urban centers to avoid sprawl.

2. Refine existing emergency response and public health preparedness planning to enable local health and emergency response agencies to:
   - *Anticipate impacts of severe heat events, droughts, wildfires, and coastal flooding.*
   - *Develop early warning systems.*
   - *Quickly respond to extreme weather events.*
   - *Help local health departments assess their capacity to respond to health threats and to integrate climate preparedness into their hazard response plans and daily operations.*

[77] Washington State Dept. of Health (2010).

Strategy A-4. Engage and motivate citizens and organizations to take actions to build resilient communities.

Actions:

1. Collaborate with the Northwest Center for Public Health Practice and other academic partnerships to develop a web-based resource hub to provide information and technical resources on public health and climate change preparedness. This website should provide information in several languages to help meet the needs of communities most at risk.

2. Enhance the ability of local organizations to understand climate risks and reach vulnerable populations. Provide vulnerable populations with information on what they need to know and how to prepare for and address the risks of climate change.

3. Pursue partnerships with nonprofit organizations and businesses to develop climate change communication tools, messages, and social support networks that promote active community involvement and raise public awareness about the health problems related to changing climate.

4. Using the medical system, enhance awareness of the projected health problems that come from a changing climate and the services (response strategies) that are available—including the mental health system.

5. Distribute information on how a changing climate can affect human health to doctors, nurses, and emergency response personnel that provide direct services to vulnerable citizens. Expected impacts include increased asthma, heat exhaustion, and potential new diseases transmitted from animals to humans.

6. Pursue opportunities to engage with medical and academic institutions to raise awareness of the overarching mental health problems that come from the social and environmental disruptions related to emergencies. Potential partners include the state's mental health system, the Washington Medical Association, Washington State Department of Social and Health Services, University of Washington Medical School and School of Public Health, and the schools of social work at Washington State University, Portland State University, and Eastern Washington University.

7. Distribute alerts to the service providers of the medical and mental health communities during extreme weather events (and in advance, when possible), so they can be best prepared to serve members of their communities that may be adversely impacted.

8. Encourage the Washington State Public Health Association to dedicate time at the annual Joint Conference on Health to raise awareness and engage the public health and healthcare service providers about the health problems related to a changing climate. This conference also provides an opportunity to raise awareness about the tools and strategies that local communities can use to prepare for health problems associated with climate change.

9. Use existing programs within the Department of Health's Office of Drinking Water to educate and alert public water system operators and their customers about likely impacts of climate change and the need for enhanced emergency preparedness.

Strategy A-5. Build capacity and support to safeguard human health in the face of climate change.

Actions:

1. Expand training and education of health and social services providers, including mental health agencies, to build capacity to respond appropriately to human health risks of climate change.

2. Improve our understanding of human health impacts of climate change and extreme weather through continued interdisciplinary studies at the University of Washington, Washington State University, and with agency scientists. Further work needs to focus on better understanding the risks; identifying the areas and populations at greatest risk; and exploring new methods to address the identified risks.

3. Seek more reliable funding mechanisms that can support more localized forecasting and risk modeling to address the health implications of climate change from extreme heat events, flooding, other extreme weather events, and increased forest fires.

4. Pursue future funding opportunities, such as the Centers for Disease Control and Prevention (CDC) funds, to support the enhancement of critical public health infrastructure needed to promote healthy communities and to address the impacts of climate change.

5. Ecosystems, Species, and Habitats



5. Ecosystems, Species, and Habitats

Washington is home to nearly 600 mammals, birds, fish, amphibians, and reptiles. Among these are the iconic salmon, orca, and bald eagle, as well as game species such as elk, mule deer, ducks, and geese. Our diversity of fish, wildlife, and plants is supported by distinctive habitats and ecosystems, from the grasslands of the rolling Palouse prairie to the glaciated alpine tundra of the Cascade mountains, and from towering Douglas fir forests to the teeming Columbia River estuary.

Washington hosts a large number of imperiled species, listed by federal or state agencies as endangered, threatened, or a species of concern. Their populations have been reduced to the point that they require special attention and management to prevent extinction. Most of these species began their decline due to non-climate stressors such as habitat destruction, degradation, and fragmentation (breaking up of a habitat into smaller units); invasive species; or excessive hunting and fishing. Climate change adds a new stressor, however, that may further weaken already reduced populations and may cause formerly healthy populations to decline.

Ecosystem Products and Services

Washington's ecosystems also provide a wide range of products and services that benefit Washington residents, including food, clean water, flood and storm protection, recreation, and cultural heritage. These products and services support millions of dollars of economic activity and a significant number of jobs. Although it is difficult to calculate the full economic contributions of many ecosystem services, the economic value associated with some aspects of ecosystem services have been calculated for Washington. For example:

- Habitat in marine and coastal ecosystems in Washington State sustains commercial and recreational fishing that directly and indirectly supported over 16,000 jobs and $540 million in personal income in 2006.[78]
- Washington's biodiversity supported hunting, fishing, and wildlife viewing activities that added nearly $3.1 billion to Washington's economy in 2006.[79]
- The annual benefit of ecosystem services in the Puget Sound watershed is conservatively estimated to range between $9.7 billion and $83 billion.[80]

Climate change is eroding the valuable benefits and services our diverse ecosystems provide, and the impacts could be costly. The following sections describe the scientific understanding of climate change impacts on Washington's ecosystems, fish, wildlife, plants, and habitats. Following the discussion of impacts are recommended strategies and actions to support state and local efforts to protect these ecosystem assets and lower risks to our environment.

[78] Washington Department of Fish and Wildlife (2008).
[79] U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau (2006).
[80] Batker *et al.* (2010).

Impacts of Climate Change on Ecosystems, Species, and Habitats

Climate change is altering Washington's diverse ecosystems, and the effects are projected to harm many of the benefits we gain from ecosystems. Climate change will likely increase the stress on species that are already sensitive or vulnerable and will reduce the potential for their recovery and protection.

Climate change is expected to affect ecosystems, species, and habitats in at least six key ways:

- Degradation and loss of habitat.
- Increase in major ecosystem disturbances.
- Shifts in geographical ranges of some native plants and animals.
- Change in timing of life history events for plants and animals.
- Declines in species populations and loss of biodiversity.
- Spread of invasive species and disease.

1 Habitat degradation and loss

Changing conditions—such as rising air and water temperatures, increasing sea levels, and acidification of the oceans—will alter, and in some cases, destroy habitats. Existing land use activities and growing pressure from urban development and new infrastructure can increase habitat loss.

The human response to climate change also has implications for species and habitat. As sea levels rise, shoreline armoring may temporarily protect structures from flooding but will also likely eliminate coasts and beaches. Levees installed for flood protection may reduce the quantity, quality, and diversity of riparian habitat for fish.

Coastal areas. Rising sea levels will increase erosion of beaches and flood coastal marshes, tidal flats, and other important habitats for many species of fish and wildlife.[81] In a study of selected sites in Washington, researchers project that a 27-inch rise in sea levels would cause the loss of 58 percent of low tidal areas and 24 percent of freshwater tidal areas. Grays Harbor and Willapa Bay will likely experience the greatest loss of key habitats, although the Lower Columbia estuary will likely gain habitat.[82] Development of coastal areas and shoreline armoring (e.g., bulkheads, seawalls) prevent habitat areas from reestablishing inland.

Marine waters. Ocean waters are becoming warmer, altering the species found in our waters, affecting migration and breeding patterns, and increasing harmful algal blooms. Ocean acidification is a significant problem for species that depend on calcium carbonate to make shells or skeletons, including shellfish, corals, and some types of plankton. This acidification could result in the decline of species that provide the foundation of the marine food web and support commercial fisheries.

Streams and rivers. Warmer temperatures—coupled with resulting reductions in snowpack and water supply, along with increased agricultural and domestic water withdrawals—are projected to further stress the river systems, riparian areas, and springtime pools that are critical to the survival of plants and animals. Rising stream temperatures and lower summer streamflows will reduce the quality and quantity of freshwater habitat for salmon and other coldwater fish.[83]

Mountains. Alpine and subalpine habitats are declining primarily because warmer temperatures are allowing tree lines to advance upwards, thereby squeezing alpine systems. These trends are expected to continue, leading to a substantial decline or potential disappearance of high-elevation tundra and subalpine vegetation in the Olympic Peninsula by 2100. Species that live in these high-elevation systems would need to seek alternative habitats or perish.[84]

Aridlands. Washington's aridlands include habitats ranging from shrub-steppe grasslands, dunes, and the Palouse prairie. These habitats host numerous native plant and animal species. Many of these species already live near their physiological limits for water and temperature

[81] Glick *et al*. (2007).
[82] Ducks Unlimited (2010a, 2010b, 2010c, and 2010d).
[83] Mantua *et al*. (2010).
[84] U.S. Department of Agriculture, U.S. Forest Service (2011).

stress, and projected higher summer temperatures will further stress already vulnerable species. Increased temperatures will also benefit invasive species such as cheatgrass, which thrives in hot, open environments and crowds out native species.

2 Increase in major disturbances

Climate impacts may occur rapidly through major disturbance events such as wildfires, floods, drought, or disease or insect outbreaks. When climate change exceeds a species' physical or ecological tolerance thresholds, it can trigger rapid and potentially widespread responses. Disturbances are a natural part of ecosystem dynamics, and some disturbances are integral to maintaining healthy ecosystems. However, climate change is affecting when and how often disturbances occur and how large they are, and these events are likely to significantly alter many ecosystems and the animals and plants that depend on them.

In some cases, multiple climate-related disturbances can combine, such as when forest systems are stressed by increased temperatures, reduced snowpack, and reduced summer soil moisture—and then further weakened by mountain pine beetle or other insects or disease.

3 Shifts in geographic range

With higher temperatures and shifts in precipitation patterns, some native plants and animals will no longer be able to thrive in their current ranges. The ranges of many species in the U.S. have shifted northward and upward in elevation.[85] These changes are likely to continue. Shifts in geographic range depend on the availability and accessibility of appropriate habitat and the behavior of the species. Species that can shift their range will require migration corridors that are not restricted by natural landscape features or human development. Freshwater species are likely to be particularly susceptible to climate change impacts because their opportunities for migration and movement may be especially limited.

[85] U.S. Global Change Research Program (2009).

4 Change in timing of life history events

Shifts have already occurred in the timing of the seasons, animal migrations, and other life history events for plants and animals.[86] Spring now arrives on average of 10 days to two weeks earlier than it did 20 years ago in the U.S., the growing season is longer, and many migratory bird species are arriving earlier.[87] Climate change is likely to further alter the timing of life history events for plants and animals.

Of particular concern is the potential for interrupting lifecycle events among species, such as when a bird or insect relies on the timing of a flowering plant. If climate change prevents interactions needed for survival or reproduction, both species could perish.

5 Declines in species populations and diversity

While plants and animals can often accommodate a range of temperature, moisture, and other conditions, climate change is causing changes that occur at a faster rate, with greater intensity, in different patterns, or on a broader spatial scale than many species have previously experienced. Those species that cannot adapt are at risk of extinction.[88] Scientists estimate that 20 to 30 percent of the earth's plant and animal species assessed to date could be at increased risk of extinction if average temperatures increase 2.7°F to 4.5°F.[89]

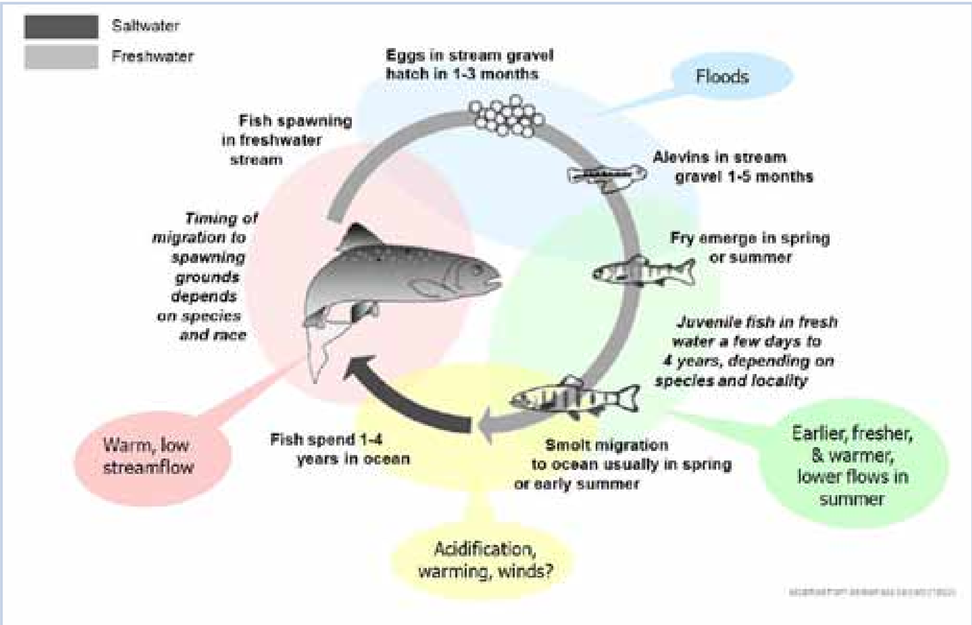


Figure 2. Effects of climate change across salmon life cycle[90]

[86] U.S. Global Change Research Program (2009).
[87] U.S. Global Change Research Program (2009).
[88] Noss (2001).
[89] IPCC (2007a).
[90] Littell *et al*. (2009).

Salmon, already disturbed by a variety of human activities, will be affected by climate change at every stage of their life cycle. Warmer stream temperatures, lower summer streamflows, and changes in the size and frequency of floods will put increasing stress on salmon (see Figure 2). The relative importance of climate factors will vary for different salmon stocks.[91]

The greater sage-grouse is another population that climate change will likely affect. As the impacts of climate change interact with other stressors such as disease and habitat degradation, these birds may be at increased risk of extinction. Under projected future temperature conditions, the cover of sagebrush within sage-grouse territory is anticipated to be reduced due to non-native grass invasions, making the areas prone to destructive fires.

6 Spread of invasive species and disease

Warmer temperatures allow insects and pathogens to expand their range and increase winter survival. Mountain pine beetle, western spruce budworm, blister rust, and needle blight are just a few of the insects and pathogens on the increase in our forests because of climate change. Insects and pathogens affect approximately 3 million acres of Washington's forests, leaving them susceptible to major tree die-offs or fires in the next 15 years.[92] Mountain pine beetle outbreaks in Washington's lodgepole pine and whitebark pine forests are of particular concern because the beetles are spreading rapidly and migrating to higher-elevation trees.

Cheatgrass, another invasive species thriving because of climate change, is replacing native shrubs and grasses and is transforming the remaining shrub-steppe and grassland habitats.[93] Vast areas of shrub-steppe lands have already been converted to cheatgrass over the past century. Once established, cheatgrass is extremely difficult to eliminate.[94] In concert with hotter temperatures and reduced moisture from climate change, cheatgrass tends to increase the size of wildfires, as well as cause the wildfire season to begin earlier and continue longer into the fall. Cheatgrass and other invasive species recover quickly and thrive after fires, at the expense of many native species. Consequently, more frequent fires can lead to irreversible loss of native shrubs and grasses, threatening the habitat of species dependent on the shrub-steppe environment.[95]

91 Mantua *et al*. (2010).

92 Seattle Times (2011) citing DNR. See http://seattletimes.nwsource.com/html/localnews/2016699269_barkbeetle06m.html.

93 Bradley (2009).

94 Bradley (2009).

95 Bradley (2009).

Recommended Adaptation Strategies and Actions—Ecosystems, Species, and Habitats

The five strategies and accompanying actions included in this section are intended to sustain species and natural systems as well as the critical ecological services they provide for human health and well-being. The strategies focus on the conservation, restoration, and improvement of ecological functions and processes, and promote ways to help species and ecosystems recover from the impacts of climate change and extreme events.

Strategy B-1. Conserve habitat necessary to support healthy fish, wildlife, and plant populations and ecosystem functions in a changing climate, and protect connectivity areas between critical habitats to allow the movement of species in response to climate change.

Actions:

1. Identify opportunities and priorities for habitat connectivity, such as buffers, wildlife corridors, and a connected network of conservation areas in Washington. This action builds on the work of the Washington Wildlife Habitat Connectivity Working Group and the Western Governors' Wildlife Corridors Initiative.

2. Increase the quantity, quality, and size of conservation areas, buffers, and connectivity corridors using the full range of conservation tools available. This action will enhance key habitat areas, facilitate migration opportunities for species vulnerable to climate change, and increase connectivity in areas at high risk from climate impacts, such as coastal habitats at risk of sea level rise.

3. Encourage partnerships with federal, tribal, and local government, private landowners, and conservation organizations to implement landscape planning and foster adaptation strategies and actions that protect and restore habitat corridors across jurisdictional and land ownership boundaries.

The Western Governors' Wildlife Corridors Initiative: Multi-state collaboration to protect migration corridors

In 2007, the Western Governors' Association (WGA) launched the Wildlife Corridors Initiative as part of its focus on "Protecting Wildlife Migration Corridors and Crucial Wildlife Habitat in the West." The Initiative is a multi-state, collaborative effort to improve knowledge and management of wildlife corridors and crucial habitat. Its main objective is to develop policies and tools to help states integrate important wildlife corridor and crucial habitat values proactively into planning decisions, promote best practices for development, and reduce harmful impacts on wildlife. A 2008 report presents several recommendations, including establishing a regional climate change adaptation information clearinghouse relevant to wildlife corridors and crucial habitat. The clearinghouse should include data and analysis tools, visualization and interactive mapping tools, and state-of-the-art tools to integrate climate predictions with current and future wildlife corridors and crucial habitat.

The clearinghouse will ensure that decision makers can easily obtain the best and most up-to-date scientific and policy information.

www.westgov.org/wga/publicat/wildlife08.pdf

4. Identify high-quality habitats and conservation areas that are minimally affected by (or resistant to) climate change, able to sustain diverse and healthy populations, and can be used as refugia for species under stress from climate change. Prioritize these areas for protection and ecosystem management.

5. Protect and restore high-quality freshwater habitat through the reintroduction of beavers, wetland mitigation and creation, groundwater recharge, flow augmentation, and protection of coldwater springs.

Climate refugia are areas where climate change is likely to occur more slowly or to a lesser extent than other areas, due to physical landscape features, such as north-facing slopes, valleys or other low areas that act as sinks for cold air, or streams fed by deep coldwater springs. These areas provide refuge to species under stress from climate change.

Wildlife habitat connectivity through a climate lens

The Washington Wildlife Habitat Connectivity Working Group is a science-based partnership of land and natural resource management agencies, organizations, tribes, and universities. The Washington Department of Fish and Wildlife and the Washington State Department of Transportation co-lead the working group. The group is conducting detailed analyses aimed at identifying habitat and linkage areas that will most likely continue to provide connectivity as climate changes and to accommodate climate-driven shifts in species ranges.

The first products addressing habitat connectivity and climate change can be found on the Working Group website.

www.waconnected.org/climate-change-analysis

Strategy B-2. Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems be more resilient to the effects of climate change.

Actions:

1. Use and improve existing regulatory and enforcement programs to build the resilience of natural systems to climate change, including such efforts as the following:
   - *Protect and restore the connections between rivers and their floodplains.*
   - *Reduce existing pollution and contamination of freshwaters.*
   - *Manage freshwater withdrawals.*
   - *Maintain and restore streamflows and lake levels.*
   - *Reduce forest fuel buildup.*
   - *Reduce other human-induced impacts in watersheds most vulnerable to climate change.*
2. Define priorities for land management in areas important to biodiversity to emphasize resilience to fire and decrease the likelihood of severe fires.
3. Take early action to eliminate or control non-native invasive species that take advantage of climate changes, especially where they threaten native species or current ecosystem function.
4. Restore riparian zones, estuaries, wetlands, and floodplains by implementing appropriate conservation, restoration, and other land stewardship actions and practices, such as mitigation banking.
5. Collaborate with local governments to reduce and reverse habitat fragmentation and loss through comprehensive land use policies, zoning regulations, critical area ordinances, and other regulatory and non-regulatory approaches.

Changes in hunting and fishing opportunities

In 2008, the Theodore Roosevelt Conservation Partnership (TRCP) and a number of other national hunting and fishing groups produced a successful publication, Seasons' End: Global Warming's Threat to Hunting and Fishing, detailing the predicted impacts of global climate change in the habitat and distribution of fish and wildlife in the United States.

In the 2010 sequel, Beyond Seasons' End: A Path Forward for Fish and Wildlife in the Era of Climate Change, the TRCP and its partners provide recommendations to address the effects of climate change. Since the publication of these reports, the need for adaptation strategies to help fish and wildlife cope with our changing climate has become increasingly clear.

www.trcp.org/issues/climate-change

Mitigation banking is the restoration, creation, enhancement, or preservation of a wetland, stream, or habitat conservation area, for the purpose of providing compensation for unavoidable impacts to ecosystem resources that a proposed project would adversely affect.

Strategy B-3. Manage species and habitats to protect ecosystem functions and provide sustainable cultural, recreational, and commercial use in a changing climate.

Actions:

1. Incorporate climate change considerations into existing and new management plans for protecting sensitive and vulnerable species, using best available science regarding projected climate changes and trends as well as vulnerability and risk assessments. Modify protection and recovery plans to accommodate migration as well as longer-term shifts in species range associated with climate change and its effects.

2. Conduct and refine species and habitat vulnerability assessments (such as the Pacific Northwest Climate Change Vulnerability Assessment for Habitats and Species) and other scientific studies to determine appropriate management approaches.

3. Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species. Such efforts may include identifying areas for seed collection across different elevations and across the ranges of target species.

Assessing the Vulnerability of Species and Ecosystems to Projected Future Climate Change in the Pacific Northwest

The Pacific Northwest Vulnerability Assessment project is designed to assist conservation and natural resource managers in understanding the potential effects of climate change on the species and ecosystems they manage. The project has six specific objectives:

- Downscale future climate simulations for the Pacific Northwest.
- Simulate potential future vegetation and habitat changes using vegetation models.
- Model potential shifts in the distributions of 12 or more focal animal species selected based on discussions with land managers from the region.
- Assess the vulnerabilities of species, ecosystems, and managed lands to projected changes in climate, vegetation, and species distributions.
- Summarize uncertainties in the simulated future climate, vegetation, and species distribution changes.
- Work with managers to incorporate research results into management plans.

An important component of this project involves collaborations with managers, scientists, and decision makers to integrate the research results into management and conservation plans, such as state wildlife action plans.

http://esp.cr.usgs.gov/info/nccwsc/vulnerability/index.html

Strategy B-4. Integrate climate adaptation considerations for species and ecosystems into natural resource and conservation planning, land use and infrastructure planning, and resource allocation and public investment initiatives.

Actions:

1. Incorporate climate change considerations for species, habitats, and ecosystem processes into planning and regulatory activities related to implementation of the Growth Management Act, Shoreline Management Act, Watershed Management Act, State Environmental Policy Act, and other state goals and policies.

2. Ensure that land and water resources managers at the state and local levels integrate adaptation options into plans, programs, and practices. These options should address and limit the impacts of climate extremes, such as severe storms, floods, droughts, and heat waves, without causing harm to fish, wildlife, habitats, and ecosystem functions.

3. Engage with cities and counties to support incorporation of climate change considerations into activities, guidelines, and both regulatory and non-regulatory programs that protect or conserve habitats and species. The changes should consider the impacts of climate change on habitats and species and potential for safeguarding priority habitats and species from the effects of climate change and catastrophic events.

4. Update natural resource protection plans, land use plans, and water resources management plans to address climate change considerations for species and ecosystems and to support habitat resilience in a changing climate.

5. Develop criteria and guidance to consider impacts of climate change on species and ecosystems when funding new infrastructure and economic development, mitigating impacts from ongoing degradation associated with human development, and compensating private landowners for conservation practices.

Strategy B-5. Build capacity and support for the adoption of response strategies that help protect and restore ecosystem function and services at risk from climate change.

Actions:

1. Establish an interagency, multidisciplinary forum (such as an interagency climate change task force) to strengthen existing partnerships and build new collaborations across jurisdictions. The forum would facilitate sharing new research and approaches to address climate impacts to ecosystems and to ensure that the needs of species, habitats, and ecosystems are considered in other areas such as agriculture, forests, infrastructure, and human health.

2. Increase coordination and participation in existing regional and national research and policy forums—such as the National Climate Assessment, Climate Science Centers, Regional Integrated Science and Assessment partnerships, and Landscape Conservation Cooperatives—to ensure that regional efforts recognize Washington's unique and important natural resources.

3. Develop and integrate messages about the benefits of ecological services at risk from climate change into education programs and curriculum related to natural resources management.

4. Initiate and support efforts to quantify the benefits of ecological services and natural systems at risk from climate change. Compare lifetime cost-effectiveness of nature-based versus engineered options for climate response to help identify cost-effective adaptation options.

5. Develop programs to engage citizens in monitoring impacts of climate change on our shorelines, forests, rivers and streams, and other natural systems and in sharing their observations, case studies, stewardship efforts, and other activities using multimedia resources.

6. Coordinate development and maintenance of integrated long-term, large-scale monitoring of early-warning indicators of species responses, including range shifts, population status, and changes in ecological systems functions and processes. Reconsider monitoring approaches to ensure that indicators track changes associated with climate change.

7. Develop applied tools for decision makers and land managers to maximize the adoption of climate adaptation strategies for species and ecosystems. Such efforts may include:

    - *Guidance, tools, and technical assistance to local governments to enable them to identify, designate, and protect locally important habitats, corridors, and species at risk from a changing climate.*
    - *Incentives, tools, and information to increase the contribution of working lands to ecological resilience.*
    - *Tools to promote nature-based alternatives to engineered adaptation options such as flood control, erosion control, and protection of water quality and quantity.*

6. Ocean and Coastlines

6. Ocean and Coastlines

Washington State has a unique array of coastal and estuarine environments along the Pacific Ocean and Puget Sound. Around 70 percent of Washington residents live in counties that border the coast.[96] Coastal tourism, marine industries, and Washington's robust commercial fishing industry provide important jobs that sustain coastal communities. Washington's coastal areas and marine waters are not only an important economic engine for the state but also are central to the quality of life we enjoy. They provide vital recreational, transportation, and cultural benefits to Washington residents and support a stunning array of wildlife.

Climate change imposes pressures on coastal environments already experiencing environmental stressors from human activities and population growth. Rising sea level, storm surge, ocean acidification, and other climate impacts will pose serious risks for coastal communities and wildlife.

Because Washington has more than 3,000 miles of marine shoreline and a growing coastal population, understanding and planning for the effects of climate change on these environments is of paramount importance. The following sections describe the scientific understanding of the impacts of climate change on Washington's coasts and outline key strategies to support state and local efforts to protect these areas and lower risks to our communities and ecosystems.

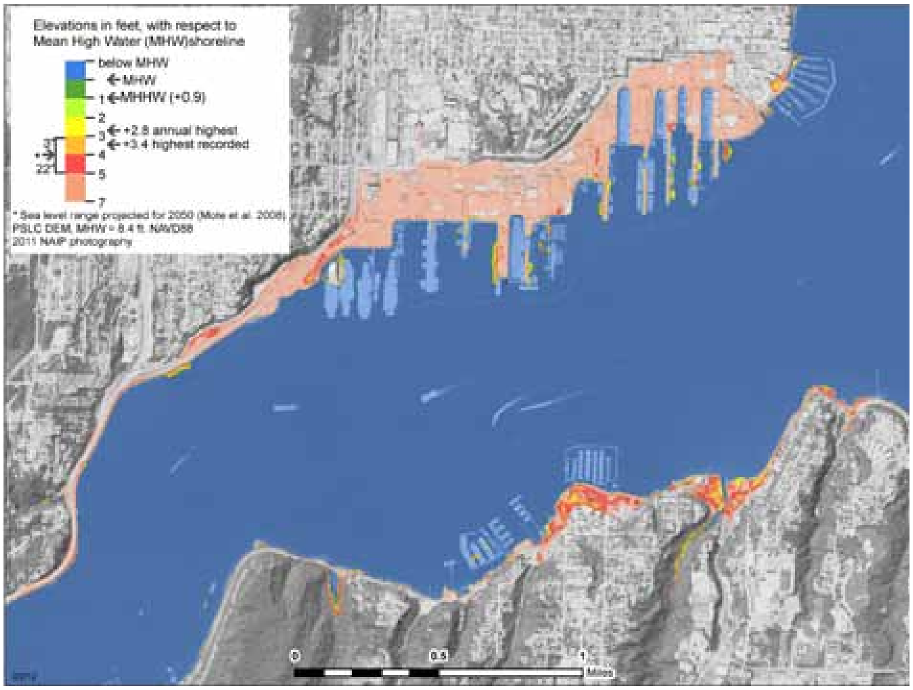
[96] U.S. Census Bureau (2010).

Impacts of Climate Change on Ocean and Coastlines

Climate change will affect coastal and marine environments in distinct ways:

- Sea level rise and storm surge will increase the frequency and severity of flooding, erosion, and seawater intrusion—thus increasing risks to vulnerable communities, infrastructure, and coastal ecosystems.
- Increased ocean acidity will affect marine ecosystems and Washington's commercial shellfish industry.[97]
- Warmer marine temperatures could alter the magnitude, frequency, and duration of harmful algal blooms and cause harmful effects to humans and animals.[98]
- Together, these impacts will have profound effects on Washington's coastal and marine areas and the resources they provide to our communities, wildlife, economy, and our way of life.

1 Sea level rise



Source: *Washington State Department of Ecology*

Global sea level is rising as a result of melting glaciers and ice caps and the expansion of warming ocean waters. Long-term tide gages and recent satellite measurements show that global sea levels rose approximately 8 inches from 1870-2008, an average of 0.06 inches per year. In the past decade, global sea level has risen at an accelerated rate of around 0.14 inches per year. Globally, sea level is expected to rise for several centuries due to current and projected greenhouse gas emissions and the oceans' delayed response to increasing global temperatures. [99] Current projections for global sea level rise by the end of this century are in the range of 3 to 4 feet or more, [100] well above the 7 and 23 inches that the Intergovernmental Panel on Climate Change projected in 2007.[101]

[97] Huppert *et al*. (2009); Feely *et al*. (2010).
[98] Huppert *et al*. (2009).
[99] IPCC (2007). Synthesis report
[100] Rahmstorf (2010).
[101] IPCC (2007a).

Sea level rise is expected to vary across regions of Washington State depending on several factors, such as changes in local land levels caused by tectonic movement, sedimentation patterns, and changes in wind patterns. Projections of sea level rise in Washington developed by Ecology and the University of Washington's Climate Impacts Group (see Table 1) indicate that Puget Sound and the central and southern outer coast (on the Pacific Ocean) are likely to experience more sea level rise than the northwest Olympia Peninsula. Through movement of the earth's crust, the northwest Olympic Peninsula is rising at a rate that is likely to offset rising sea levels in that region for most of the 21st century.[102]

Year	Puget Sound	Northwest Olympic Peninsula	Central and Southern Outer Coast
2050	+3 to +22 inches	-5 to +14 inches	+1 to +18 inches
2100	+6 to +50 inches	-9 to +35 inches	+2 to +43 inches

Table 1. Projected sea level rise estimates for Washington
Source: Mote et al. (2008).

Washington, Oregon, and California are jointly funding a National Academy of Sciences study to evaluate sea level rise on the West Coast for the years 2030, 2050, and 2100. The study will provide updated projections of sea level rise for Washington. The final report will be published in summer 2012 and will cover both global and local sea level rise factors and estimates.

2 Flooding and damage to coastal communities

Rising sea levels will increase the frequency and severity of coastal flooding, increase erosion, and result in greater levels of storm damage along developed shorelines. The hazards associated with coastal areas will grow, and the demand for protection and reconstruction will increase. Coastal defenses may become necessary in places where they do not yet exist. Existing defenses—including seawalls, and dikes—may become more vulnerable and need to be repaired or expanded.

At the same time, pressure for people to retreat from vulnerable areas and maintain natural coastal ecosystems will increase. Communities will face increasingly complicated decisions about balancing demands for stabilizing the shorelines with calls for protecting habitats and publicly accessible shorelines.

Hardened or armored shorelines

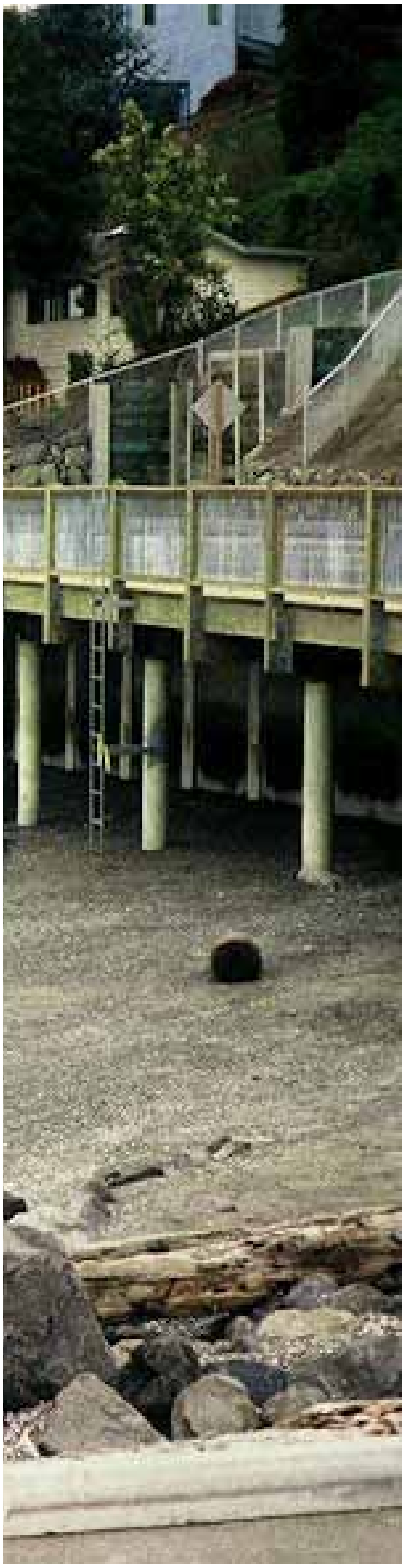
Many shorelines have been hardened with concrete, steel, gabions, or armor stone to prevent erosion. Such reinforcement usually results in the elimination of shoreline vegetation and cover that is important to fish and other wildlife.

[102] Mote *et al*. (2008).

With increased vulnerability to coastal hazards, many communities will need to increase their attention to emergency management, hazard mitigation, and the costs of preparing for and recovering from natural disasters.

Levels of risk vary by location, and many specific impacts, such as the following, are possible:

- Coastal roads will be subject to more frequent closures and more frequent repairs.
- Shoreline parks will be subject to increased damages and closures. Access to the water and to natural shorelines will become more difficult as water levels rise and people construct hardened shorelines in response.
- Intrusion of seawater could damage equipment and strain the capacity of wastewater and stormwater systems. Backflow of water through stormwater pipes could cause localized flooding in low-lying areas. Drainage of low-lying areas will become more difficult, and stormwater management may require installation of tide gates, control works, and pump systems.
- Higher water tables and increased flood events may increase corrosion of underground utilities.
- Contaminated sites within shoreline areas may be affected by changes to water tables and increased flooding, spreading contaminants to Puget Sound and coastal marine waters.
- Sea level rise may affect fuel storage facilities and pipelines. Large oil handling facilities constructed their tanks, containment areas, and pipeline conveyance systems based on current water levels. Changes to the water level could alter the stability of the ground or the flow of groundwater, increasing the chance of a spill reaching Washington waters.
- Increasing storm severity off the Pacific Northwest coast could increase the risk of vessel incidents and oil spills.
- Puget Sound river deltas will be more vulnerable to longer-duration flooding, high water tables, and increased salinity, which could affect coastal agriculture and restoration projects.



3 Increase in erosion

Rising sea level is expected to increase shoreline erosion and the vulnerability of low-lying coastal areas to storms and flooding. On bluffs, which compose much of Puget Sound's shoreline, rapid erosion rates may put upland structures at risk and increase the likelihood of landslides. On spits and barrier beaches, erosion is likely to accelerate, and the potential for flooding and storm damage to low-lying areas will increase. Residential communities built on spits are common both in Puget Sound and on Washington's ocean coast. High-tide storms and chronic erosion already pose significant threats to many of these communities, and these threats will increase in the future. Extreme high tides can damage structures and utilities, contaminate water supplies, and cut off emergency access.

Rising sea level, erosion, and changes in surface water runoff patterns will alter coastal sediment transport systems from current trends that are in relative equilibrium. These changes could result in the delivery of a large volume of eroded sediment to new areas, or to existing areas in newly increased quantities, disrupting both ecosystem services and human infrastructure. Examples include ports that will require more frequent dredging and aquaculture areas and other nearshore habitats (like eelgrass beds) that are impaired by additional sediment.

In addition, small bays that now have inlets with sheltered salt marsh habitats could close from sediment buildup, with significant impacts to the associated salt marsh and coastal ecosystem. These changes will cause additional loss of those habitats, along with others inundated by rising sea levels.

4 Disruptions and damages to ports and harbors

The ports of Seattle and Tacoma are important gateways for international trade, and are the third largest load center for containers in North America. Other major ports in Washington include the Ports of Everett, Bellingham, Olympia, Grays Harbor, Vancouver, Longview, and Port Angeles. Rising sea levels could affect port operations, damage seawalls and structures, and flood low-lying port land and surrounding transportation networks. The severity of impacts will depend on the local rate of sea level rise, the proximity to rivers subject to flooding, and the dependence of the port on vulnerable transportation links.

Marinas and waterfront recreation facilities could also require more frequent repairs and modifications. Changes in the water level and coastal erosion could submerge or undermine fuel tanks for marinas and other facilities, which often locate their tanks close to their operations.

5 Loss of coastal habitats

Beaches and nearshore areas provide critical habitat for innumerable species of fish and wildlife.

In their natural state, beaches and bluffs are fairly resilient to modest increases in sea level rise. Erosion may increase, but beaches can shift landward, preserving their associated habitats. In addition, increased erosion provides sediment to nearby beaches that makes them more resilient to rising water levels. On developed and armored shorelines, however, erosion is prevented, and higher sea levels will squeeze out beaches and nearshore habitats.

One of the challenges of rising sea level is that it will increase the pressure to harden the shoreline. Armoring of shorelines to protect upland development prevents the natural migration of sediment that maintains beaches and coastal marshes, resulting in more rapid beach erosion; loss of critical habitat for young fish, shorebirds, shellfish, and other species; and ultimately decreased resilience of coastal environments.

Rising sea levels may diminish and even destroy coastal marshes and wetlands. Some coastal wetlands may be able to migrate landward as sea level rises, but where dikes or natural topography prevent this movement, wetlands may be lost. In addition, salt marshes may be able to expand vertically as water levels rise but only if natural sources of sediment are maintained.

Nearshore environments along the Pacific coast and Puget Sound will likely face dramatic shifts in the extent and diversity of marshes, swamps, beaches, and other habitats.[103] With 27 inches of sea level rise, impacts to coastal ecosystems could include:

- Loss of two-thirds of the low tidal areas in Grays Harbor and Willapa Bay.
- Loss of 11 to 56 percent of freshwater tidal marsh in Grays Harbor, Willapa Bay, and Puget Sound.
- Loss of 40 percent of freshwater tidal areas in Whatcom, Skagit Bay, and Snohomish.[104]

[103] Glick *et al*. (2007).
[104] Ducks Unlimited (2010a, 2010b, 2010c, and 2010d).

6 Saltwater intrusion into coastal aquifers and rivers

Sea level rise could cause an increase in saltwater intrusion in coastal aquifers known to be hydraulically connected to saltwater bodies. The San Juan Islands and several coastal areas are susceptible to seawater intrusion. Groundwater is the main source of freshwater supplies for the Islands. The small amount of yearly precipitation keeps the islands' groundwater system in a fragile balance between the recharge rates and the groundwater pumping. Increased pumping rates may upset this balance and result in seawater intrusion into nearshore aquifers. Expert opinion suggests that sea level rise will have only a minor effect on coastal aquifers, however, and the amount of freshwater available is not expected to change for coastal areas. [105]

7 Increasing ocean acidity

The world's oceans absorb carbon dioxide (CO_2) from the atmosphere. As the oceans soak up excess carbon emissions, the chemistry of the seawater changes—both locally and globally. This absorption alters the ocean's natural acid-base balance. This move toward a lower pH value is called ocean acidification.

Washington State is particularly vulnerable to ocean acidification. Washington's coastal waters experience seasonal upwelling where waters that are naturally low in oxygen and rich in CO_2 rise to the surface. Coastal waters also receive excess nitrogen from human activities that can stimulate algae blooms. As these blooms die and sink, bacteria decompose them, depleting oxygen from the surrounding water. The combined effects of upwelling, nitrogen inputs, and low oxygen zones mean that Washington is likely to see the impacts of ocean acidification on marine organisms earlier than other coastal areas.

Ocean acidification and climate change

Ocean acidification is related to but distinct from climate change, though they share a common cause—increasing carbon dioxide in the atmosphere. Climate change encompasses the effects associated with changes in the Earth's temperature, which cause global warming and changes in weather patterns.

Ocean acidification refers to the lowering of ocean pH resulting from its increased absorption of carbon dioxide from the atmosphere. Ocean acidification does not include the warming of the ocean.

[105] Huppert *et al*. (2009).

Many animals and plants rely on calcium carbonate to form their skeletons or shells. The trend toward more acidic conditions can reduce the calcification in shellfish species including oysters, clams, scallops, mussels and other species. Acidified waters are suspected of contributing to a recent crisis in larval supplies in the Northwest's shellfish industry. The effects of ocean acidification are serious and real, putting at risk Washington's:

- Shellfish aquaculture.
- Commercial and tribal harvesting of wild shellfish resource.
- Important fish species that use marine plankton as a vital food source.

A decline in the shellfish and marine food web could also have serious economic consequences. Washington leads the country in production of farmed clams, oysters and mussels with an annual value of over $107 million a year.[106] Washington shellfish growers directly and indirectly employ more than 3,200 people and provide an estimated total economic contribution of $270 million each year. In addition, tourists and residents purchase more than 300,000 licenses to harvest clams and oysters from Washington waters, providing more than $3.3 million per year in state revenue.

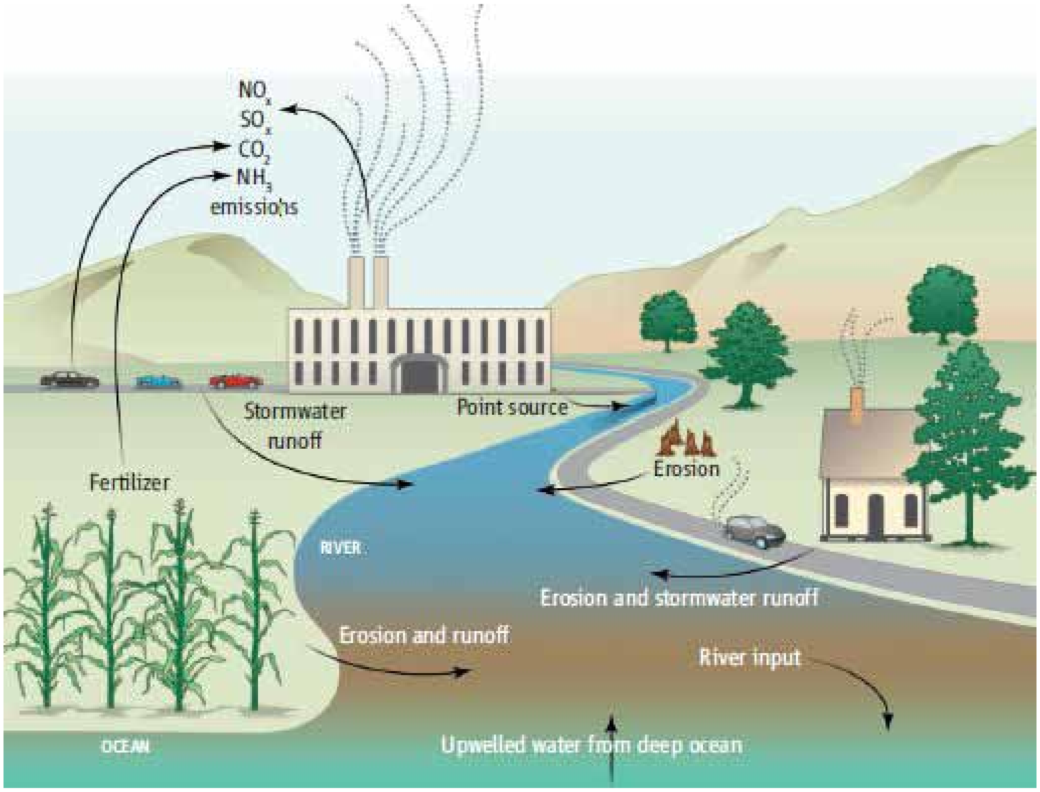


Figure 3. Contributors to ocean acidification[107]

[106] Northern Economics, Inc. (2010).
[107] Kelly *et al*. (2011).

8 Algae blooms and coastal hypoxia

Harmful algal blooms (HABs) are overgrowths of algae that can produce potent toxins. These toxins harm humans and other animals that eat contaminated fish or contact contaminated water. Warmer water and air temperatures promote algae blooms and may also promote earlier and longer-lasting blooms. Increase in nutrient rich runoff from rivers could also increase the frequency of algae blooms in coastal waters.[108]

Hypoxia: low oxygen concentration

More spring runoff and warmer coastal waters will worsen the seasonal reduction in oxygen resulting from excess nutrients. **Dead zones**—areas with low oxygen—are likely to increase in size and intensity as temperatures rise unless efforts to control runoff are strengthened.[109]

[108] Huppert *et al*. (2009).
[109] U.S. Global Change Research Program (2009).

Recommended Adaptation Strategies and Actions—Ocean and Coastlines

We already have some excellent tools and strategies for better managing our shorelines. The strategies and accompanying actions described below will help us better prepare for and adapt to climate change impacts on Washington's Pacific Coast, Puget Sound, and coastal communities by:

- Limiting new development in highly vulnerable areas.
- Protecting the shoreline from rising sea levels using green or "soft" alternatives to traditional "hard" shore armoring, seawalls, and dikes.
- Accommodating rising sea levels through engineering and construction practices or raising the height of piers or buildings.
- Managing retreat from highly vulnerable sites.
- Restoring and maintaining wetlands, preserving sediment transport processes, and preserving habitat for vulnerable species.
- Enhancing monitoring and research of ocean chemistry changes and effects on marine ecosystems.

Managed retreat:

Managed retreat is the deliberate process of altering barriers or other defenses to allow flooding of a presently defended area. Such efforts can reduce both coastal flooding and erosion. Managing this flooding process helps to reduce risk and negative impacts.

Strategy C-1. Lead by example by developing a state framework to guide decision-making and protect people, assets, and natural areas from coastal hazards.

Actions:

1. Evaluate and propose revisions of laws and rules that govern land use, shoreline management, and other programs to effectively address sea level rise and other climate change impacts.

2. Develop guidance and require state agencies to integrate current and anticipated coastal climate impacts into planning, policies, programs, and investment decisions related to:
   - *Land use.*
   - *Transportation.*
   - *Shoreline management.*
   - *Economic development.*
   - *Facility siting and design.*
   - *Conservation and restoration.*
   - *Emergency preparedness.*

3. Require all projects that the state funds, permits, or approves in vulnerable coastal areas to consider the effects of sea level rise and other coastal hazards. Evaluate alternatives to reduce vulnerability and protect communities and coastal ecosystems.

4. Identify essential public infrastructure at risk and develop a decision-making process to determine when to protect, retrofit, relocate, or manage retreat.

5. Revise oil spill response plans to consider climate change. The plan revisions should include geographic-specific response strategies based on risk assessments and considerations of changes in infrastructure and logistical support.

6. Recommend an institutional arrangement to align state agencies' coastal adaptation strategies and actions, help prioritize actions across state agencies, and enhance emergency preparedness and response to extreme weather events.

Strategy C-2. Avoid development in highly vulnerable areas and promote sustainable development in appropriate, less vulnerable areas.

Actions:

1. Provide guidance, updated maps, tools, and information to help local jurisdictions assess risk and vulnerability and incorporate best available information on sea level rise, climate impacts, and adaptation options into their planning, regulations, project siting, and permitting.

2. Identify incentives and regulatory tools to reduce exposure to risk and discourage new public development in coastal areas at high risk from erosion, landslides, flooding, and storm surges. The tools should include:
   - *Acquisitions and easements.*
   - *Transfers of development rights.*
   - *Setbacks.*
   - *Rebuilding restrictions.*
   - *Tax incentives and fees.*

3. Update various planning guidelines and provide incentives to local governments to consider impacts of climate change and adaptation actions when amending shoreline master programs, land use management plans, and other plans.

4. Develop policies and information to guide insurers in dealing with properties in vulnerable areas. Inform property purchasers and investors regarding sea level risks that may affect coastal property.

5. Assess damage costs and remove incentives that encourage rebuilding in at-risk areas.

6. If rebuilding is the only option, construction techniques and building code amendments should be adopted to increase resilience and reduce risk to development projects.

Swinomish Climate Change Initiative

In 2008, the Swinomish Indian Tribal Community started work on a landmark two-year Climate Change Initiative to study the impacts of climate change on the resources, assets, and community of the Swinomish Indian Reservation and to develop recommended actions to adapt to projected impacts.

With expert assistance from scientists at the University of Washington Climate Impacts Group, in 2009 the Tribe issued the *Impact Assessment Technical Report*, an assessment of projected impacts. The report identified potential impacts from sea level rise and storm surge on infrastructure and tribal land. Detailed maps were developed highlighting coastal inundation risk zones on tribal lands and in neighboring areas.

In 2010, the Swinomish published the *Climate Adaptation Action Plan* outlining actions to help build a climate-resilient community that can meet the challenges of anticipated climate impacts in the years to come.

www.swinomish-nsn.gov/climate_change/climate_main.html

Strategy C-3. Accelerate efforts to protect and restore nearshore habitat and natural processes.

Actions:

1. Identify priority conservation and restoration areas that can increase natural resiliency and protect vulnerable communities. Identify regulatory and non-regulatory mechanisms that local jurisdictions can use to conserve and protect those areas.

2. Develop guidelines for state agencies, local governments, watershed groups, nongovernmental organizations, and others to address sea level rise in coastal habitat restoration and protection. Direct state agencies to use the guidelines to incorporate sea level rise into state-managed and supported coastal restoration and protection projects.

3. Identify feasible state level policy options to avoid or minimize shoreline hardening, especially in Puget Sound. Policy options should seek to streamline state and local permitting processes to provide incentives for green shoreline and soft armoring practices.

4. Develop a program to promote green shoreline programs for Puget Sound and some urbanized coastal areas. This program can be built on the lessons learned from pilot projects currently in progress in San Juan County and Lake Washington (City of Seattle), as well as the green shores initiative in British Columbia.[110] Develop and provide state and local jurisdictions with green shoreline design manuals for different types of shoreline along Puget Sound and the Pacific coast.

5. Incorporate future sea level rise in the prioritization, design, and post-project maintenance of toxic clean-up sites near the shoreline.

[110] For more information on green shores in Canada, visit www.greenshores.ca

Strategy C-4. Build local capacity to respond to coastal climate impacts by providing tools to assess vulnerability and advancing research, monitoring, and engagement efforts.

Actions:

1. Complete a coast-wide (including Puget Sound) sea level rise vulnerability assessment. Update periodically as new and improved scientific information becomes available.

2. Identify and provide local jurisdictions with information, web-based tools, training, case studies, locally effective adaptation policies and actions, and other resources needed to build resilient coastal communities. Case studies could address, for example, how communities are using the National Oceanic and Atmospheric Administration's (NOAA) Digital Coast, which provides data, tools, and training to help manage coastal resources.

3. Assist coastal planners with activities such as:
   - *Simulating potential impacts of long-term sea level rise on wetlands and shorelines.*
   - *Analyzing risks and potential losses from floods, sea level rise, and storm surges.*
   - *Mapping hazard areas.*
   - *Assessing and evaluating the risks from sea level rise and other climate change impacts in local jurisdictions.*
   - *Enhancing sustainable development in coastal areas.*
   - *Identifying community exposure to climate change—considering land cover, land use, zoning, structures, vacant lots, parcel values, and social disruption.*

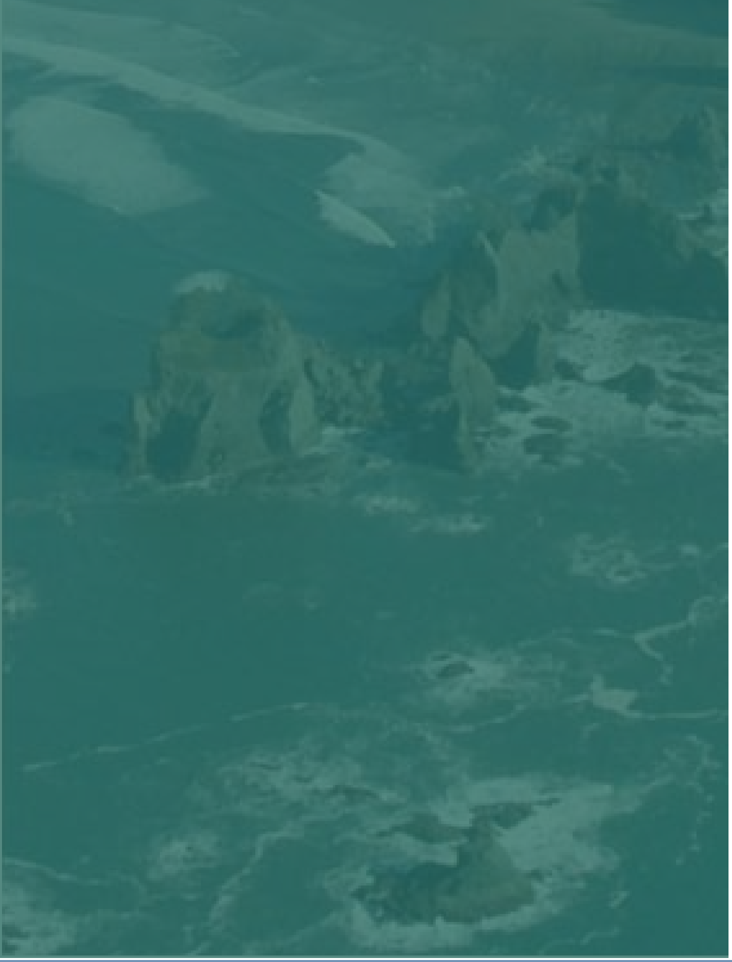
4. Identify potential funding mechanisms and help local governments seek funding to incorporate climate adaptation into plans, policies, and projects.

Washington’s Coastal Planning for Climate Change Training

The Coastal Training Program’s Planning for Climate Change course is designed for planners to increase awareness about climate impacts to Pacific Northwest shorelines and specific action steps to prepare for climate change.

The Coastal Training Program provides practical, science-based training to professionals who make decisions about coastal management in Washington State. The program is administered through the Padilla Bay National Estuarine Research Reserve, which is part of the Department of Ecology and NOAA.

www.coastaltraining-wa.com



5. Assist local jurisdictions in raising awareness about the impacts of sea level rise and the need for adaptation actions by providing educational materials, participating in local events, and engaging the communities in efforts such as the King Tides, Washington Beach Program, and water quality monitoring programs.

6. Collaborate with local partners—including local governments, tribal governments, federal agencies, universities, nonprofits, NOAA Sea Grant, and National Estuarine Research Reserves—to monitor the effectiveness of climate adaptation tools and options and to identify changes that are needed.

7. Expand essential data collection and monitoring programs to improve our understanding of climate impacts, including:
   - *The impacts of sea level rise and storm surge on the shoreline.*
   - *Changes in erosion.*
   - *Unstable bluffs.*
   - *Saltwater intrusion and inundation of freshwater areas.*

8. Develop an inventory of dikes, levees, tide gates, clean-up sites, nearshore fuel storage facilities, and other facilities. Provide this information to local jurisdictions and others to plan for and adapt to rising sea levels and coastal hazards and to aid investment decisions in coastal areas. Ensure that the inventory products and maps are widely available to planners, agencies, tribes, and other users.

Strategy C-5. Enhance our understanding and monitoring of ocean acidification (pH) in Puget Sound and coastal waters as well as our ability to adapt to and mitigate effects of seawater acidity on shellfish, other marine organisms, and marine ecosystems.

Actions:

1. Support the work of the newly created Blue Ribbon Panel on Ocean Acidification, convened under the auspices of the Washington Shellfish Initiative. The Panel will focus on documenting the current state of scientific knowledge and ways to advance our scientific understanding of the effects of ocean acidification. The Panel will recommend actions to respond to increasing ocean acidification, reduce harmful effects on Washington's shellfish and other marine organisms, and adapt to the impacts of acidified waters. A report will be submitted to the Governor, NOAA's administrator, regional research groups, and other policymakers in October 2012.

2. Expand collaboration with NOAA Fisheries, other federal agencies, nonprofit organizations, academic groups, and the shellfish industry to enhance monitoring to track biological and chemistry changes in the Pacific Ocean, Puget Sound, and coastal areas of Washington, including key areas such as Hood Canal and Willapa Bay.

Washington Shellfish Initiative

In December 2011, Washington became the first state in the nation to have the Governor endorse an agreement among federal and state government, tribes, and the shellfish industry to respond and expand Washington's shellfish resources, promote clean-water commerce, and create family-wage jobs.

The agreement builds on the National Shellfish Initiative created by the National Oceanic and Atmospheric Administration (NOAA) to stimulate coastal economies and improve the health of ailing estuaries through increasing commercial shellfish production and native shellfish populations and habitats in our nation's waters.

As a part of the Washington Shellfish Initiative, and with strong support from the NOAA administrator and scientists, Governor Gregoire has convened a Blue Ribbon Panel on Ocean Acidification of leading tribal, local, state, and federal policymakers; scientific experts; public opinion leaders; and industry representatives.

For more information:

www.ecy.wa.gov/water/marine/oceanacidification.html

NANOOS: Creating customized ocean information and tools

The Northwest Association of Networked Ocean Observing Systems (NANOOS) is a partnership of federal and state agencies, local governments, tribes, nongovernmental organizations, industry, and educational institutions involved in a wide range of decisions about our oceans and estuaries.

NANOOS is the regional association of the national Integrated Ocean Observing System (IOOS) in the Pacific Northwest, primarily Washington and Oregon. The system operates several buoys in the Puget Sound monitoring hypoxia (low oxygen concentrations), algae blooms (indicated by chlorophyll), and climate effects (especially on temperature, salinity, and underwater sunlight penetration).

A pilot project between NANOOS and the National Estuarine Research Reserve System is providing real-time water quality data for shellfish growers in the Pacific Northwest, which can help oyster growers determine whether oysters have enough oxygen.

www.nanoos.org

3. Coordinate with state and federal agencies to improve monitoring by evaluating and adopting improved pH measurement protocols to support fine-scale data analysis and tracking of small changes in pH. Create a new baseline data set.

4. Continue to actively address problems of pollutants in marine waters (which add to acidity problems) by studying toxics and nutrients entering Puget Sound. Develop models to determine the effects of nitrogen discharges on dissolved oxygen levels in Puget Sound. Evaluate trends in water quality over time and detect emerging issues.

5. Continue to explore how Clean Water Act authorities can be used to prevent or reduce localized effects from ocean acidification and climate change.

7. Water Resources

7. Water Resources

A reliable supply of water is vital for the communities, businesses, industries, ecology, and quality of life in Washington State. Washington communities rely to varying degrees on our snow-fed water supply to provide safe and clean drinking water. Our $2.5 billion irrigated agriculture industry, which helps drive the local and state economy, relies on water to irrigate crops. That same water also feeds rivers and streams that support salmon, a state icon and valuable commercial fishery. Washington's abundant hydropower resources supply two-thirds of the electricity for the state.

The impacts of climate change will intensify our current challenges in managing water resources in Washington. The state's water resources are already under stress from:

- Excessive water withdrawals.
- Increasing conflicts among water users and demands on water resources.
- Increasing water quality degradation.
- More frequent and intense droughts and floods.
- Loss of species, habitats, and ecosystems.

Climate change impacts will vary across different watersheds in Washington. More frequent and extreme precipitation events will likely strain our urban stormwater systems and increase the amount of polluted runoff flowing into Puget Sound. Flood risk will increase for some basins in the state, putting people and infrastructure in harm's way.

Climate change will increase the variability—widening the range—of future supply and demand of water. As climate change shifts the timing and volume of streamflow and reduces snowpack, lower flows during the summer will make it more difficult to maintain an adequate supply of water for communities, agriculture, and fish and wildlife. Lower summer flows and higher stream

temperatures will continue to degrade our water quality and place further stress on salmon.

Our current management systems for water are designed around past patterns of temperature and precipitation. Preparing for and adapting to the impacts of climate change will require new management approaches that take into account how future conditions are likely to change. Many initiatives are in place and partners are engaged in addressing these challenges and anticipating future needs, using approaches such as:

- Conservation and demand management.
- Technical innovations.
- Water transfers, markets, and water banks.
- Infrastructure improvements.
- Enhanced information systems and hydrologic forecasting.
- Water management and efficiency practices.

However, no single project or initiative can adequately address the challenges we face and the tradeoffs we need to make. Our region needs well-coordinated adaptation strategies at the state, local, and regional levels to improve resiliency, reduce risks, and increase water sustainability. Long-term integrated planning and investing in comprehensive actions at a region or basin level will help prepare Washington for future changing climate and balance our water management objectives related to:

- Water availability and demand.
- Water quality.
- Agriculture.
- Fish and wildlife.
- Flood and storm control.
- Hydropower.
- Navigation, recreation, and tourism.

Washington's quality of life depends on adequate, reliable amounts of clean water. The sections below describe the scientific understanding of the impacts of climate change on Washington's waters, followed by key strategies and recommended actions to protect these waters and lower risks to our communities and ecosystems.

Impacts of Climate Change on Water Resources

Climate change has already altered and will continue to alter the snowpack and streamflows in the western United States, affecting where, when, and how much water is available for all uses.[111] Projected climate change impacts include:

- Reductions in the amount of water naturally stored in snowpack and glaciers, due to rising temperatures and increasing winter runoff.
- Declining late summer streamflow, increasing demand for water, and more intense competition for scarce water resources.
- Increases in winter precipitation, posing additional challenges for managing reservoirs for flood control, fish, and hydropower.
- Reduced water quality due to lower late summer streamflow, warmer summer temperatures, and increased winter flooding.

1 Declining snowpack and loss of natural water storage

During the winter, when the majority of precipitation occurs, snow accumulates in upper elevations and forms a "natural reservoir" that stores water during times when demands are relatively low. As the climate warms, more precipitation falls as rain and less as snow, leaving less water naturally stored in snowpack and glaciers. The snow melts earlier in the spring, and less water is available to feed our streams in the late summer when demands for water are highest.

Widespread declines in spring snowpack have already occurred across the western U.S., especially since the 1950s.[112] Greater losses in snowpack have been observed in mid-elevation mountain ranges such as the Cascades, where sensitivity to changes in temperature is high. Snow is melting earlier, and peak runoff occurs from 1 to 4 weeks earlier across much of the western U.S. than in the 1950s.[113]

These patterns are expected to continue and further alter the hydrologic behavior of many watersheds in Washington. Spring snowpack across the state is projected to decrease 29 percent by the 2020s, 44 percent by the

[111] Hidalgo *et al*. (2009).
[112] Mote *et al*. (2005).
[113] Stewart *et al*. (2005)

2040s, and 65 percent by the 2080s (relative to the 1971-2000 average) under a moderate emissions modeling scenario (A1B). The low emissions scenario (B1) shows slightly less severe projected decreases of 27 percent for the 2020s, 37 percent for the 2040s, and 53 percent for the 2080s.[114]

2 Changes in seasonal streamflow

Increasing temperature, declining snowpack, and earlier snowmelt are expected to shift streamflow timing. The impact will differ by basin type (see Figure 4), however. Hydrologic modeling shows that:

- **Mixed rain- and snow-dominated basins**, such as the Yakima River, are likely to shift to rain-dominated basins. Peak streamflow will shift earlier in the spring and late summer streamflow will decline.
- **Snow-dominated basins**, such as the Columbia River, are likely to see reduced peak spring streamflow, increased winter streamflow, and reduced late summer flow.
- **Rain-dominated basins**, such as the Chehalis River, will likely see relatively little change in streamflow timing. However, they will likely experience higher winter streamflow, due to the potential for more winter precipitation.

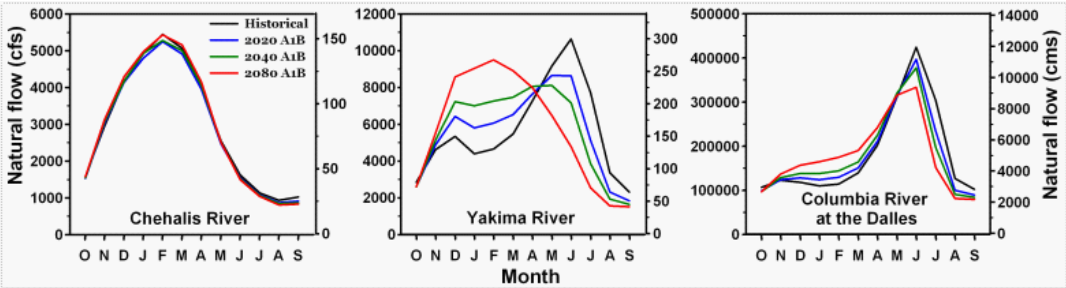


Figure 4. Projected average monthly streamflow for a rain-dominated watershed (Chehalis River), a mixed rain-snow watershed (Yakima River), and a snowmelt-dominated watershed (Columbia River). Hydrographs represent monthly averages of simulated daily streamflow for 1916-2006 and three future periods: 2020s, 2040s, and 2080s. (Elsner et al. 2010)

[114] Elsner *et al*. (2010).

In the winter, average runoff is projected to *increase* by:

- 11 to 13 percent by the 2020s.
- 16 to 21 percent by the 2040s.
- 26 to 35 percent by the 2080s.[115]

In the summer, average runoff is projected to *decrease* by:

- 16 to 19 percent by the 2020s.
- 22 to 29 percent by the 2040s.
- 33 to 43 percent by the 2080s.[116]

Yearly precipitation changes are expected to be small overall. Seasonal patterns are expected to intensify, however, with most (but not all) models projecting more winter precipitation and less summer precipitation. Extreme precipitation events are also projected to increase in Washington. Future changes in precipitation due to climate change may be difficult to distinguish from natural variability, given the wide range of natural variability in annual and seasonal precipitation in the Pacific Northwest.

3 Higher drought risk and more competition for scarce water resources

Climate change is expected to increase the risk of summer water shortages and increase demand for water, which will intensify competition for water for both instream and out-of-stream uses.

Yakima Basin: Water shortages are projected to occur more frequently in the Yakima Basin, and the reservoir system will likely face difficulty supplying water to all users, especially those with junior water rights. The average production of apples and cherries could decline by approximately $23 million in the 2020s and by $70 million in the 2080s.[117]

Salmon in the Columbia Basin: Lower summer streamflow and higher stream temperatures will substantially reduce the quality and extent of freshwater salmon habitat.[118] By the 2080s, the duration of stream

[115] Relative to 1916-2006. Elsner *et al*. (2010).
[116] Relative to 1916-2006. Elsner *et al*. (2010).
[117] Stöckle *et al*. (2010).
[118] Mantua *et al*. (2010).

temperatures that cause thermal stress and migration barriers for salmon is projected to at least double and possibly quadruple for most streams in the interior Columbia Basin.

Hydropower: Summertime hydropower production is likely to decline by 9 to 11 percent by the 2020s. Meanwhile, summer demand for energy will increase significantly due to higher electricity needs from air conditioning as well as population growth.[119]

Puget Sound water supplies: Urban water supply systems in Puget Sound will collect less water in their reservoirs in late spring and early summer. Climate change impacts could result in water demand increases of as much as 12 percent by 2060.[120] Many of the region's water utilities have adapted in the past to fluctuations in water supplies and are actively implementing and planning long-term adaptations to respond to climate change challenges.

Small water systems and groundwater: Increased drought risk could alter drinking water supplies for small public, private, and independent water systems. Many communities in rural areas rely on groundwater, which could be affected by climate change. Reductions in spring and summer streamflow could limit surface water supplies, triggering heavier reliance on groundwater. On the "plus" side, warmer, wetter winters could increase the amount of water available for groundwater recharge.[121] The impacts of climate change on groundwater sources of supply are not well understood, however, and this area needs further study.

Forests: Drought stress is likely to reduce forest productivity in eastern Washington. The area of severely water-limited forests is projected to increase 32 percent by the 2020s and an additional 12 percent in the 2040s and 2080s.[122] Drought-stressed forests may be more susceptible to mountain pine beetle outbreaks.[123]

Wildfires: Warmer temperatures and reductions in summer precipitation will likely increase the areas burned by wildfire. Wildfires disrupt the watershed processes through erosion, warmer water temperatures, increased stormwater runoff, and loss of forest canopy. These changes will likely alter the soil's capacity to retain water and recharge aquifers.[124]

River navigability: Reductions in summer water levels could also affect the navigability of rivers and lakes in the region, although the risk is not well understood.

[119] Hamlet *et al*. (2010).
[120] Water Supply Forum (2009).
[121] U.S. Department of the Interior, U.S. Bureau of Reclamation (2011).
[122] Littell *et al*. (2010).
[123] Littell *et al*. (2010).
[124] U.S. Global Change Research Program (2009).

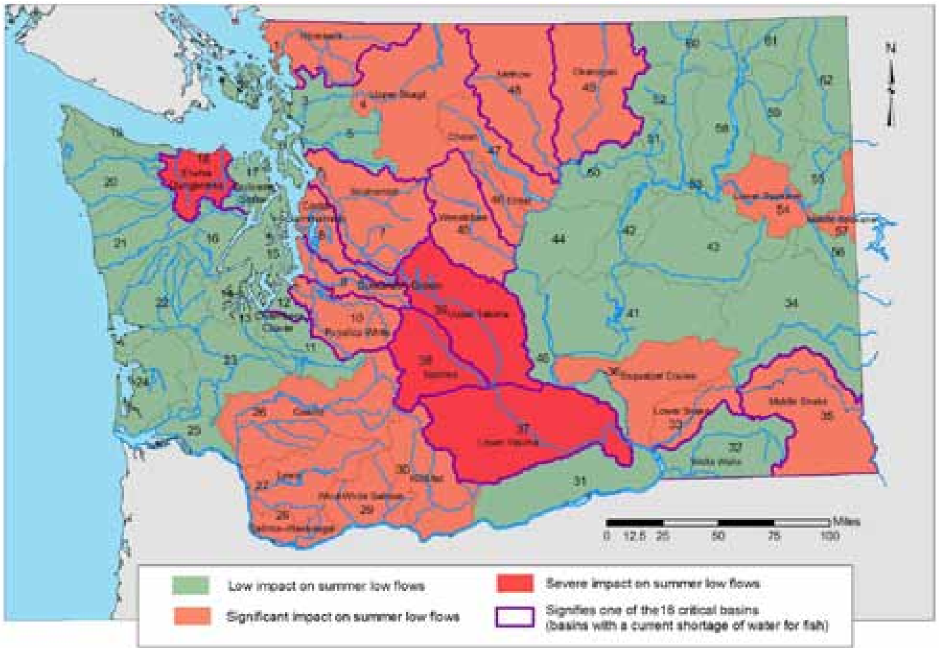


Figure 5. 2040 Projected climate change impact on summer flows by watershed. Climate change will intensify current water needs of people, fish, and farms in at least 45 percent of the state, shown in red on the map.

Source: Washington Department of Ecology

4 More severe winter flooding

Washington already faces challenges from severe flooding, and the damages can be very costly. Projected increases in winter runoff, increases in winter precipitation, and more intense precipitation will increase the frequency of flooding, particularly for mixed rain/snow-dominated basins sensitive to changes in temperature. For many large rivers near major population centers in western Washington, the magnitude of the 100-year flood under natural conditions is projected to increase by 20 to 30 percent by the 2040s (see Figure 6).[125] Low-lying, rain-dominated basins show modest increases in winter flood frequency due to projected increases in winter precipitation and extreme precipitation events.

Flood frequency east of the Cascades is typically driven by rapid spring snowmelt, particularly in snow-dominated basins. In general, snow-dominated basins are expected to experience

[125] Hamlet *et al*. (2010).

minimal changes in flood event frequency due to anticipated climate changes, and spring flood event frequency could decline in some eastern Washington basins because of declines in spring snowpack.

More frequent flooding poses challenges for managing reservoirs for flood control, fish, and hydropower production. More flooding will strain existing flood control infrastructure, such as reservoirs, dikes, levees, tide gates, and dams. Flooding, erosion, and rising snow/freeze-thaw levels increase the flow of sediment to lower elevations in watersheds, potentially changing the width and depth of stream channels. Low-lying buildings, roads, energy facilities, wastewater facilities, and other infrastructure in or near floodplains or along coastal areas will be at a higher risk of flood damage. The risk of erosion, landslides, and mudslides could also increase. In Puget Sound and lower elevation basins in the interior Columbia basin, winter flood risk will likely increase the risk of streambed scouring of spawning habitat.[126]

[126] Mantua *et al*. (2010).

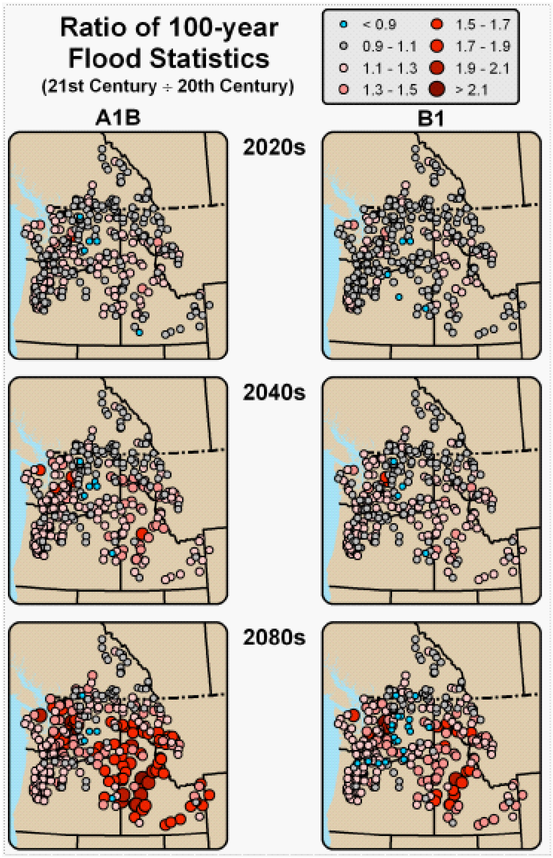


Figure 6. Maps of the ratio of the 100-year flood magnitude (future/historical) for three future time intervals, under two climate scenarios. (Higher ratios, shown with larger dots in red, indicate more intense flooding events projected for the future). (Source: Tohver and Hamlet 2010)

5 Declining water quality

Projected increases in temperature, winter flooding, and prolonged low summer flows will pose challenges for water quality. High runoff during the wet winter months will increase the flow of polluted runoff into waterways. Stormwater flows over the land and carries with it pollutants from the ground or paved surfaces, such as car oils, antifreeze, brake lining dust, pet and farm waste, fertilizers, and pesticides. Stormwater is the leading contributor to pollution of urban waterways in Washington, and this polluted runoff endangers sensitive species and habitats.

Winter flooding could also strain the capacity of urban drainage infrastructure and result in more frequent overflows. In coastal communities, marine water could inundate wastewater and stormwater systems and could discharge water into the streets from flooded storm drains.

Warmer and drier summers, and elevated stream temperatures could potentially impact the established water quality standards for rivers and streams and the effluent limits (amount discharge to the water body) set on existing wastewater treatment facilities.

Recommended Adaptation Strategies and Actions—Water Resources

Many water resources managers and users are already engaged in efforts to improve Washington's ability to respond to climate change. The recommended strategies and actions below are aimed at reducing climate risks and vulnerabilities, while accommodating non-climate demands of a growing population, ecosystem restoration, clean energy production, and protection from drought and floods.

Strategy D-1. Manage water resources in a changing climate by implementing Integrated Water Resources Management approaches in highly vulnerable basins.

Actions:

1. Ensure that long-range plans developed for highly vulnerable basins—including the Columbia, Yakima, and Walla Walla river basins—account for climate change impacts. Consider the risks and vulnerabilities to water resources and infrastructure, agriculture, forest, and other sectors. Integrate adaptation actions into basin plans to enhance water supply reliability, improve water quality, and improve instream flows and fish passage at existing reservoirs.

2. Promote broader recognition that an integrated approach is feasible and beneficial, by documenting lessons learned and conclusions from the implementation of integrated water resources management plans in the Columbia, Yakima, and other river basins.

3. Expand the models of the Columbia River Program, the Yakima River Integrated Water Management Plan, and the Walla Walla flexible water management system to other basins (such as the Dungeness and Wenatchee river basins), sub-basins, and aquifers, based on:

   - *Existing and emerging water management issues.*
   - *Need for integrated planning.*
   - *Community and stakeholder engagement.*
   - *Legal and institutional framework.*
   - *Capacity to develop and implement an integrated plan.*

4. Develop guidance for analyzing whether and how to incorporate projected climate information and adaptation actions into planning, policies, and investment decisions. The analysis would help state, local, federal and tribal governments and water organizations understand how changes in watershed hydrology, ecosystems, water quality, and species and habitat conditions in a given watershed may affect activities such as:

   - *Water allocation decisions.*
   - *Water delivery.*
   - *Water systems operations.*
   - *Water quality standards.*
   - *Stormwater and floodplain management.*
   - *Infrastructure safety.*
   - *Ecosystem restoration and species recovery.*
   - *Environmental preservation and restoration efforts.*

5. Incorporate climate change realities—recognizing that past hydrological data are no longer a reliable guide to project future conditions—into agency decision-making to:
    - *Approve new or change existing water rights.*
    - *Adopt instream flows for fish habitat and ecological purposes.*
    - *Decide whether water users are able to use their water rights for the amount allowed, when purchasing or banking trust water rights.*
6. Use the watershed-based framework created under Watershed Planning (RCW 90.82) to establish a well-coordinated water and land use policy that takes an integrated approach to planning. Such plans should reduce risks to rural and urban communities from extreme weather events (such as intensive flooding and frequent droughts).
7. Integrate climate change adaptation into ongoing efforts that address management of stormwater, wastewater, water quality, water reuse, and potable water demand—to ensure that planning decisions and investments made now are not increasing future vulnerability and causing unintended consequences. Require consideration of the impacts of extreme weather events in planning, siting, and designing of water, wastewater, and stormwater infrastructure and related facilities.

Integrated Water Resources Management in the Yakima Basin

Water shortages are a chronic problem in the Yakima River Basin. Demand for water to irrigate crops, provide drinking water and ensure salmon and steelhead survival is greater than available supply.

In 2009, Ecology and the U.S. Bureau of Reclamation brought representatives from the Yakama Nation, irrigation districts, environmental organizations, and federal, state, and local governments to develop a consensus-based solution to the basin's water problems. The group agreed upon a proposed approach to improving water management in the Yakima River Basin—an Integrated Water Resources Management (IWRM) plan.

The IWRM Plan, the most comprehensive effort to date in the Yakima Basin, includes seven elements: reservoir fish passage, structural and operational changes to existing facilities, surface water storage, groundwater storage, habitat and watershed protection and enhancement, enhanced water conservation, and market reallocation of water. The new plan has brought together once-conflicting water interests to support the plan.

Yakima River Basin Integrated Water Resource Plan:

www.usbr.gov/pn/programs/yrbwep/2011integratedplan/plan/integratedplan.pdf

Strategy D-2. Improve water supply and water quality in basins most likely to be affected by changing climate.

Actions:

1. Strengthen and increase the capacity of natural systems to respond to droughts, streamflow changes, and flooding by encouraging local governments to adopt land use policies and best practices. Examples include practices that reduce impervious surfaces to protect surface water quality, improve infiltration, and reduce stream erosion and sedimentation. These policies and practices would:
   - *Direct development away from vulnerable areas.*
   - *Decrease flood risk.*
   - *Expand the protection and restoration of prime agricultural and forest lands, aquifer recharge areas, wetlands, floodplains, and wildlife habitat and corridors.*

2. Encourage the state Department of Natural Resources and the U.S. Forest Service to develop and implement forest management practices that would improve water-holding capacity in watersheds and help protect water quality from increased temperature, erosion, and associated pollutants.

3. Support new surface and aquifer storage by capturing winter and spring runoff to make up for summer low flows, where feasible and environmentally sound; and increase storage capacity in existing reservoirs. Doing so could improve water supply reliability, and enhance instream flows, if and when stored water is released during low flow conditions.

4. Conserve water and support water reuse, retention, and infiltration by designing development sites to minimize water needs (such as drought-tolerant landscaping), retaining graywater and stormwater on site and using reclaimed water, and expanding adoption of low-impact development (LID).

5. Foster the development of climate-ready water utility initiatives. Highlight existing utility efforts to evaluate and incorporate climate information into planning, and support the development of peer-to-peer information sharing. Assist water and wastewater utilities,

along with stormwater and floodplain managers, in implementing climate change adaptation and mitigation strategies, with the goal of fostering more resilient water systems. Provide water system planners and operators with the knowledge, capacity, resources, and skills necessary to adapt to a changing climate and continue to fulfill their public health and environmental missions.

6. Support the development and delivery to water utilities of early-warning or rapid-response information, to address challenges and disaster risk to water systems from extreme climate events, such as devastating floods, droughts, fires, and storms.

7. Aggressively pursue reallocation and redistribution of water in critical basins, through water transfers, water transactions, water markets, and water banks with the goal of increasing streamflows for fisheries and improving habitat conditions.

8. Work with federal and local partners to improve the performance of existing water infrastructure, such as reservoirs, to respond to extreme events that may result from climate change and to improve local water supplies.

Columbia River Basin

A temperature-sensitive cycle of snow accumulation and melting dominates surface water flows in the Columbia River Basin. Average temperatures are 1.5°F higher in the Columbia River Basin than they were a century ago, and annual average temperatures are expected to increase by 2.5 °F in the next 50 years. This warming could fundamentally change the patterns of rain and snow in the Columbia River Basin. The changes in water supply and demand are important features of Washington State University's 2011 Forecast.

The forecast found that climate change will shift water availability away from the irrigation season when demands are highest. Water supply at Bonneville Dam is forecasted to decrease nearly 21 percent between June and October, while increasing up to 36 percent between November and May.

Current out-of-stream diversion demands for municipal and agricultural irrigation are projected to increase by 2030. This increased demand is likely to exacerbate water supply issues in some locations, and during the summer, will make it more difficult to meet all demands, including instream demands for fish. The forecast information will guide the state in developing a water management plan and in making strategic capital investments in water infrastructure to meet eastern Washington's environmental and economic needs.

www.ecy.wa.gov/programs/wr/cwp/wsu_supply-demand.html

River Management Joint Operating Committee (RMJOC)

Climate change will alter how the Columbia River and its tributaries will be managed for flood control, power generation, and protection of endangered fish. The U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Bonneville Power Administration began a climate change initiative in 2008.

In 2011, the three federal agencies produced the "Climate and Hydrology Datasets for Use in the River Management Joint Operating Committees' Longer-Term Planning Studies – Part IV Summary." The data sets show how climate change could alter hydrology and water supplies in the Columbia River Basin and how climate change could affect the operation of the Columbia River and its tributaries.

www.bpa.gov/power/pgf/ClimateChange/Final_PartIV_091611.pdf

Strategy D-3. Implement water conservation and efficiency programs to reduce the amount of water needed for irrigation, municipal, and industrial users and to improve basin-wide water supply.

Actions:

1. Adopt the most up-to-date water conservation technologies, water-efficient practices, and alternative water supplies whenever possible and where they:
   - *Provide the most beneficial and least costly way to decrease water demand across all sectors.*
   - *Reduce stress on existing water supplies.*
   - *Increase the benefits to aquatic ecosystems.*

   Because of the connection between water and energy use, new energy-efficient technologies may provide opportunities to reduce both energy and water use, along with greenhouse gas emissions.

2. Expand and accelerate improvements of irrigation infrastructure, starting with aging systems in basins most vulnerable to droughts and climate change. Local conservation districts and various funding agencies—such as the Natural Resources Conservation Service (NRCS), Ecology, U.S. Bureau of Reclamation (USBR), and the Bonneville Power Administration (BPA)—must continue to help irrigation organizations and landowners improve water delivery and distribution systems. These improvements can be done through projects such as:
   - *Lining ditches.*
   - *Piping.*
   - *Re-regulating reservoirs.*
   - *On-farm conservation.*
   - *Pump exchange (replacing water from one source with water from another).*
   - *Water use management projects.*

Climate Change in the Methow Valley

A team of USGS, local stakeholders, and consultants are looking at long-range water-related issues in the Methow Basin, anticipating changing climatic conditions. The major issues include water availability and providing riverine habitat for several endangered fish species.

The team is developing a decision analysis tool for water users and the public, interested in whether water will be available for irrigation in the future, whether the current fish populations can be supported with declining summer runoff, and whether there will be enough lowland snow to support the tourism industry of cross-country skiing. The tool will also enable decision makers and water managers to make more targeted decisions on specific restoration activities in the basin.

wa.water.usgs.gov/projects/methow/cc.htm

3. Expand and accelerate implementation of water conservation and efficiency standards for industries and businesses.

4. Expand the U.S. Geological Survey (USGS) and the National Weather Service (NWS) Methow Basin project—"Future Runoff Scenarios for Decision Makers for the Methow River, Washington"—to other watersheds to understand and quantify how hydrologic systems respond to land use, water use, and climate changes.[127] (This effort includes using the interactive web-based database being developed for the Methow.)

5. Expand and accelerate implementation of municipal water efficiency improvements to reduce amount of water used per person or household. Improvements could include:

   - *Water rate setting.*
   - *Water-smart landscape programs.*
   - *Rebates to install or upgrade water-efficient irrigation systems.*
   - *Regulations to reduce waste of water used outdoors.*
   - *Water-efficient development codes and policies for new development.*
   - *Rainwater harvesting from roofs.*
   - *Education and public outreach campaigns.*

6. Seek more reliable funding mechanisms to help water providers implement climate-ready plans and practices.

[127] USGS/NWS. http://wa.water.usgs.gov/projects/methow/summary.htm

Strategy D-4. Build the capacity of state, tribal, and local governments; watershed and regional groups; water managers; and communities to identify and assess risks and vulnerabilities to climate change impacts on water supplies and water quality.

Actions:

1. Provide local communities and watershed groups with water forecast projections using best available data, tools, and models to assess watershed vulnerability and determine priority risks that require a response. Provide examples of management strategies that will build resilient watersheds and communities.

2. Help watershed groups and communities identify vulnerable areas and assets at risk. Develop climate-readiness plans using approaches that would most sustainably and effectively prepare for and adapt to changes in the watershed.

3. Provide tools and incentives to watershed groups to implement watershed protection and restoration plans focusing on:

    - *Controlling stormwater on a regional or watershed basis.*
    - *Reducing flood peaks.*
    - *Reducing sedimentation.*
    - *Increasing recharge of aquifers.*
    - *Restoring instream flows.*

Climate Ready Water Utilities

Extreme weather events, sea level rise, shifting precipitation and runoff patterns, temperature changes, and resulting changes in water quality and availability contribute to a complex scenario of climate challenges that may have significant implications for drinking water, wastewater, and stormwater utilities.

Seattle Public Utilities (SPU) worked closely with the University of Washington's Climate Impacts Group to examine the effects of climate change on SPU's system performance and to project future changes in water supply and demand. SPU used this information to analyze a range of adaptation options and identified several "no-regrets" options that provide benefits regardless of the magnitude of climate change.

EPA's Climate Ready Water Utilities (CRWU) initiative provides resources for water utilities to adapt to climate change:

water.epa.gov/infrastructure/watersecurity/climate/

Climate Change Vulnerability Assessments: Four Case Studies of Water Utility Practices:

cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=233808

4. Collaborate with the scientific community and water management entities to develop and disseminate best available data, information, and tools on:
   - *Hydrologic changes and hazards, such as extreme floods and droughts.*
   - *Projected impacts and risks of climate change on long-term water budgets and on ecological resources in a given basin.*
   - *Alternatives to respond to these changes effectively.*
5. Expand the central clearinghouse of data and case studies to support climate change and adaptation planning. Provide information and examples of effective strategies to prepare for climate impacts, including:
   - *Operational changes.*
   - *Engineering and design options.*
   - *Green infrastructure approaches.*
   - *New infrastructure investment.*
   - *Planning.*
   - *Land use controls.*
6. Inform utilities about the Climate Ready Water Utilities Initiative and tools such as the Climate Resilience Evaluation and Assessment Tool (CREAT). Support water utilities, working with the University of Washington's Climate Impacts Group (CIG) and the Climate Impacts Research Consortium (CIRC), to incorporate information on climate impacts into models used in water, wastewater, and stormwater systems planning and site design.

7. Continue to invest in improvements and expansion of online data-sharing systems to provide farmers, water utilities, and other customers with timely information on weather, soil conditions, crop water requirements, as well as water efficiency and conservation practices.

8. Improve information on water use by expanding use of meters and implementing methodologies using satellite imagery and other technologies.

9. Improve understanding of climate change impacts on water resources by supporting expansion and refinement of regional climate impact assessment tools and models developed by CIG, CIRC, U.S. Geological Survey (USGS), and other scientific entities. These tools are intended to cover climate change impacts on surface waters, groundwater recharge and groundwater availability and the interaction between climate, hydrology, and vegetation.

10. Explore cooperative work with regional Climate Science Centers, NRCS, USGS, CIRC, and the Climate Impacts Group. Continue and expand existing monitoring networks, such as streamflow gages.

8. Agriculture

8. Agriculture

Washington's agriculture industry is important to the nation and the world. The combination of diverse climate, soils, and topography creates opportunities for growing a wide variety of crops. Agriculture is practiced in almost every region of the state, and it is the key economic driver and employer in most counties of the state. Washington's agriculture is highly diversified, with more than 300 commodities produced commercially. Washington is the ninth largest grower of crops in the U.S. and first in the production of nine commodities.[128] Further, Washington is the nation's third largest exporter of food and agricultural products.

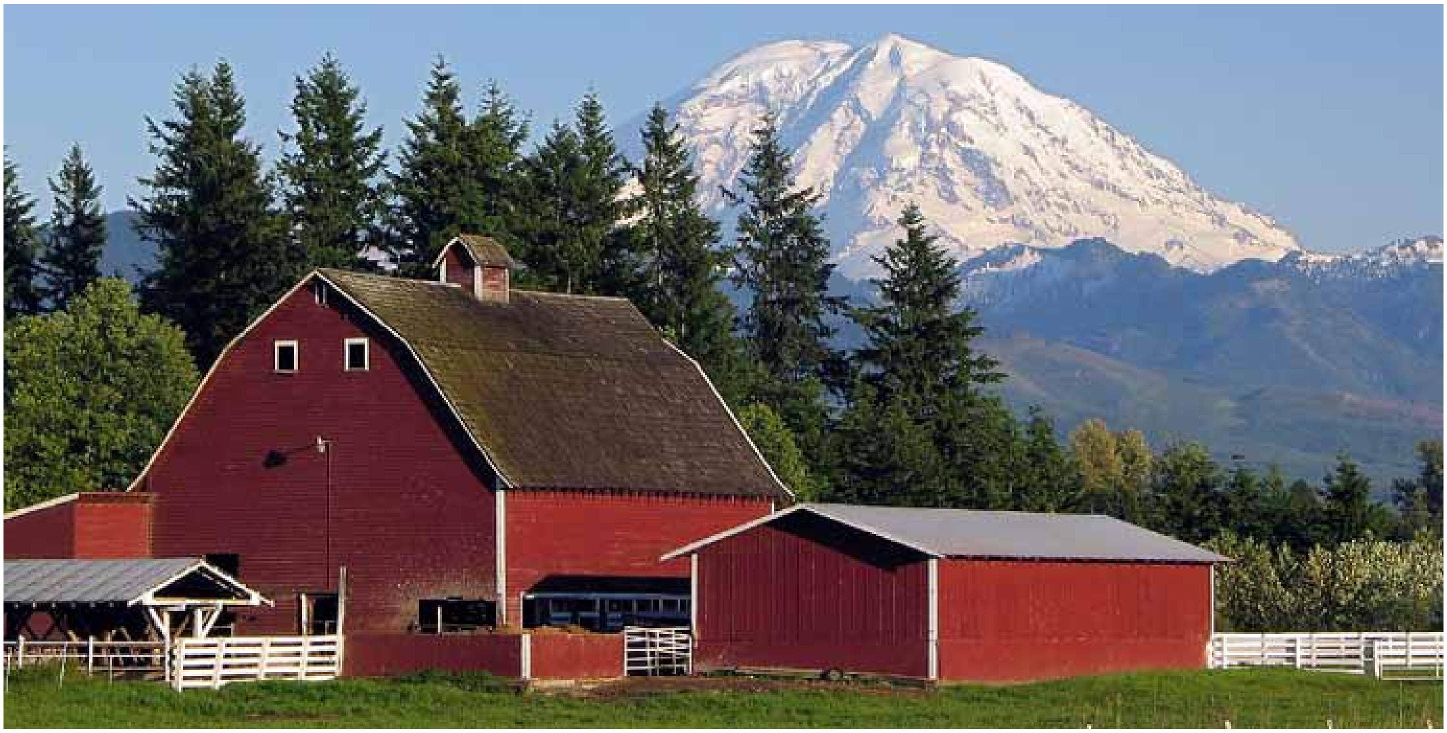
Total farmland was about 15 million acres in 2007, with more than 1.8 million acres under irrigation. Washington's 39,500 farms and ranches produced crops and livestock valued at $7.9 billion in 2010, up from $7.1 billion in 2009. Field crops, livestock, and fruits accounted for most of the state's farm production value. Moreover, farming supports a wide range of economic activities, including a large food processing and distribution industry. The food and agriculture industry contributes 12 percent to the state's economy and employs 160,000 people.[129]

Biofuels such as ethanol and biodiesel are increasingly produced as alternative liquid fuels to replace petroleum-based gasoline and diesel and reduce greenhouse gas emissions. The resulting increase in wheat and other grain prices has benefited some farmers. However, biofuel production has contributed to increased costs and feed shortages for cattle, hogs, and other livestock industries, reducing profitability and increasing consumer prices.

[128] See agr.wa.gov/Marketing/International/Statistics.aspx; OFM (2011).
[129] See agr.wa.gov/AgInWA/Crop_Maps.aspx

Agriculture is sensitive to changing climate conditions and weather extremes, such as droughts, floods, and severe storms. Understanding the implications of climate change on agriculture is important for policymakers, governmental agencies, and agriculture producers. This information will help them to plan and make decisions that sustain productivity and ensure the economic viability of the sector in a changing environment.

The following sections describe the scientific understanding of the impacts of climate change on Washington's agriculture and outline key strategies to support state and local efforts to protect the agricultural sector.



Impacts of Climate Change on Agriculture

Climate change will affect agriculture in a number of ways, depending on the sensitivity of specific crops to the interaction of rising temperatures, changes in water availability, increasing carbon dioxide levels, and more frequent and severe events. Longer growing seasons, warmer temperatures, and higher carbon dioxide concentrations may increase productivity for some crops. But limited water availability along with more weeds, pests and diseases, extreme heat, drought, and flooding will likely negatively affect some crops and livestock.

Different crop zones across Washington support different commodities and agricultural practices, and these zones are likely to have different responses to climate changes. Changes in climate may affect which crops can grow efficiently in the state. For example, some cooler parts of Washington could see an increase in premium grape-growing acreage due to warming.[130] Climate impacts in other regions of the world may also affect Washington's agriculture sector and our global competitiveness.

Some of the key impacts of climate change on agriculture are:

- Changes in crop productivity.
- Decreases in water availability.
- Increased stress from extreme events.
- Reduced livestock productivity.
- Increased stress from invasive weeds, diseases, and pests.
- Global economic impacts from climate change.

1 Changes in crop productivity

Changing climate conditions is expected to alter the geographic regions in which specific crops can be grown. Crop productivity will be affected by several factors, including changes in average temperature and extremes, elevated carbon dioxide levels, availability of water, and stress from weeds, pests, and invasive species. Research on selected crops in Eastern Washington indicates that climate impacts will generally be mild over the next couple decades. Elevated carbon dioxide levels will likely offset some of the negative effects of climate change and result in yield gains for some crops. However, climate impacts will likely be increasingly harmful over time.[131]

[130] See news.stanford.edu/news/2011/june/wines-global-warming-063011.html
[131] Stöckle *et al*. (2010)

The vulnerability of cropping production systems in Washington is highest for crops that have very small windows for optimum performance, for perennial crops, and for farming systems currently on the margin of climatic production zones.

The decrease in snowpack and changes in streamflow patterns will limit the availability of water for irrigated crops. For example:

- The Yakima Basin reservoir system will be less able to supply water to all users, especially those with junior (newer) water rights.
- Average apple and cherry yields are likely to decline by 20 to 25 percent by the 2020s for junior water rights holders, due to lack of irrigation water. The value of apple and cherry production in the Yakima Basin is likely to decline by about $23 million, or 5 percent by the 2020s. [132]

2 Increased stress from extreme events, such as extreme heat, drought, and flooding

Extreme events, such as droughts and heavy downpours, are likely to reduce crop yields and affect livestock productivity. Excessive rainfall can flood cropland, delay spring planting, affect crop quality and quantity, and increase susceptibility to root diseases. It can also cause erosion and increase runoff of agricultural chemicals to surface and groundwater. Low-lying agricultural areas such as the Skagit River delta could be at higher risk of flooding as sea levels rise. [133]

More frequent and severe droughts will limit the water available for crops at the same time that warmer temperatures will increase water demand.

[132] Vano *et al*. (2010).
[133] U.S. Global Change Research Program (2009).

3 Reduction in livestock productivity

Heat and humidity stress pose a significant threat to livestock well-being, especially in confined conditions such as dairy, beef, pig, and poultry operations. A large number of animal mortalities have been reported in recent heat waves, with some states reporting losses of 5,000 head of cattle in a single heat wave in one summer. Heat stress and mortality will likely increase as temperatures rise in Washington. [134]

Warmer temperatures will also affect production efficiency and result in:

- Decreases in voluntary feed intake, leading to reduced weight gains and lower milk production.
- Increases in the energy requirements to maintain healthy livestock.
- Allowing greater proliferation and survival of parasites and disease pathogens.[135]

Studies show that the negative effects of hotter summers will outweigh the positive effects of warmer winters for agricultural production.

Climate change has already disrupted western U.S. rangelands and livestock populations, and the effects are expected to be more severe in the future.[136] Production of animal feed will likely be extended into late fall and early spring. However, quality of animal feed will be negatively affected, water will be limited, species of plants will shift, and plant productivity will decline.[137]

[134] U.S. Global Change Research Program (2009).
[135] U.S. Global Change Research Program (2009).
[136] U.S. Climate Change Science Program and U.S. Dept. of Agriculture (2008).
[137] U.S. Global Change Research Program (2009).

4 Increased stress from invasive weeds, diseases and pests

With higher temperatures and changing precipitation patterns, Washington will likely become increasingly susceptible to invasion by new agriculture pests, invasive weeds, and carriers of human and livestock disease. Warmer temperatures will allow invasive weeds and pests to expand their ranges northward, spreading weeds and pests not previously seen in Washington. These new insects will be able to survive the winter and complete additional life cycles in the longer growing season.[138]

Increases in weeds, insects, and diseases will most likely:

- Increase the cost of crop production.
- Decrease yields and crop quality.
- Increase the costs of controlling weeds.
- Increase risks to food safety, human exposure, and the environment.

For example, in recent years the potato tuber moth has become a major pest in eastern Washington. This invasion is believed to be due to warmer winter temperatures that increase moth survival during the winters, with fewer dying off. Warmer temperatures result in earlier emergence (5 to 10 days) of adults in the spring, an increase in the percent of additional generation that growers would have to control, an increase in control costs, and the potential that moth would develop resistance faster to insecticides.

[138] U.S. Global Change Research Program (2009).

Economic impacts on Washington agriculture

Washington's agriculture industry will likely experience both economic benefits and disruptions from global climate change and global markets. For example, several staple crops consumed in developing counties, such as cereal grains, are major commodities grown in Washington State.

If global climate predictions are realized, the Pacific Northwest will likely be looked upon to provide food to other parts of the world experiencing crop failures due to rising sea levels, heat waves, droughts, floods, and increased pests.

Also, as the purchasing power of people in the most populous countries increases, demand for high-value food crops grown in Washington will also increase.

While these global changes may increase demand for Washington's commodity exports, rising costs of energy and transportation may reduce this opportunity.

5 Economic impacts from global climate change

Other global and local factors will affect Washington's agriculture sector and how it responds to climate change. For example:

- The Pacific Northwest may be called upon to provide food to other parts of the world that are more vulnerable, have food shortages, and are less able to adapt to changes in climate.
- The impact of climate change on the hydropower system will affect the food processing industry. The freezing of fruits and vegetables is Washington's primary food processing industry. This industry is energy-intensive and has depended on the relatively low cost of hydropower in the region.
- Potential impacts of climate change on the state's transportation infrastructure and the cost of fuels will very likely affect Washington agricultural exports. Washington ships about 70 percent of its harvest out of the state, with the nearest major markets over 1,000 miles away. The current global distribution of goods depends on well-developed infrastructure that provides fast, low-cost transportation.

Recommended Adaptation Strategies and Actions—Agriculture

Washington's farmers and ranchers have been successful in increasing agricultural productivity. This success is due in large part to their ability to adapt to changing growing conditions through changes in management practices and in crops or animal selection. However, projected changes in temperature and precipitation and an increase in extreme events (such as drought, heat waves, and heavy downpours) are likely to challenge the effectiveness of current farming practices—affecting crop growth, yields, and livestock productivity.

How the agriculture sector responds to climate change will likely not only affect food production and livestock products but also may impact ecosystems and fish, wildlife and native plants. The four strategies recommended here focus on a number of economically profitable and socially and environmentally acceptable practices. The strategies aim to help farmers anticipate and respond to opportunities and challenges of climate change and extreme weather events. The strategies are grouped according to the following separate but related areas of concern:

- Protection of productive agricultural land.
- Reduction of impacts of severe droughts and floods.
- Prevention and control of invasive species.
- Engagement of agricultural communities in research, data sharing, and adaptation policies and actions.

Strategy E-1. Maintain and enhance agriculture productivity by helping farmers and ranchers transition toward sustainable agriculture.

Actions:

1. Conserve and protect productive and adaptable farmlands by supporting county and city policies and programs that limit sprawl and conversion of agricultural lands to development and facilitate locally-grown food and community garden plots.

2. Maintain agricultural land in production and compensate farmers for the environmental benefits of conservation projects implemented on their lands. Examples of projects include ones that:

   - *Preserve and restore wetlands, riparian corridors, and wildlife habitat.*
   - *Improve water quality.*
   - *Sequester carbon (keep carbon in the soil)*

3. Compensate farmers using mechanisms such as purchases, leases, and establishment of conservation markets. Support the agricultural community in accessing funding programs within various state, federal, and local agencies and conservation organizations.

4. Protect the productivity of agricultural soils from water runoff, erosion, wind storms, and excessive heat through such management practices as:

   - *Direct-seeding.*
   - *No-till farming.*
   - *Reduced-volume irrigation systems.*
   - *On-farm water conservation and storage.*
   - *Biological and organic soil amendments, such as manure and compost.*
   - *Integrated pest management practices.*
   - *Cover-crops and fall-planted crops.*

5. Facilitate access by farmers and growers to technical and financial assistance to implement the practices.

6. Help growers select more economically and ecologically resilient crops, such as:

   - *Pest-resistant crops.*
   - *Drought-tolerant crops.*
   - *Diversified variety of crops.*
   - *Soil and water holding crops, such as alfalfa seed.*

Conservation markets give economic values to environmental benefits and are sold to purchasers, typically land developers required to mitigate impacts of their development projects.

7. Safeguard livestock against the impacts of climate change, and protect livestock by:
    - *Modifying facilities to reduce heat stress.*
    - *Limit the enclosure of livestock during hot weather and allow livestock access to pastures.*
    - *Ensuring properly managed grazing.*
    - *Improving herd performance through good genetic stock.*
    - *Adapting the reproduction season to fit the climate and sources of feed and forage.*
    - *Establishing a herd health program in impacted areas.*
8. Ranchers can be provided with assistance from conservation districts, Washington State University's cooperative extension service, and other agricultural organizations.

Dryland Farming and Climate Change

To address questions related to climate change and dryland agriculture, the region's land-grant universities—Washington State University, Oregon State University, and the University of Idaho—recently received a $20 million grant from the U.S. Department of Agriculture.

Known as Regional Approaches to Climate Change in Pacific Northwest Agriculture (REACCH PNA), this grant will support 20 scientists at the three universities and the USDA's Agricultural Research Service to begin a comprehensive evaluation of the impacts of predicted climate change on the region's cereal grain production.

reacchpna.uidaho.edu/reacchpna

Strategy E-2. Reduce impacts of severe droughts and extreme weather events on irrigated agriculture.

Actions:

1. Increase the ability of the state, local governments, irrigation districts, and other entities to obtain the most up-to-date forecasts of droughts and extreme events. Integrate these forecasts into drought planning and decision-making by policymakers, water users, and water managers. Improve and update existing data provided through federal agencies such as the National Oceanic and Atmospheric Administration, Natural Resources Conservation Service, and National Weather Service as well as universities including the WSU AgWeatherNet Program.

2. Prepare for and respond more effectively to droughts. This may require revising the statutory authority for drought emergency declarations by the Governor. The declaration triggers several drought response activities.

3. Identify highly drought-vulnerable basins, provide advance warning of drought and extreme events, develop drought plans, and enable decision makers to reduce risks and damages from droughts.

4. Enhance water conservation and efficiency activities at the farm and district levels in highly drought-vulnerable basins by expanding technical and financial cost-share assistance programs. These programs help growers reduce irrigation needs and runoff, such as improving water conveyance, improving groundwater infiltration and soil retention/capture, and planting drought-tolerant crops.

5. Improve water reliability and increase water supplies through continued support for integrated basin water management planning and by fostering voluntary transfer of water. (Changes to current statutes may be needed to provide incentives to increase participation of existing water right holders in water transfer programs.)

6. Expand and improve the effectiveness of the state's water right transfer program by seeking statutory changes that provide flexibility and incentives to current water right holders interested in transferring their water to other users.

Strategy E-3. Prevent, eradicate, and control pests, diseases, and weeds potentially harmful to public health, the environment, and agriculture production.

Actions:

1. Implement tracking and monitoring, pest and weed control, and eradication actions. State and federal agencies, county noxious weed boards, and county pest and disease boards should conduct these efforts collaboratively.

2. Provide information to the agricultural community to enable farmers and growers to modify agricultural practices and to adapt to new pests and diseases.

3. Increase awareness and protect pollinator (bees) habitat by incorporating conservation of bee habitat into land management and farm practices that minimize land use impacts on pollinators—including tillage, pesticide use, burning, grazing, cover-cropping, and roadside management.

4. Develop and enhance emergency response plans to manage significant pest outbreaks that harm human health, the environment, and the economic viability of the agriculture sector. These plans should include streamlined approval mechanisms of new biological and chemical tools as well as monitoring.

Strategy E-4. Promote opportunities to engage the agricultural sector and rural communities in developing and implementing new policies, technologies, and practices addressing the impacts of climate change.

Actions:

1. Increase participation of farmers, producers, farm organizations, industry leaders, and rural communities in research, changes to public policies, and implementation of new policies and programs that promote:
   - *Ecosystem services.*
   - *Environmental health.*
   - *Economic profitability.*
   - *Social and economic equity.*
2. Create or enhance existing networks to facilitate rapid transfer and adoption of new knowledge and technologies to help farmers adapt to changing climate, promote sustainability, and benefit the environment, rural communities, and farmers.
3. Engage the agricultural community in research to assess vulnerability of various annual (e.g., cereal grains) and perennial crops, and select crop varieties capable of adapting to expected climate changes.

9. Forests

9. Forests

Climate change is expected to affect Washington's forested landscapes in multiple ways. Forests cover 22 million acres in Washington, or over half of the total area of the state. Approximately 44 percent of forest land is in federal ownership; 13 percent is in state and local ownership; and 43 percent is privately owned.[139]

Washington's forests, timber supply and forest-related industries contributed approximately $16 billion to Washington's economy in 2005 and employed 45,000 people with a total payroll of $2 billion. [140] Forestry is the major employer in many rural communities in the state. The Washington State Department of Natural Resources manages about 2.1 million acres of forested state trust lands, producing about $200 million each year in revenue for designated public beneficiaries such as schools, universities, counties, and other public institutions.

Forests provide environmental and social benefits that Washington residents value, including clean water and air, fish and wildlife habitat, natural open space, and recreation opportunities. Forests also absorb and store carbon dioxide, and timber practices can produce biomass for energy production, in addition to primary forest products.

Biomass fuel:

Plant material, wood, vegetation, or agricultural waste used as a fuel or energy source.

Forests are sensitive to climate variability and change. Warmer temperatures, earlier spring snowmelt, changes in precipitation patterns, and more frequent and severe extreme weather events are expected to change patterns of fire, insects, tree growth, and regeneration in the state. Understanding and accounting for future climate helps support long-term planning to manage and preserve healthy forests and the economic and environmental benefits they provide.

The following sections describe the scientific understanding of the impacts of climate change on Washington's forests and outline key strategies to support state and local efforts to protect forests and lower risks to our communities and ecosystems.

[139] Campbell *et al*. (2010).
[140] Partridge and MacGregor (2007).

Impacts of Climate Change on Forests

Climate change could fundamentally change the nature of forests in Washington, particularly in ecosystems where water shortages are greatest. Disturbances such as droughts, insects, disease, and fire are a natural part of ecosystem dynamics, and some disturbances are integral to maintaining healthy ecosystems. Climate change is affecting when and how often disturbances occur and how large they are, however. These events are likely to significantly alter many forest ecosystems and the animals that depend on them. Climate change is likely to reduce forest health and productivity and alter the geographic range of certain tree species.

Many impacts will likely occur first in forests on the east side of the Cascade mountains, but forests west of the Cascades also will likely experience significant changes in disturbances and species distribution before the end of the 21st century. Human factors—such as changes in land use patterns, population growth, and land and water management practices—also affect forests and could increase the vulnerability of forests to the impacts of climate change.

The key impacts of climate change on forests include:

- Larger and more frequent wildfires.
- Increase in mountain pine beetle outbreaks.
- Changes in geographic range, growth, and productivity.

1 Larger and more frequent wildfires

Fire plays a critical ecological role in many of Washington's forest types, particularly in the fire-adapted dry forests east of the Cascades. However, over a century of fire suppression, extensive logging, and overgrazing have resulted in forest conditions in many areas that are currently at an increased risk of unnaturally severe and extensive disturbance from fire, insects, and disease.[141]

[141] Hessburg and Agee (2003); Hessburg *et al.* (2005); Franklin *et al.* (2008).

Drier, hotter conditions are expected to increase the frequency and magnitude of wildfires. The annual area burned by fire in the Columbia Basin is projected to double or triple from an average of about 425,000 acres annually (1916–2006) to:

- 800,000 acres in the 2020s.
- 1.1 million acres in the 2040s.
- 2.0 million acres in the 2080s.[142]

Widespread areas of dead or damaged trees due to insect infestations make forests vulnerable to large, severe forest fires.

Fire regimes in different ecosystems in the Pacific Northwest have different sensitivities to climate. In forested ecosystems such the western and eastern Cascades, Okanogan Highlands, and Blue Mountains, the area burned is projected to increase by a factor of 3.8 by the 2040s, compared to 1980-2006.[143] In some drier areas, the year-to-year variation will also likely increase. In wetter regions in western Washington, the relationship between fire and climate is weaker, and future fire projections are less certain. However, rising summer temperatures, lower soil moisture, and higher evaporation rates could result in large disturbances in western Washington forests that have not traditionally been considered "fire-prone."[144]

Large, severe wildfires have serious economic and social consequences. On average, $26 million is spent annually (2002-2011) suppressing wildfires in Washington.[145] The true costs of such wildfires may be from 2 to 30 times greater, however, if we account for the myriad adverse environmental and social impacts.[146]

142 Littell *et al*. (2010).
143 Jamison (2012).
144 Littell *et al*. (2010).
145 Cline (2010), as cited in DNR (2010).
146 WFLV (2010).

Impacts of wildfires to plants, wildlife, rivers, human health, and property

Increases in fire frequency could result in shifts in vegetation toward more fire-tolerant species or otherwise alter plant communities that depend on a given fire regime to persist.[147] These shifts could disturb wildlife populations that depend on affected forest habitats, and key wildlife migration corridors may be cut off.

Increased incidence of fire could also reduce the land's ability to absorb and slowly release rainwater, increasing erosion and sediment in rivers. Forest fires could also contribute to human health problems, primarily smoke inhalation, and to damage to houses and public facilities.

2 Mountain pine beetle outbreaks

Mountain pine beetle outbreaks in Washington's lodgepole pine and whitebark pine forests are of particular concern because they are spreading rapidly and migrating to higher elevation trees, killing trees in their path. Temperatures currently leave forests vulnerable to mountain pine beetle outbreaks in large areas of the Olympic Mountains, northern Rocky Mountains, in a mid-elevation band on the west and east sides of the Cascade Mountains, and to a lesser degree in the Blue Mountains of southeastern Washington.[148]

With warmer temperatures and more drought stress, mountain pine beetle outbreaks are projected to increase in frequency. Warmer temperatures allow for more winter survival of insects and pathogens as well as faster insect growth. Warmer conditions also shift their ranges, and drought stress makes trees more susceptible to attack. Mountain pine beetle outbreaks will reach higher elevations as temperatures warm. At lower elevations, the mountain pine beetle could become less of a threat, however, and the total susceptible area for outbreaks could decline. Other insect species may emerge in areas that are no longer suitable for the mountain pine beetle.[149]

[147] Noss (2001).
[148] Littell *et al*. (2010).
[149] Littell *et al*. (2010).

3 Changes in geographic range, growth, and productivity

With increases in temperature and decreases in water availability, the climate will become unsuitable for certain tree species. Conifers such as Douglas-fir, yellow cedar, and western hemlock dominate Washington's landscape, and climatic and elevation gradients strongly influence their distribution. Growth and vigor is expected to decline in Douglas-fir, lower-elevation ponderosa pine, and western hemlock forests.

Douglas-fir: Douglas-fir productivity varies with climate across the region and will potentially increase in wetter parts of the state during the first half of the 21st century, but productivity is expected to decrease in the driest parts of its range. The area that can support Douglas-fir in Washington is projected to shrink by 32 percent by the 2060s and by 55 percent by the 2080s.[150] This decline will be most pronounced at lower elevations, especially in the Okanogan Highlands and the south Puget Sound/southern Olympics.

Pine forests: About 85 percent of the current habitat for pine will shift outside the climatically suitable range for one or more pine species.[151] This shift will be especially apparent in pine forests in the Columbia Basin and eastern Cascades as early as the 2040s, particularly in parts of the Colville National Forest, Colville Reservation, and central Cascades.[152]

The area of severely water-limited forests is projected to increase by at least 32 percent in the 2020s and an additional 12 percent in the 2040s and 2080s. Geographic patterns of forest productivity will likely change; statewide productivity may initially increase due to warmer temperatures but will then decrease due to increased drought stress.[153]

[150] Littell *et al*. (2010). Actual quote: About 32% of the area currently classified as appropriate climate for Douglas-fir would be outside the identified climatic envelope by the 2060s, and about 55% would be in the 50%-75% range of marginal climatic agreement among models. Only about 13% of the area currently suitable for Douglas-fir would be suitable in >75% of the statistical species models.
[151] Littell *et al*. (2010).
[152] Littell *et al*. (2010).
[153] Littell *et al*. (2010).

Recommended Adaptation Strategies and Actions—Forests

Washington's forests and rangelands provide a significant source of revenue to the state, along with tremendous environmental, social, and ecological benefits such as watershed protection, wildlife habitat, recreation, carbon storage, and biomass for energy production. Forests reduce erosion, recharge aquifers, regulate streamflows, moderate water temperatures, and protect water quality. Urban forests play a significant role in protecting public health from rising temperatures, air and water pollution, flooding, and precipitation runoff. Climate change will not only affect forest health and productivity—it will also affect our ecosystems and the range of goods and services they provide. The following four strategies focus on ways to protect, manage, and restore our forests.

Strategy F-1. Conserve and restore healthy, resilient forests across ownership boundaries and large geographic ranges to minimize the threats from climate change and extreme weather events.

Actions:

1. Develop a comprehensive approach that integrates objectives and actions for preservation of working forests, wildfire management, insects and diseases control, and forest health protection and restoration. Developing the integrated approach needs to occur in partnership with tribal, federal, state, and local resource protection agencies; public land management agencies (Department of Natural Resources, U.S. Forest Service, Bureau of Land Management and others); private forest landowners; nongovernmental organizations; and other stakeholders.

2. Develop a coordinated plan for fire hazard reduction and suppression for at-risk forests to assist policymakers, communities, and jurisdictions with land-management decisions so that forest fire threats are reduced. Information on existing and projected forest health and fire hazard conditions should be widely shared with forest landowners, managers, decision makers, and the public.

Statewide Forest Resource Assessment and Strategy

The 2008 federal Farm Bill required state forestry agencies to conduct a Statewide Forest Resource Assessment and Strategy as a condition of receiving forest landowner assistance funds. Washington State Department of Natural Resources (DNR) completed the forest resource assessment and strategy in June 2010. The assessment identified wildfire hazard reduction and forest health restoration as major issues, with the greatest risk of wildfire in eastern Washington, mountain gap wind zones, and the San Juan Islands.

DNR recently completed its 2010-2014 Strategic Plan (see box on the next page) to guide the agency's focus and new initiatives. Several issues identified in the Statewide Forest Resource Assessment are addressed in the Strategic Plan and can be seen as an expression of agency-wide priorities.

www.dnr.wa.gov/Publications/em_wa_statewide_a_cover_contents_intro_section.pdf

3. Reduce development pressures on forestlands by working with local governments to protect forestlands from conversion, such as through zoning and transfers of development rights. Facilitate implementation of best practices, and engage private landowners through market and investment opportunities.

4. Secure sustainable funding and expand financial and technical assistance to forest landowners. Use an "all-lands" approach for allocating public funding to forest landowners to implement new and modified practices that reduce risks from:

   - *Forest fires.*
   - *Pests and diseases.*
   - *Erosion and sediment loads into rivers.*
   - *Loss of habitat.*
   - *Loss of soil moisture.*

5. Advocate at the federal level for:

   - *Increased funding for the Land and Water Conservation Fund, Forest Legacy Program, and Environmental Quality Incentives Program, which will benefit several states including Washington.*
   - *Passage of the Community Forestry Conservation Act, a bill to authorize tax-exempt revenue bonds for working forest conservation.*

Transfer of development rights (TDR) allows owners of property zoned for low-density development or conservation use to sell development rights to other property owners located in "receiving" zones, such as designated urban areas, that can accept additional density.

DNR's 2010-2014 Strategic Plan: The Goldmark Agenda

The DNR Strategic Plan, known as the Goldmark Agenda, identifies preserving forest cover and protecting working forests from conversion as major goals for the Department. DNR has established several initiatives to support small forest landowners to maintain their land as working forests, advance policies and incentives to maintain private working forest lands and associated jobs, consolidate DNR-managed working forests into strategically positioned blocks that help provide compatible management for neighboring forest lands, and permanently maintain DNR-managed working forests at greatest risk of conversion.

Biodiversity and **habitat conservation** connect with the agency's strategic priorities for **natural area conservation** and **climate adaptation**. In addition, **upland water quality, quantity, and Puget Sound restoration** are central to DNR's responsibilities to regulate forest practices and manage state trust lands sustainability.

www.dnr.wa.gov/Publications/em_strategic_plan_2010_goldmark_agenda.pdf

Strategy F-2. Maintain and protect forest species and genetic diversity across the landscape to ensure long-term conservation of our forest genetic resources and help buffer against impacts of climate change.

Phenology:

Study of periodic biological phenomena, such as breeding, flowering, and migration, especially as related to climate.

Actions:

1. Ensure forest landowners continue to manage for native species and structural diversity. Use current reforestation practices to maintain species and genetic diversity across their forest lands.

2. Build disease resistance in five-needle pines and other tree species with serious disease issues, in cooperation with existing U.S. Forest Service efforts.

3. Maintain and expand participation in tree breeding, testing, and selection programs, such as those operated by the Northwest Tree Improvement Cooperative and the Inland Empire Tree Improvement Cooperative. Ensure that testing by cooperative members incorporates greater geographic diversity and adaptive traits such as cold-hardiness and drought-tolerance.

4. Create a gene conservation plan for tree species in Washington based on vulnerability assessments to climate change of various eastern and western Washington tree species. The U.S. Forest Service has completed a vulnerability assessment for western Washington.

5. Create a cooperative tree seed bank within Washington State Department of Natural Resources to provide for recovery from large-scale disturbances, such as fire or insect outbreaks. This effort may begin with a "virtual" seed bank created with cooperative agreements among landowners who maintain seed inventories and are willing to make their seed available in the event of major disturbance.

6. Build on existing monitoring and evaluation programs to detect problems with tree growth, phenology, reproduction, or tree health.

Strategy F-3. Protect, expand, and manage urban forests to help communities reduce impacts of rising temperatures and extreme precipitation runoff events.

Actions:

1. Expand the Urban Forests Assistance Program (authorized under the Washington State Urban and Community Forestry Act) to help mitigate the impacts of climate change, such as the following:
    - *Airborne pollution.*
    - *Higher water temperatures in urban streams.*
    - *Urban heat island.*
    - *Heat waves.*
    - *Severe stormwater runoff.*
    - *Flooding.*
    - *Erosion.*

Urban Heat Island:

A metropolitan area that is significantly warmer than its surrounding rural areas.

2. Secure sustainable funding sources to build the Urban Forest Assistance Program's capacity to increase participation by cities, towns, and communities in planting and sustaining healthy trees and vegetation in urban areas.

3. Support cities and towns in developing education and community programs to enhance community awareness of the benefits that trees provide—including public health, environmental, ecological, and economic improvements. Support communities in adopting sound tree protection and management ordinances in all communities faced with threats from heat waves, flooding, and landslides.

4. Promote urban forests by engaging cities, communities, neighborhoods, local and state park officials, and volunteers in:
    - *Planting trees more tolerant of heat and drought conditions.*
    - *Implementing effective options for tree watering and maintenance.*
    - *Selecting pest- and disease-resistant trees.*
    - *Removing invasive species.*
    - *Monitoring the health of the trees.*

Strategy F-4. Build capacity and support for maintaining, enhancing, and restoring resilient and healthy forests.

Actions:

1. Build on existing or create new pilot projects, experiments, and research to better understand how forests are likely to respond after severe disturbance events. For example, would a combination of thinning and prescribed fires help vulnerable forests better adapt to fire?

2. Strengthen existing partnerships and build new collaborations across jurisdictions to share knowledge and information on climate change impacts and adaptation across all sectors and across broad landscapes of varying ownerships and jurisdictions. This approach is referred to as an all-lands approach.

3. Increase coordination and collaboration with federal and tribal governments, the scientific community, and private conservation groups to ensure that research and management strategies address Washington's forest needs and recognize the important social, economic, and environmental benefits of forests.

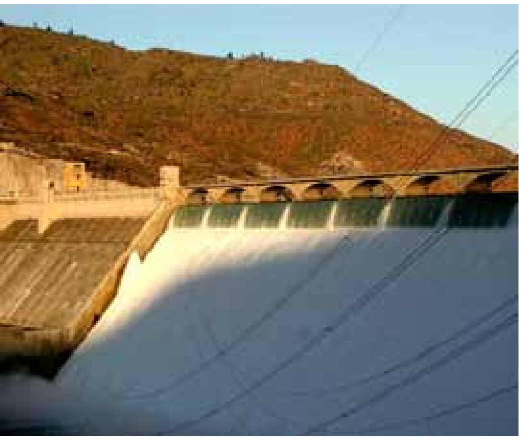
4. Improve forest health and reduce forest hazard conditions by providing information to landowners, policymakers, and the public about wildfires, pests, and diseases—and benefits that forest ecosystem services provide.

5. Improve understanding and communication of impacts and adaptation responses by engaging all levels of government, stakeholders, and the public in adaptation planning and decision-making affecting forests.

6. Integrate messages about the benefits of forest ecosystem services into education programs and curriculum related to natural resources management, environmental protection, urban planning, economics, and other programs.

7. Coordinate development and maintenance of integrated long-term, large-scale monitoring of early-warning indicators of species responses, including range shifts, population status, and changes in ecological systems functions and processes.

10. Infrastructure and the Built Environment



10. Infrastructure and the Built Environment

Maintaining safe and reliable infrastructure is critical for Washington's economy, environment, and way of life. This chapter addresses climate impacts and strategies to prepare our transportation, energy, communities, and communications infrastructure for a changing climate. Coastal and water infrastructure are addressed more fully in Chapter 6, **Ocean and Coastlines**, and Chapter 7, **Water Resources**.

Washington's infrastructure is vulnerable to a changing climate. Infrastructure systems are designed and maintained based on our past and current experiences. For example, bridges are built to allow logs and other debris to pass under during anticipated high flows. Climate change is moving us beyond the range where past experience is a good guide for what we might experience in the future. Climate change could both create new challenges and exacerbate our current challenges in managing infrastructure systems for coastal erosion, flooding, unstable slopes, higher temperatures, and extreme events.

Climate impacts could:

- Increase maintenance and repair costs.
- Affect public safety.
- Interrupt critical evacuation routes and energy supplies.
- Cause travel delays and disruptions.
- Disrupt economic activity.
- Degrade our quality of life.

The impacts of climate change will vary across the state depending on geography, topography, and the capacity of different communities to adapt. Recognizing the risks associated with climate change is an important first step toward better planning of new infrastructure investments and mitigating potential damage to existing infrastructure.

Because infrastructure is designed to last for decades, it is important to consider climate change in planning and design. The high costs and length of time it takes to alter infrastructure means that, for responsible asset management, we must begin to take into account future climate conditions now. The work we do to prepare for and adapt to our changing climate will protect taxpayer investments and our vital infrastructure systems for conditions both today and in the future.

The following sections describe the scientific understanding of the impacts of climate change on Washington's infrastructure and built environment and outline key strategies to support state and local efforts to protect them and lower risks to our communities.

Impacts of Climate Change on Infrastructure and the Built Environment

Climate change is expected to increase the risk of flooding and damage to infrastructure and communities, resulting in travel delays and disruptions to transportation, energy, communities, and communications systems.

- Sea level rise and storm surge will increase the risk of flooding, erosion, and damage to coastal infrastructure.
- More extreme precipitation will increase the risk of flooding, landslides, and erosion, which may damage or disrupt infrastructure systems and overwhelm drainage structures.
- Warmer temperatures and heat waves could strain energy and transportation systems—though they also offer benefits such as reduced snow and ice removal costs.
- Prolonged low summer flows could affect river navigation.
- Lower summer streamflow will reduce summer hydropower production at a time when warmer temperatures will increase electricity demand for cooling.
- Larger and more intense forest fires could damage buildings, roads, and other infrastructure.

Our infrastructure is an interconnected network, which will require an integrated approach to addressing climate change impacts. Utility lines are often strung along bridges or within the road right-of-way. Parts of our energy distribution systems, like fuel delivery for vehicles and for heating rely on road networks.

Many climate impacts are common to all types of infrastructure. For example, rain or sea-level inundation could flood underground equipment and instruments associated with power stations, telecommunication and cable boxes, and traffic signals for all modes of transportation. Increased flooding and landslides would affect operations and maintenance of many types of infrastructure.

1 Transportation systems

Climate change impacts pose significant challenges to our transportation system. Sea-level rise and storm surge will increase the risk of major impacts to vulnerable transportation infrastructure along coastlines. Airports, rail lines, roads, and other structures in low-lying coastal areas will be at a higher risk of temporary or permanent flooding and erosion.[154] Closures and travel delays could increase, especially in densely populated areas near the coasts. Evacuation routes along the coast could be washed out. Washington's seaports and the connected distribution networks will face higher risks of flooding. Together, these impacts could significantly affect communities and economic activity along the coasts.

Extreme weather events are becoming more frequent and intense, and they pose major challenges for transportation. Heavy downpours have increased by 25 percent in magnitude in the Puget Sound region over the past 50 years, and they are projected to continue to increase.[155] When combined with changes in streamflow, population growth, and development pressures, this change could increase the risk of flooding, weather-related accidents, delays, and traffic disruptions.[156] In 2007, flooding closed a 20-mile section of Interstate-5 in the Chehalis Basin for four days, resulting in $47 million in lost economic output to the state. The 2007 storm caused approximately $23 million in damages to interstate and state highways in Washington as well as $39 million in damages to city and county roads.[157] More severe flooding will increase the risk of damage to bridges and could overwhelm drainage structures, such as culverts.[158] The risks to public safety will increase, along with the risk of major economic impacts from closures and delays.

More heavy downpours and more precipitation falling as rain instead of snow could increase the risk of landslides and slope failures, leading to more frequent road closures and higher maintenance costs.[159] In 2010, nearly 130 Amtrak Cascades passenger trains were delayed or canceled because of mudslides and hillside washouts. In 2011, the number of

[154] U.S. Global Change Research Program (2009).
[155] Rosenberg *et al.* (2009)
[156] U.S. Global Change Research Program (2009).
[157] Washington State Department of Transportation (2008a).
[158] Washington State Department of Transportation (2008a).
[159] Washington State Department of Transportation (2008a).

delays and cancelations had doubled by October.[160] Along the 466-mile route for Amtrak Cascades, more than 60 areas have been identified as at risk for mudslides. The closures also affect Sound Transit's Sounder, the Amtrak Coast Starlight long-distance train, and BNSF (Burlington Northern Santa Fe Corporation) Railway freight trains. These types of events will potentially become more common.

An increase in extreme heat can negatively affect pavements, rails, striping, and other materials. Infrastructure impacts include:

- Heat-related buckling of pavements and rails.
- Traffic-related rutting of pavements.
- Thermal expansion of bridge joints.

Rising temperatures could benefit our transportation system by reducing road closures and costs for snow and ice removal. The temperature changes for our region are unlikely to cause catastrophic failures; rather, the change in conditions can be addressed through selection of materials that can withstand the new temperature norms.

Larger and more severe wildfires will increase risks to traffic operations and safety by obscuring visibility for drivers. Large fires can sometimes create enough smoke to require closure of roadways, limiting mobility and creating economic impacts.[161] Fires and insect damage can also have a secondary impact of reducing vegetation coverage, leading to increased erosion and landslides that can erode or cover roadways during or following heavy rains and snowmelt.[162]

Climate risks to our transportation infrastructure will vary by location. Effectively preparing for climate change requires an improved understanding of the areas and assets at high risk. The Washington State Department of Transportation (WSDOT) recently completed work to pilot a risk assessment model developed by the Federal Highway Administration. As part of the pilot, WSDOT completed a qualitative assessment and initial screening of state-owned transportation infrastructure vulnerable to climate impacts. The results of the assessment will be used to help prepare for future conditions and incorporate climate information into decision-making. (See box on page 162 for more information.)

[160] See wsdotblog.blogspot.com/2011/10/wsdot-takes-mudslides-head-on-to.html
[161] Hamlet *et al*. (2011).
[162] Hamlet *et al*. (2010).

2 Energy systems, supply, and use

Climate change is expected to alter the supply and demand for energy in Washington State (see Table 2). Shifts in the amount and timing of streamflow are expected to lead to substantial changes in seasonal hydroelectric power generation, which supplies two-thirds of the state's electricity needs. Winter hydropower production is projected to increase, and summer hydropower production is projected to decline.

Extreme heat wave events are likely to increase in frequency, generating an increase in the peak demand for electricity for air conditioning and industrial cooling in the summer. The increase in summer demand will coincide with a decline in summer hydropower availability.

Warmer temperatures will decrease demand for heating in the winter, which is primarily from natural gas. Because of expected growth in population, however, the overall demand for winter heating is still projected to increase.

Year	2020s	2040s	2080s
Summer hydropower generation	Decrease 9-11%	Decrease 13-16%	Decrease 18-21%
Winter hydropower generation	Increase 0.5-4%	Increase 4-4.2%	Increase 7-10%
Annual hydropower generation	Decrease 1-4%	Decrease 2.5-4%	Decrease 3-3.5%
Winter demand for energy for heating*	Decrease 11-12%	Decrease 15-19%	Decrease 24-32%
Summer demand for energy for cooling*	Increase 92-118%	Increase 174-289%	Increase 371-749%

Table 2. Projected changes in hydropower generation and energy demand compared to 1917-2006 (not including population growth).

**Figures are for a fixed year 2000 population. Population growth is projected to increase winter demand for energy for heating and summer demand for energy for cooling.*

Source: Hamlet et al. (2010).

Climate change is also likely to affect the potential to generate electricity from other renewable energy sources besides hydropower—such as wind, solar, and biomass (plant-based sources)—although these effects are not well understood.[163]

Sea level rise, storm surge, and extreme weather events could increase the risk of flooding and damage to energy production and delivery systems, such as power plants, transmission lines, pipelines, and oil refineries. More storm activity could increase the cost of power and infrastructure maintenance and lead to more, longer blackouts and disruptions of services. Extreme heat could affect transmission efficiency. Declines in summer streamflows could also threaten supplies of cooling water for thermal power plants.

3 Communities and development

Climate impacts will also affect local communities and the infrastructure they depend on. Commercial and residential buildings near floodplains or along the coast could face higher risks from flood damage. Heavier downpours could strain the capacity of stormwater systems, creating backups and flooding and increasing the risks of combined sewer overflows that pollute rivers, lakes, and Puget Sound. Climate risks will vary by location and will affect decisions about land use and development patterns.

4 Communications infrastructure

Along the coasts, inundation from sea level rise and flooding may affect access chambers, vaults, and other underground communications facilities. Increased storm activity may raise the cost of telecommunications supply and infrastructure maintenance, due to increased frequency and length of network outages and disruption of communication services.

[163] U.S. Global Change Research Program (2009).

Recommended Adaptation Strategies and Actions—Infrastructure and the Built Environment

Moving forward to protect our infrastructure minimizes risk and helps ensure that infrastructure, services, and operations remain effective in both current and future climate conditions. The five adaptation strategies and actions presented below emphasize building on existing work to identify risks and vulnerabilities and taking proactive measures to prepare for risks.

Adaptation approaches vary based on the risk and importance of the infrastructure, and efforts may include:

- Protecting infrastructure by strengthening dikes and levees and by using other hard or soft structural approaches.
- Strengthening infrastructure to better withstand climate impacts (such as flooding or extreme heat) through improved materials, design, and construction techniques.
- Raising or elevating infrastructure to protect it from flooding.
- Relocating, decommissioning or abandoning selected infrastructure where the costs of protection and maintenance outweighs the benefit.
- Care must be taken to avoid approaches that have negative impacts on fish and wildlife or cause unintended consequences.

To protect infrastructure, we must also integrate consideration of climate change impacts and adaptation into existing planning, operations, and investment decisions at the state and local levels. These include plans related to:

- The Growth Management Act.
- The Shoreline Management Act.
- Emergency preparedness and response.
- Transportation.
- Energy.

Because land use drives the location of substantial public investment, care should be used in planning where future development occurs. Availability of data, mapping, resources, and the policy guidance would allow each local government to determine the appropriate set of decisions for its situation and likely impacts.

Adaptation responses require coordination among multiple jurisdictions and private entities that own and operate infrastructure, respond to emergencies, and engage in long-range planning related to land use, transportation, energy, and emergency preparedness.

Strategy G-1. Protect vulnerable infrastructure and ensure it is safe, functional, and resilient to climate impacts.

Actions:

1. Develop a common framework and methodology for transportation infrastructure risk assessment at a regional scale and for all transportation modes and operations.
2. Encourage local, regional, tribal, and federal governments and private entities to prepare detailed inventories and climate vulnerability assessments to identify critical and vulnerable infrastructure within their jurisdictions.
3. Work with ports to determine short- and long-term strategies to protect port infrastructure and transportation linkages to ensure movement of commerce and international trade.
4. Encourage owners and operators of critical energy infrastructure to evaluate vulnerability to the impacts of climate change, including risks of damage and the potential for disruptions and outages from flooding, sea level rise, extreme heat, erosion, and extreme weather events.
5. Adopt regulatory and incentive programs to encourage state, tribal, and local transit organizations; public works departments; utilities; and other partners to demonstrate awareness and, where possible, consistency with efforts to address vulnerable systems.
6. Work with the insurance industry to identify and implement mechanisms to reduce risks to property owners from climate-related hazards and to educate consumers on ways to reduce exposure to risk.

Washington's Transportation Infrastructure

The Washington State Department of Transportation is one of five entities that the Federal Highway Administration funded to "test drive" its draft vulnerability and risk assessment conceptual model for transportation infrastructure.

WSDOT conducted the statewide assessment on state-owned and managed infrastructure, using data from the University of Washington's Climate Impacts Group. Through workshops and the FHWA model, WSDOT found vulnerable infrastructure across the state. Most of our newer bridges are resistant to climate changes—some can withstand a sea level rise of up to 4 feet or more.

In some areas, however, road approaches to bridges appear more vulnerable than previously thought. From the data and maps that came out of the workshops, WSDOT can see where climate changes are likely to intensify the threats already facing our transportation facilities.

www.wsdot.wa.gov/SustainableTransportation/adapting.htm

Strategy G-2. Guide future development away from areas at risk.

Actions:

1. Gather and provide the best available scientific information on climate impacts and areas at high risk from flooding, seawater inundation, landslides, extreme heat, and wildfires. Provide information for a range of climate scenarios, for all regions in the state and on a basin-by-basin basis, using consistent data from the UW Climate Impacts Group and other reputable sources. Make the information available and readily accessible to citizens, businesses, local governments, tribes, and others to assist in making informed decisions to prepare for and adapt to climate impacts.

2. Develop guidance as well as regulatory and incentive programs to encourage state and local governments to limit new development in high-risk areas and to incorporate projected climate change impacts and adaptation actions into long-term planning, policies, and investment decisions. These policies and plans include regional or countywide planning policies, comprehensive plans, shoreline master plans, development regulations, and urban growth area expansions.

3. Determine how to consider potential climate impacts and adaptation options for non-project and project actions, as part of the State Environmental Policy Act.

4. Encourage the federal government to accelerate modernized flood mapping and implement fundamental reforms to the National Flood Insurance Program to incorporate risks from climate change.

5. Limit new development in floodplains and coastal areas vulnerable to sea level rise and return some coastal and floodplain areas to natural conditions.

6. Encourage local jurisdictions to identify and implement ordinances and other approaches to reduce wildfire risks.

Strategy G-3. Reduce or avoid climate risks by considering climate in the planning, funding, design, and construction of infrastructure projects and by promoting improved design and construction standards in areas vulnerable to climate risks.

Actions:

1. Develop a framework to guide the state's planning and investments to:
   - *Protect, repair, elevate, or decommission vulnerable infrastructure.*
   - *Protect safety and key evacuation routes.*
   - *Protect critical transportation facilities and corridors for the movement of people and freight, both within Washington and to nearby states and Canada.*
   - *Address potential financial, social, and environmental impacts.*
2. The framework should identify a process to decide when the state will not invest in at-risk projects with a long lifespan.
3. Require incorporation of climate impacts and response strategies in the state's long-range transportation plans; mode-specific plans for highways, rail, aviation, and ferries; and regional transportation plans.
4. Develop transportation design and engineering guidance to minimize climate change risks. The design guidance should be used when siting and designing new transportation infrastructure and project-related infrastructure, such as stormwater treatment and flow control, wetlands protection and mitigation, and fish passages. The guidance should provide information on techniques and materials resistant to increased heat and other climate impacts.
5. Require consideration of climate risks and response strategies in the site selection, design, and construction of state-funded infrastructure projects.
6. Advance the adoption and enforcement of progressive building codes and design standards to reduce vulnerability of structures to climate-related hazards.

7. Provide incentives to incorporate climate risks and response strategies in the design of commercial and residential buildings. Promote strategies and technologies, including those that:
   - *Reduce energy and water use.*
   - *Accelerate deployment of smart-grid technologies—using electronic control, metering, and monitoring to reduce energy use (see box on page 167).*
   - *Maximize rain and snow seepage into the ground, which reduces runoff and replenishes groundwater, using green infrastructure and low-impact development approaches.*
   - *Collect rainwater onsite.*
   - *Maximize open spaces to reduce urban heat effects.*
8. Identify and provide financial incentives to property owners to reduce exposure to risk, such as low-cost loans or financial incentives to rebuild—or relocate—according to improved construction standards, increased setbacks, or elevation of the structure.

Green infrastructure encompasses the preservation and restoration of natural landscape features, such as forests, wetlands, floodplains, and natural drainage features. At the site scale, it involves low-impact development (LID) and sustainable building features, such as rain gardens, green roofs, permeable pavement, rainwater harvesting, urban forestry, and preservation of green open spaces such as parks and wetlands.

Benefits of green infrastructure include:

- Better management of stormwater runoff.
- Lower incidence of combined sewer overflows (CSOs).
- Water capture and conservation.
- Flood prevention.
- Storm surge protection.
- Defense against sea level rise.
- Accommodation of natural hazards.
- Reduced ambient temperatures and urban heat island effects.

For more information:

www.ccap.org/green_infrastructure.html

Strategy G-4. Enhance the preparedness of transportation, energy, and emergency service providers to respond to more frequent and intense weather-related emergencies.

Actions:

1. Incorporate information about climate impacts into state and local emergency planning efforts, including the Comprehensive Emergency Management Plan, the State Hazard Mitigation Plan, and the Hazard Identification and Vulnerability Analysis.
2. Bolster contingency plans for key critical transportation, energy supply and distribution networks, telecommunications, and water infrastructure at risk.

3. Identify and protect critical evacuation routes. Coordinate emergency evacuation planning among adjacent cities and counties.

4. Improve systems to provide engineers, public works, and maintenance staff with early warning of problems, engage onsite protections in advance of an emergency, and provide early warning to the public. Revise existing systems—or develop better systems, such as using sensors and smart technologies—for monitoring:
   - *Bridge abutments.*
   - *Land slopes.*
   - *Stormwater runoff and drainage systems.*
   - *Real-time flood levels and storm surge.*
   - *Other climate impacts on infrastructure.*

5. Adjust routine operations, maintenance and inspection, and capital budget expenses to prepare for more frequent and intense storms, floods, landslides, wildfires, and extreme heat events.

6. Seek more reliable funding mechanisms to ensure that local governments can safeguard vulnerable populations, especially during heat waves. Provide incentives to prepare for energy supply interruptions and develop backup systems in schools, clinics, and emergency shelters.

7. Foster interaction with communication service providers to improve reliability of emergency services during extreme weather events, encourage communication companies to identify alternative means of communication during emergencies, and seek incentives for new technology to diversify and decouple communications from electric grids or otherwise improve their resilience.

Strategy G-5. Build capacity of the energy sector to respond to climate-related disruptions and meet potential increases in energy demand and changes in supply.

Actions:

1. Continue to consider climate-related changes in energy supply and demand, system reliability, and in the State Energy Strategy and the Northwest Power Plan. Encourage utilities to consider potential climate impacts in integrated resource plans.

2. Require consideration of climate risks in relicensing existing and siting new energy projects.

3. Aggressively increase energy efficiency and conservation efforts.

4. Encourage additional research into the impacts of climate change on alternative energy sources. Identify how future climate impacts could affect the state's renewable energy goals , and work with utilities to ensure that renewable energy and energy conservation goals are met.

5. Encourage the development of small energy sources on site (e.g., solar panels) to increase reliability by having redundant systems and to reduce risks associated with the long-distance transmission of energy.

6. Construct stronger, more resilient transmission and distribution systems to improve system reliability and to create additional capacity and redundancy.

7. Adjust reservoir management to account for climate impacts—either too little water or too much water—in considering multiple objectives for energy production, agriculture irrigation, flood management, fish flows, and other needs.

What is Smart Grid?

Smart Grid is an advanced telecommunications and electric grid with sensors and smart devices linking all aspects of the current grid—from generator to consumer—and delivering enhanced operational capabilities that:

- Provide users with the information and tools necessary to respond to electricity grid conditions, including price and reliability, through the use of electric devices and new services.
- Ensure efficient use of the electric grid, optimizing current assets while integrating emerging technologies such as renewable energy and storage devices.
- Enhance reliability by protecting the grid from cyber attacks, increasing power quality, and promoting early detection and self-correction of grid disruptions.

For more information:

www.pnwsmartgrid.org/

11. Research and Monitoring

11. Research and Monitoring

In the Pacific Northwest, a wide body of research exists on the impacts of climate change. The Climate Impacts Group (CIG) at the University of Washington has taken several steps to improve science/policy interactions through multiple methods and interdisciplinary approaches. In 2009, CIG completed a comprehensive assessment on the impacts of climate change on Washington and the implications for nine key economic sectors in the state. CIG also worked with several water management agencies in Washington to determine the effects of climate change on water resources, including development of hydrologic climate scenarios for nearly 300 streamflow locations in the Columbia River Basin and selected coastal drainages in western Washington.

Over the past few years, universities, regional organizations, federal and state agencies, local communities, tribes, and nongovernmental organizations formed several new partnerships. These collaborations are working to improve regional climate science projections, expand and coordinate scientific research and monitoring, and provide best available information to policymakers, managers, and the public.

State agencies need to be involved with various regional research organizations to ensure that scientific research agendas developed by the organizations can apply toward reducing Washington State's vulnerability to climate change and climatic extremes. Identifying the need for additional research and scientific information involves interactions with local experts, decision makers, and other groups, such as water users and managers, forest fire managers, and the conservation community.

Support is needed for additional research and monitoring to expand our understanding of the impacts of climate change; develop tools to ensure that climate information is accessible, relevant, and useful for decision makers and resource managers; and allow managers to track how climate change is progressing and how natural and human systems are responding. Tools that effectively incorporate past and future climate changes into land and water management are critical to making good decisions affecting natural and built systems. Also, new and improved partnerships are needed to tailor scientific information to local decision-making needs.

Improving our capacity to respond to climate change may require new monitoring networks or the expansion or adjustment of existing monitoring systems. Monitoring information can be used to refine and test the models and assumptions we use for projecting future climate changes. Monitoring networks that agencies and others currently manage are typically not well-coordinated and integrated, nor are they adequately funded to clearly focus on climate change and climate variability. Better integration is needed to ensure that monitoring data are easily accessible and can be shared.

Recommended Strategies and Actions—Research and Monitoring

Strategy H-1. Improve scientific knowledge and ensure that climate science is responsive and applied to the needs of policymakers, managers, planners, and others.

Actions:

1. Solicit input from local governments, tribes, businesses, nongovernmental organizations, and other stakeholders to identify needs for data, information, and resources that would foster their understanding of the risks and consequences of climate change at the regional, state, and local levels.

2. Participate in current research efforts conducted by the UW Climate Impacts Group, Northwest Climate Science Center, Regional Integrated Science and Assessment Center - Climate Impacts Research Consortium (CIRC), the North Pacific and Great Northern Landscape Conservation Cooperatives, and others to ensure the scientific research agenda recognizes Washington's distinctive natural resources and addresses priority needs of the state.

3. Support the periodic update of the U.S. National Climate Assessment for the Northwest and CIG's comprehensive regional climate scenarios for Washington State.

Understanding Washington's marine waters

The Puget Sound Assessment and Monitoring Program is an extensive network of regional scientists who monitor key indicators of water and sediment quality, nearshore habitat, and the health or abundance of fish, seabirds, shellfish, and marine mammals. With more than 25 years of water quality monitoring—including temperature, pH, and sediment—we are in a unique position to assess status and trends in our waters. This long-term monitoring lets us know if our waters are healthy or impaired and tracks trends over time.

Ecology's Marine Monitoring Unit conducts a variety of marine observations, including monthly sampling at 40 core monitoring stations. Ecology uses a floatplane to take photos of Puget Sound water conditions during routine transit flights between the Kenmore base and Olympia.

"Eyes Over Puget Sound" is the result, and the effort provides an example of how we are optimizing our resources to monitor Puget Sound. "Eyes Over Puget Sound" combines high-resolution photo observations with satellite images, data collected en route on ferries traveling across Puget Sound and to Vancouver Island, and measurements from moored instruments.

For more information:
www.ecy.wa.gov/programs/eap/mar_wat/mwm_intr.html
www.ecy.wa.gov/programs/eap/mar_wat/eops/

Strategy H-2. Partner and collaborate with state, federal, tribal, and local governments and various organizations to enhance existing monitoring systems, and develop new systems where needed to monitor the impacts of climate change and the efficacy of adaptation responses.

Sentinel sites are monitoring stations for which long-term monitoring data are available.

Actions:

1. Establish an extensive network of sentinel site monitoring stations at locations that are not expected to be subject to local land use changes. Include continuous monitors that track multiple measures, such as temperature, water quality and stream flows, at sentinel sites and at selected long-term ambient monitoring sites.

2. Take measurements in and around streams to:
   - *Assess hydrologic effects to stream channels from extreme storm events, including measuring the geometry and sediment composition of stream channels.*
   - *Assess biological integrity with regard to climate change impacts, such as monitoring of sediment-tolerant/intolerant organisms (taxa) and heat-tolerant/intolerant organisms.*
   - *Assess the stresses to riparian vegetation from dropping water tables and changing temperatures.*
   - *Evaluate signals in hydrology such as those developed by The Nature Conservancy through the Indicators of Hydrologic Alteration (IHA) software.*[164]

3. Work with the U.S. Geological Survey to implement a robust, multi-purpose groundwater monitoring program in Washington State, which will be part of the national groundwater climate response network (CRN).[165]

4. Implement monitoring programs designed specifically to test the effectiveness of adaptation actions and the assumptions underlying proposed adaptation actions. Encourage each agency or partner to monitor the implementation of its respective actions.

5. Collaborate with various agencies to monitor the spread of pests and diseases and to increase the overall efficiency and sensitivity of current surveillance systems.

[164] See http://conserveonline.org/workspaces/iha.

[165] See http://pubs.usgs.gov/fs/2007/3003/pdf/2007-3003-lowres.pdf.

Strategy H-3. Support development and use of applied tools for decision makers and land and water managers to help them understand the risks and consequences of changing climatic conditions on communities, infrastructure, and natural systems; and select effective adaptation options to build resilience.

Actions:

1. Share existing tools with local governments, state and tribal agencies, and local communities to help them understand key vulnerabilities to climate impacts and what actions can be taken. Examples include the Climate Ready Water Utilities Toolbox, Georgetown Climate Center sea level rise tool, and other tools. Incorporate climate change considerations into existing planning tools that evaluate the effects of alternative land use policies, such as ENVISION, INVEST, and models from the Natural Capital Project.[166]

2. Maintain the state's climate adaptation clearinghouse and link to other clearinghouses to improve the availability of information.[167] Leverage and link existing efforts to support climate adaptation efforts at the state, tribe, and local levels.

Climate Adaptation Clearinghouse

The Washington Department of Ecology's climate adaptation clearinghouse contains links to information on the impacts of climate change, regional and federal adaptation efforts, and resources to help communities plan and adapt.

www.ecy.wa.gov/climatechange/ipa_resources.htm

[166] See www.naturalcapitalproject.org
[167] See www.ecy.wa.gov/climatechange/ipa_resources.htm

12. Climate Communication, Public Awareness, and Engagement

12. Climate Communication, Public Awareness, and Engagement

To date, the public dialogue on climate change has largely focused on greenhouse gas emissions and reduction strategies. Moving forward, the public discussion needs expand to prepare Washington for the unavoidable consequences of climate change and extreme weather events. Without an informed public conversation, the adaptation strategies and actions will lack the support they need for effective implementation.

Building support to reduce climate risks is proving to be difficult as policymakers, local communities, and the public are currently challenged with urgent issues such as the economy and jobs. The risks that climate change will result in more frequent and severe floods, wildfires, droughts, and other extreme events make it necessary for policymakers and scientists to step up efforts to increase public awareness and build grassroots action.

Climate change is creating a new and dynamic decision environment. Citizens, governments, and businesses need an accurate understanding of the problem and its causes, the likelihood and severity of the impacts, how the risks may affect them personally and collectively, and the costs and benefits of taking action. Communication, education, and outreach are powerful tools that government agencies, private organizations, and nonprofits can use to dispel misconceptions and to bring climate impacts and hazards to the attention of the public.

Recent surveys of Washington's local government officials, planners, and stakeholders highlight the need for more outreach and education about impacts of climate change—for accessible information on how climate change could affect their communities and for insight into effective mechanisms to build resilience and engage the public.

The state Legislature directed Ecology to identify "methods to increase public awareness of climate change, its projected impacts on the community, and to build support for meaningful adaptation policies and strategies." The recommended strategies and accompanying actions described below are intended to:

- Raise awareness about risks and consequences of changing climate trends on various economic sectors, natural resources, and human health.
- Foster dialogue between state and local community leaders, scientists, resource managers, and policymakers on what we can do to prepare for and respond to the threats of changing climatic conditions.
- Engage and motivate organizations and individuals to take action.
- Explore opportunities for collaboration among government agencies, the private sector, and nongovernmental organizations to shape and strengthen future efforts to adapt to climate.

Recommended Strategies and Actions—Climate Communication, Public Awareness, and Engagement

Strategy I-1. Create coordinated and cohesive communication messages and tools on climate change impacts and adaptation, and ensure they are effectively distributed to a wide variety of people and professionals across all levels of government and the public.

Actions:

1. Continue to leverage partnerships between state agencies and research organizations to develop clear and consistent messaging on climate change impacts and adaptation. The messages must connect to other priority issues and resonate with people's core values, such as health, safety, and the economy.

2. Develop targeted climate change risk communication training for use communication staff within by state agencies and other entities.

3. Conduct targeted outreach to state and local elected officials, leaders, and staff to share information and outreach materials, improve the understanding of risks, and inform decision-making.

4. Develop communication materials focused on vulnerable communities that are at high risk and have a low capacity to respond, paying particular attention to low-income and underserved populations.

5. Develop risk maps and decision-support tools to identify climate change risks for specific geographic areas throughout the state.

6. Support additional research to identify how people perceive climate risks, what messages resonate with people, and how people learn and respond to information about climate change.

Strategy I-2. Leverage existing education and outreach networks and integrate communication about climate change.

Actions:

1. Build on existing networks and integrate climate change into current state agency education and outreach efforts related to public health, land use, ecosystems, water resources, coastal management, agriculture, forests, and infrastructure.

2. Use a variety of channels to communicate about climate change, such as:
   - *Web sites, agency listservs, newsletters, and news releases.*
   - *Social media, including Facebook, Twitter, and video clips.*
   - *Meetings of climate educators and climate communicators group.*
   - *Presentations at public events.*
   - *Publications including Frequently Asked Questions (FAQs).*

3. Promote effective integration of climate change education into K-12 educational programs and school curricula.

4. Bolster the network for climate educators, such as hosting peer-to-peer networking events and summits to share and exchange information, experiences, and best practices.

5. Encourage universities and community colleges to integrate climate considerations into vocational and educational training programs. For example, provide training for engineering students to incorporate more frequent and severe weather, flooding, sea level rise, or other climate impacts into design.

6. Build on the existing climate education website hosted by state agencies to provide information on existing tools, materials, and best practices in teaching and learning about climate change.

7. Partner with extension programs to incorporate climate information into community outreach efforts and programs. Build on successful models such as the Washington State University Extension's Carbon Masters program, the Master Gardeners program, and others.[168]

8. Provide peer-to-peer professional training opportunities and encourage sharing of information among levels of government, nongovernmental organizations, and professional associations.

[168] See http://carbonmasters.wsu.edu/ and http://mastergardener.wsu.edu/

Strategy I-3. Engage the public in climate change conversations and solutions for addressing impacts.

Actions:

1. Develop a framework for citizen engagement and action, modeled after the framework developed in 2007 as part of the Governor's climate change challenge.[169]

2. Develop compelling, visual stories and social media to connect climate change impacts to concerns people already have, convey the benefits of addressing climate change, and demonstrate how actions currently underway can address impacts of climate change.

3. Partner with scientists, community leaders, and organizations credible to target audiences and those affected directly by the impacts of climate change when delivering messages on climate change to citizens.

King Tide Photo Initiative

"King tides" occur naturally when the sun and the moon align, causing an increased gravitational pull on the Earth's oceans. The Washington Department of Ecology invites residents and visitors to take photos of Washington's king tides. Documenting how very high tides affect the natural environment and our coastal infrastructure will help us visualize what sea level rise might look like in the future.

In 2010 and 2011, Washington's King Tides Photo Initiative gathered over 400 photos.

Ecology's King Tide website:
www.ecy.wa.gov/climatechange/ipa_hightide.htm

[169] See http://www.ecy.wa.gov/pubs/0801005.pdf

4. Engage the news media and provide information to help citizens make informed choices.

5. Develop "citizen science" initiatives that engage the public in making observations and collecting and recording data on climate change and its effects on communities and the environment. Build on successful initiatives, such as the Washington King Tides Photo Initiative,[170] Washington Sea Grant citizen science initiatives,[171] National Phenology Network, and Audubon's Christmas Bird Count.

6. Improve Ecology's climate change clearinghouse to make the information more accessible and easier to understand. Build off successful models in other states, such as the Cal-Adapt website [172] and link to existing tools, case studies, projects, and portals, such as the Climate Adaptation Knowledge Exchange (CAKE) and the Georgetown Climate Center's Adaptation Clearinghouse.[173]

[170] See http://www.ecy.wa.gov/climatechange/ipa_hightide.htm
[171] See http://www.wsg.washington.edu/citizenscience/projects.html
[172] See http://cal-adapt.org/
[173] See www.cakex.org and www.georgetownclimate.org/adaptation/clearinghouse

Climate Adaptation Knowledge Exchange (CAKE)

Climate Adaptation Knowledge Exchange (CAKE), a joint project of Island Press and EcoAdapt, is aimed at building a shared knowledge base for managing natural systems in the face of climate change. It includes a virtual library of adaptation resources, case studies, a directory of individuals and organizations working on climate adaptation, and tools to help make adaptation decisions.

CAKE website:

www.cakex.org

The Adaptation Clearinghouse

The Adaptation Clearinghouse, developed by the Georgetown Climate Center, seeks to assist state policymakers, resource managers, academics, and others who are working to help communities adapt to climate change. The clearinghouse contains resources, tools, and case studies to help planners understand climate risks and effective response strategies.

Adaptation Clearinghouse website:

www.georgetownclimate.org/adaptation/clearinghouse

Glossary, Bibliography, and Photo Credits

Glossary and Acronyms

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

Adaptive capacity: The ability of a system or species to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Adaptive management: A systematic approach for improving resource management by learning from management outcomes. Adaptive management is an iterative approach in which managers, scientists, and stakeholders work together to evaluate a problem, select and implement strategies, monitor conditions, evaluate the effectiveness of the strategies, and adjust future actions accordingly.

Armored (or hardened) shorelines: Many shorelines have been hardened with concrete, steel, gabions, or armor stone to prevent erosion. Such reinforcement usually results in the elimination of shoreline vegetation and cover that is important to fish and other wildlife.

Biodiversity: The range of organisms present in a particular ecological community or system. It can be measured by the numbers and types of different species, or the genetic variations within and between species.

Combined sewer overflow (CSO): An overflow of stormwater, untreated waste, toxic material, and debris from a combined sewer system that collects sewage and stormwater runoff in a single pipe system. During periods of heavy rainfall or snowmelt, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies.

Dike: An embankment for controlling or holding back water.

Ecosystem: A biological environment consisting of all the living organisms or biotic component, in a particular area, and the nonliving, or abiotic component, with which the organisms interact, such as air, soil, water and sunlight.

Estuary: A partly enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea.

Green infrastructure: Encompasses the preservation and restoration of natural landscape features, such as forests, wetlands, floodplains, and natural drainage features. At the site scale, it involves low-impact development (LID) and sustainable building features, such as rain gardens, green roofs, permeable pavement, rainwater harvesting, urban forestry, and preservation of green open spaces such as parks and wetlands.

Hardened (or armored) shorelines: Many shorelines have been hardened with concrete, steel, gabions, or armor stone to prevent erosion. Such reinforcement usually results in the elimination of shoreline vegetation and cover that is important to fish and other wildlife.

Hypoxia: Low oxygen concentration; used in this context regarding oxygen concentrations in waters such as Puget Sound.

Low-impact development: A planning and design approach to help manage stormwater using on-site natural features to manage rainfall and infiltrate, filter, store, evaporate, and detain runoff close to its source.

Maladaptation: When the negatives of an adaptation action or strategy outweigh the benefits, it becomes a maladaptation. Maladaptation may include strategies that benefit one sector or community at the expense of others; strategies that decrease near-term harm but increase long-term vulnerability; strategies that result in increased greenhouse gas emissions or otherwise increase the rate or extent of global or regional change; economic actions or strategies that reduce incentives to adapt or set paths that limit choices available to future generations.

Managed retreat: The deliberate process of altering barriers or other defenses to allow flooding of a presently defended area. Managing this flooding process helps to reduce risk and negative impacts.

Mitigation banking: The restoration, creation, enhancement, or preservation of a wetland, stream, or habitat conservation area, for the purpose of providing compensation for unavoidable impacts to ecosystem resources that a proposed project would adversely affect.

Phenology: Study of periodic biological phenomena, such as breeding, flowering, and migration, especially as related to climate.

Refugia (or climate refugia): Areas where climate change is likely to occur more slowly or to a lesser extent than other areas, due to physical landscape features, such as north-facing slopes, valleys or other low areas that act as sinks for cold air, or streams fed by deep coldwater springs. These areas provide refuge to species under stress from climate change.

Resilience: The ability of a population or system to bounce back to a condition similar to its previous state following disturbance or change, with core functions and processes intact.

Riparian zone (or riparian area): The interface between land and a river or stream.

Risk: A combination of the magnitude of potential consequences of climate change impacts and the likelihood that the consequences will occur.

Scenario planning: A method used to create and evaluate alternate futures, and to make decisions that are effective and robust across a range of possible futures.

Stormwater runoff: Stormwater is rain and snow melt that runs off surfaces such as rooftops, paved streets, highways, and parking lots. As water runs off these surfaces, it can pick up pollution such as: oil, fertilizers, pesticides, soil, trash, and animal waste. From here, the water might flow directly into a local stream, bay, or lake. Or, it may go into a storm drain and continue through storm pipes until it is released untreated into a local waterway.

Sustainability: The conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations. Sustainability is important to making sure that we have and will continue to have the water, materials, and resources to protect human health and our environment.

Transfer of development rights (TDR): A mechanism that allows owners of property zoned for low-density development or conservation use to sell development rights to other property owners located in "receiving" zones, such as designated urban areas, that can accept additional density.

Urban heat island: Developed areas that are hotter than nearby rural areas. Buildings, roads, and other infrastructure change the landscape and replace open land and vegetation with impermeable dry surfaces. These changes cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures in the landscape. Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variations to which a system is exposed, its sensitivity, and its adaptive capacity. Vulnerability to climate change can be exacerbated by the presence of other stresses.

Zoonotic disease: A disease that can be transmitted from animals to people or, more specifically, a disease that normally exists in animals but that can infect humans.

Acronyms

BLM	Bureau of Land Management
BPA	Bonneville Power Administration
CAKE	Climate Adaptation Knowledge Exchange
CDC	Centers for Disease Control and Prevention
CIG	Climate Impacts Group at the University of Washington
CIRC	Climate Impacts Research Consortium
CREAT	Climate Resilience and Assessment Tool
CRN	Climate Response Network
CSC	Climate Science Center
CZM	Coastal Zone Management
DNR	Washington Department of Natural Resources
ESRL	Earth System Research Laboratory
EQIP	Environmental Quality Incentives Program
FEMA	Federal Emergency Management Agency
FLP	Forest Legacy Program
GHG	Greenhouse Gas
GMA	Growth Management Act
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LCC	Landscape Conservation Cooperative
LID	Low-impact development
LWCF	Land and Water Conservation Fund

NFIP	National Flood Insurance Program
NGO	Nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NW	Northwest
NWS	National Weather Service
OA	Ocean acidification
PSU	Portland State University
RCW	Revised Code of Washington
RISA	Regional Integrated Sciences and Assessments
Risk MAP	Risk Mapping, Assessment, and Planning (a FEMA program)
SLR	Sea level rise
TDR	Transfer of development rights
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
UW	University of Washington
WACCIA	Washington Climate Change Impacts Assessment
WSDA	Washington State Department of Agriculture
WSU	Washington State University

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Washington Department of Ecology

Washington Department of Fish and Wildlife

Washington State Department of Health

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Washington State Department of Transportation

Appendices

  

Appendix A: Advisory Group Members

Built Environment, Infrastructure and Communities Advisory Group

Co-chairs:

- Stephen Bernath, Dept. of Ecology
- Nancy Boyd, Dept. of Transportation

Members:

- Mark Augustyniewicz, Boeing
- Geri Beardsley, Washington State Transit Association
- Kristin Bettridge, Dept. of Health
- Robert Bippert, Dept. of General Administration
- Lloyd Brewer, City of Spokane
- Mike Canavan, Federal Highway Administration
- Chris Carlson, Office of the Insurance Commissioner
- Tom Clingman, Dept. of Ecology
- Joanna Ekrem, Dept. of Ecology
- Paul Fleming, Seattle Public Utilities
- Glen Gaz, BNSF Railway
- Patricia Jatczak, Office of Superintendent of Public Instruction
- Eric Johnson, Washington Public Ports Association
- Allan Jones, Office of Superintendent of Public Instruction
- Sandy Mackie, Perkins Coie LLP, Association of Washington Businesses
- Keith Maw, City of Lynnwood, American Planning Association/Washington
- Joanne McCaughan, Dept. of Commerce
- Mary McCumber, Futurewise
- John Miller, Clallam County
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- Mike Schoonover, Washington Association of Realtors
- John Ufford, Military Dept. Emergency Management Division
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- Alison Van Gorp, Cascade Land Conservancy
- Rick Wagner, BNSF
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- Laura Wharton, King County
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- Dr. Roger Rosenblatt, Physicians for Social Responsibility
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- Cathy Baker, The Nature Conservancy
- Harriet Beale, Dept. of Ecology

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- Rachael Jamison, Dept. of Natural Resources
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- Bob Edzinski, U.S. Forest Service
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- John Stuhlmiller, Washington State Farm Bureau
- David Whipple, Dept. of Fish and Wildlife

Appendix B:

Advisory Group Final Reports and Recommendations

Appendix B1

Washington State Climate Change Response Strategy

Interim Recommendations of the Built Environment:
Infrastructure & Communities Topic Advisory Group (TAG)

January 26, 2011

Built Environment: Infrastructure and Communities Topic Advisory Groups Members

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- Kurt Unger, Dept. of Ecology
- Rick Walk, City of Lacey
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Table of Contents

1. Introduction

Climate change has significant implications for the built environment, infrastructure, and communities in Washington State. Impacts and the ability to adapt will vary across the state and within the individual communities.

- Flooding and inundation of coastal and near-shore infrastructure are expected to increase in frequency and severity due to changes in flood dynamics and rising sea levels. This will likely put critical elements of our transportation infrastructure, ports, businesses and homes, water treatment facilities, stormwater infrastructure, and drinking water supplies at risk.
- Changes in precipitation amounts and patterns are expected to increase existing challenges in supplying adequate water for Washington's communities, agriculture and forestry resources, and ecosystems. Declines in summer streamflow and higher surface temperatures are expected to exacerbate current problems with water quality in the state.
- Increases in average temperature and frequency of extreme heat events are expected to result in increasing energy use in the summer at a time when declines in snowpack are anticipated to result in reduced hydropower resources.

These examples underscore the importance of proactive planning to prepare for and adapt to the impacts of climate change.

The Built Environment: Infrastructure and Communities Topic Advisory Group (TAG)

The mission of the Built Environment: Infrastructure and Communities TAG is to collect and communicate information and to develop recommendations used by the Steering Committee to inform the development of an integrated climate change response strategy for the state. The response strategy will focus on strategies and actions for state government to better enable state, local, and tribal governments; public and private businesses; nongovernmental organizations; and individuals to prepare for and adapt to the impacts of climate change.

The co-chairs and staff recruited members for the group who had a broad representation of interests in the state's infrastructure and who acknowledged the importance of developing a statewide plan for adaptation to climate change for the state's infrastructure.

The TAG's mission is primarily to focus attention on the strategies most relevant and vital to our state's communities and the services provided to those communities by transportation, energy, water, waste, and information infrastructure.

The objectives of the TAG are to:

- Select priority issues to address during the course of the TAG work.
- Summarize, for each selected priority issue, what is known about both the currently observed and projected impacts of climate change and associated adaptive strategies.
- Summarize known key vulnerabilities and risks related to each TAG priority issue.

- Assess the capacity of governments to undertake actions and the barriers to action (administrative, regulatory, and financial) related to each TAG priority issue.
- Identify near- and long-term strategies and actions to implement those strategies.
- Support suggested strategies and identify technical resources and opportunities for partnerships between state, local, and tribal governments; private businesses; NGOs; and federal agencies.
- Review funding mechanisms used in other jurisdictions and recommend funding strategies for Washington that support suggested strategies.
- Develop priority recommendations for monitoring efforts and ongoing research needs.
- Draft a report outlining TAG 1 recommendations.
- Participate in a cross-TAG dialog to identify additional broad and cross-cutting strategies.

Approach for Developing Recommendations

Early in the process, the TAG was polled to determine which infrastructures were most vulnerable to climate change. Seawalls, dikes, and floodgates rated as the most vulnerable, followed by municipal water supplies, and dams. Over time, the following areas emerged in group discussions as either vulnerable to the stressors of climate change or, in the case of sea level rise, that had impacts that affected all types of infrastructure along the coastline:

- Water supply
- Water quality
- Floodplain management
- Energy
- Transportation
- Commerce and ports
- Land use
- Sea level rise

The TAG divided into two subgroups to address issues:

- 1A focused on commerce, transportation, housing, and energy (CTHE).
- 1B focused on water (floodplain, sea level rise, water resources, and water quality).

After working separately, the members combined into the full TAG and worked together to refine goals, objectives, and recommendations.

The TAG met ten times between March 2010 and January 2011. In addition, many TAG members met separately as subgroups to tackle the TAG issues, and some were assigned homework to assist with producing draft products. To a large degree, the willingness of TAG members to commit time outside of the main meetings is the reason the TAG was able to successfully move toward developing a first cut at strategies for adapting the state's infrastructure to climate change.

2. Overview of the Impacts of Climate Change

In 2009 the Climate Impacts Group (CIG) at the University of Washington completed a comprehensive assessment of the impacts of climate change on Washington State, as mandated by the 2007 Washington State Legislature. Using global climate models scaled to the Pacific Northwest, CIG projects that Washington is likely to see:

- **Higher temperatures** – Increases in average annual temperature of 2.0°F by the 2020s, 3.2°F by the 2040s, and 5.3°F by the 2080s (compared to 1970–1999) are projected. Increasing likelihood of extreme heat events (heat waves) that will stress energy and water infrastructure.
- **Enhanced seasonal precipitation patterns** – Wetter autumns and winters, drier summers, and small overall increases in annual precipitation in Washington (+1 to +2 %) are projected. Increases in extreme high precipitation in western Washington are also possible.
- **Declining snowpack** – Spring snowpack is projected to decline, on average, by approximately 28% by the 2020s, 40% by the 2040s, and 59% by the 2080s (relative to 1916–2006).
- **Seasonal changes in streamflow** – Increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow-dominant and rain/snow mix basins, and decreases in summer streamflow are expected. Also, the risk of extreme high and low flows is expected to increase.
- **Sea level rise –** Medium projections of sea level rise for 2100s are 2 to 13 inches (depending on location) in Washington State. (see Appendix A).
- **Increase in wave heights –** An increase in significant wave height of 2.8 inches per year is expected through the 2020s
- **Warmer sea surface temperature** – Sea surface temperature is projected to increase 2.2°F for the 2040s for coastal ocean between 46°N and 49°N, relative to the 1970–1999 average.
- **Ocean acidification** – Continuing acidification is expected in coastal Washington and Puget Sound waters

More information on these impacts, including all related publication references, is found in the summary table prepared by the CIG in Appendix A. The TAG used this information as the basis for developing recommendations.

Our understanding of these climate impacts continues to evolve as models are further downscaled to the regional level and take into account “slow” feedback mechanisms, such as reduced sea ice and permafrost thaw. The choice of any future date for changes to occur is simply a best estimate of future conditions, and does not imply a new end state or slowing of the underlying change dynamic. Even at current levels of atmospheric greenhouse gases, we are locked into a pattern of long-term change that will play out over centuries.

3. Key Vulnerabilities and Risks

Using the information on the impacts of climate change provided by CIG and other reliable sources, the TAG identified the following key elements of our infrastructure and communities that are vulnerable to and at risk from the impacts of climate change:

Key Vulnerabilities

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007). Another way to say this is that vulnerability is a function of impacts and the ability to adapt. The TAG defined "infrastructure" as all public and private facilities necessary for the functioning of the economy and the people who live in Washington. In that context, the group looked qualitatively at which infrastructures are vulnerable to which climate change impacts. In most cases, our infrastructure is, or will be, subject to more than one stressor at a time. For example, a road in the Puget Sound lowlands crossing a floodplain will likely be subject to sea level rise, flooding, overwhelmed culverts, and bed aggradation due to glaciers melting. Each stressor will build upon others.

<u>Sea Level Rise and Coastal Issues</u>

Sea level rise, increases in extreme weather events, flooding, and increases in wave heights are all expected to result in inundation (flooding) of coastal areas, increased erosion of unstable bluffs, a shift of coastal beaches inland, deposition, and intrusion of salt water into freshwater aquifers.

A rising sea level can inundate the transportation infrastructure; ports and their associated facilities; drinking water, waste water, and stormwater facilities; housing; and businesses. Inundation from rising sea levels and heavy surface flow from storms will challenge the capacity of storm drains, natural conveyances (creeks and rivers), and wastewater treatment facilities. In addition, rising seas can inundate freshwater habitats, including wetland mitigation sites tied to infrastructure projects.

Sea level rise may change the nature of coastal community access and local populations and economies. Communities with single road access could be periodically and eventually totally cut off as seas rise without adaptation measures.

Severe storm impacts can include erosion and flooding; failure of urban and suburban services; disrupted transportation, energy, and information lines; and evacuations. Higher sea levels and higher storm surge will steadily increase these impacts. As bluffs are undercut and landslides occur, or as river channels migrate, transportation may be slowed or stopped, port facilities may be jeopardized, and homes may be lost along the coastline.

Heat and Temperature Changes

Average temperatures are anticipated to rise, and seasonal temperature trends may change. Minimum and maximum temperatures are predicted to rise, and the gap between daily highs and lows should decrease in winter and increase in summer. Temperature changes will influence snowpack, stream flow, soil moisture availability, wildfires, air quality, water quality and temperature, and the urban heat island effect. Cities will warm proportionally more than natural areas. Extreme heat events will become more likely, increasing stress on water and energy resources, often at times when those resources are already under stress. Increasing summer temperatures will lead to increased use of air conditioning in existing structures; once this capacity is in place, base loads as well as peak loads will increase.

The glaciers in Washington are receding, leaving bare ground where once there was snow. This results in a larger watershed contributing to flooding and movement of exposed sediment down river channels.

Many water supply systems will not meet the demand for communities, agriculture, and natural resources as they are allocated now. Warmer temperatures and population growth are projected to increase energy demand substantially in the summer, by 165–200% by the 2020s. Energy demand in the winter is projected to increase more modestly, by 22% by the 2020s, primarily due to population growth. Competition will increase between the need for energy and the need for water in streams.

Precipitation, Snowpack, and Streamflow Changes

Across Washington State, we experience annual and seasonal variability in spring snowpack, precipitation, and stream flow. Climate change is expected to result in:

- Decline in snowpack.
- Increase in winter precipitation and decrease in summer precipitation, with lower low flows in summer and higher flood risks in winter for snow-dominant and mixed rain/snow basins.
- More precipitation falling as rain instead of snow, due to warmer temps.
- Snow-dominant basins shift to mixed snow/rain basins, mixed snow/rain basins shift to rain-dominant basins.
- Earlier peak streamflow in spring.

The difference in rainfall and snowfall will vary by location, and impacts will be basin-dependent. Some watersheds will remain rainfall dominant and vary little, while others will shift from snow dominant to rain dominant. This change will affect the timing of water moving through river systems. The snowpack acts as a water reservoir. This water will be less available in the future, which will require adjustment in how water is used for housing, industry, and farming in those basins. This change in the timing of river flows will require more efficient use of municipal, industrial, and agricultural water, and may require other ways to store water for use in summer.

Earlier snowmelt and earlier peak river flows are projected to affect water supplies. By the 2020s, summer production of hydropower is projected to decrease 9–11% and winter production is projected to increase by 0.5–4%. The effect is compounded by population growth and increased summer temperatures, which create high demand during low supply.

Key Risks

In general, there are three risk types for infrastructure: reduced capacity, temporary operational failure, and complete and catastrophic failure. The type of failure will affect how and when society responds.

"Risk" is the evaluation of the likelihood and the consequence of an impact. TAG 1 did not quantitatively address the level of risk for each climate impact. Effects will be location-dependent.

Evaluating the likelihood and magnitude of an impact against the consequences of failure allows for planning in the face on uncertainty. Scenario planning can be used to evaluate risk and indicate the need and timing for action.

A qualitative risk matrix can look something like the following table:

Likelihood	Consequence			
	Complete and catastrophic failure	Temporary operational failure	Reduced capacity	Insignificant
High				
Medium				
Low				

Impacts with a high likelihood of occurrence within a short timeline, and which result in complete and catastrophic failure (red), can be addressed through strategies with a shorter timeline, while impacts with a low likelihood of occurrence and an impact of reduced consequence (blue) can be watched and reevaluated at a later date.

Risk can be evaluated using an asset management approach that is location-specific for the anticipated impacts at that location. Scenario planning can be used in the face of uncertainty to chart a course of action to address risk while further research and monitoring is being done.

4. Unifying Themes and Overarching Strategies to Prepare for and Adapt to Climate Change

Key Principles that Informed the Development of Strategies

The TAG agreed to several principles that guided the approach for developing recommendations and strategies:

- Use the best-available science on the impacts of climate change, and rely on the information developed by UW CIG and other peer-reviewed sources.
- Build from existing knowledge and research on adaptation, including the work of the Preparation and Adaptation Work Group recommendations developed in 2007–2008.
- Identify opportunities to integrate climate science and projected impacts into current planning, decision making, and funding.
- Consider key vulnerabilities and risks to plan for as a result of climate change.
- Reduce the vulnerability and increase the resilience of infrastructure and communities to climate change. Protect vulnerable human populations and ecosystems.
- Develop an integrated approach that considers implications for multiple interrelated components (such as human systems, natural systems, and the economy).
- Include adaptive management approaches that account for changes in science and information over time.
- Identify "no regrets" strategies and strategies with co-benefits. Seek to avoid unintended consequences.
- Apply risk management principles, and seek to recommend actions that are prudent and responsible for public agencies.

Key Overarching Strategies and Unifying Themes

Key overarching strategies and themes identified include:

- A forum is needed for state, regional, and local development of a framework to make decisions on when or whether to defend, adapt, or retreat. The typical life of infrastructure is decades or centuries. In what situation(s) is it acceptable to defend, adapt, or retreat due to climate change impacts?
- Adaptation actions should not increase greenhouse gases (GHGs) or jeopardize mitigation options. Counties and cities should consider the impacts of their mitigation measures. Care should be taken that mitigation does not negatively impact adaptation needs; for example, high-density development in climate risk areas.
- Sustainability Framework**:** Our preferred approach is to evaluate strategies in the context of a sustainability framework. Sustainability can be simply defined, paraphrasing the Brundtland Report, as practices that meet the needs of the present without compromising the ability of future generations to meet their own needs.

- Localized resiliency on the level of individual sites. Innovation and ability to adapt.
- Bolster risk management planning and response capacity, including emergency response systems to include actuarial costs for insurance.
- Land use planning is needed (examine jurisdictional barriers, conflicts, and regional cooperation).
- Communicating with the public and building public literacy, defining and defending leadership; capacity building, and education.
- Research, monitoring, and adaptive management.
- Governance is a cross-TAG issue that must be faced in the integrated strategy. Who decides, how, what is a balance of needs/costs, how to address competing interests among and between neighboring jurisdictions? Partnerships are critical between federal, state, local, tribal, NGO, and private sector entities.
- Integrated decision making, unified approach, bold and compassionate action is needed.
- Need interim strategy to define success – even if it is early. "Action in the face of uncertainty is unavoidable, as is elimination of all potential risk." Adaptive management is critically important to success (NAS Figure 3.3).
- Equity: Climate change impacts will fall unevenly on regions, firms, and populations. Appropriate consideration must be given to sharing the costs of adaptation responses and investments across the entire economy.
- Economics: We can't ignore the marketplace. What are the unintended consequences of recommendations? What are the near- and long-term economic consequences of taking no action to prepare for and adapt to climate change impacts?
- Interim tools and actions are needed that take into consideration future climate scenarios and ranges of uncertainty regarding local and regional impacts.

Key Unresolved Issues to Address / Divergent Viewpoints

SEPA:
The TAG discussed the State Environmental Policy Act in several contexts in regard to the development of TAG recommendations. There was agreement among the TAG that SEPA is one of the tools for considering the impacts of climate change at the planning level (sometimes referred to as the "nonproject level"). TAG members did not reach consensus on whether SEPA is an appropriate tool to use to consider the impacts of climate change at the project level.

Ecology is currently working to address issues regarding how to incorporate climate change into a SEPA analysis. It has developed a draft "working paper" to assist agencies and project proponents in performing an analysis of GHGs and their impacts on the environment as a result of climate change. (See the working paper at: http://www.ecy.wa.gov/climatechange/sepa.htm.)

Members of the group agreed to continue to work with Ecology in its efforts to clarify the role of SEPA and how to use SEPA to evaluate GHG emissions and vulnerability to climate change at the planning and project levels.

The group recognized the difference in the capacity to consider climate change at the project level between state agencies serving as SEPA lead agency and local agencies serving as lead in reviewing private proposals. For example, WSDOT is including available climate projections during the analysis of environmental effects on large transportation projects.

Key Barriers

The TAG identified key barriers to planning for and adapting to climate change impacts. The group considered these barriers and options for addressing barriers as recommendations were developed. Barriers include:

Resources needed

- Funding and capacity is lacking
- Available funding is often in response to emergencies rather than proactive planning and investment

Information needed

- Risk mapping at an appropriate level of detail
- Enhanced monitoring networks to develop better estimates of ecosystem function and support better forecasts of future changes due to climate impacts
- Tools and guidance for communities to self-identify risks and vulnerability
- Clearinghouse of information on adaptive strategies
- Clear articulation of the uncertainties embedded in the tools used to make climate projections.

Legal/regulatory barriers

- Water rights, especially in the context of long-term predictions about increasing demand and decreasing supply
- Stormwater, reclaimed water, and grey water management and reuse
- Land use: property rights, local control fragments response to large issue
- Lack of statewide planning direction on climate adaptation issues and land use planning
- Mechanism to deal fairly with at risk properties and infrastructure
- Cumulative effects
- Lack of mechanisms to address unsustainable trends
- Lack of alignment of state agency missions

Cultural barriers

- Education is needed on future impacts of climate change
- Historic settlement patterns and legal, cultural, economic patterns and the difficulty of implementing change
- Changes to communities and community structure
- Bailouts for property owners who build in threatened areas – insurance issues
- Absence of support structure to encourage abandonment

Economic Issues

- Climate impacts are risks to investment—how to adapt, minimize risks to investment in the short and long term, and not jeopardize economy
- Need to make decisions based on impacts to economic system, infrastructure, communities, and environment

Opportunities for Taking Action

- Federal action on climate impacts and adaptation.
- State, local, and tribal governments increasingly developing adaptation plans, tools, and resources.
    - In the course of the TAG's work, the group examined existing federal, state, local, and sector-specific adaptation plans, as well as tools and additional resources on adapting to climate change. Several new adaptation plans and resources were completed over the course of the group's work, such as the National Academy of Sciences report, "Adapting to the Impacts of Climate Change,"[1] the recently released Swinomish Climate Change Action Plan, and the EPA Climate Ready Utilities toolbox and Climate Ready Water Utilities Working Group report. Where possible, the TAG's recommendations were developed in consideration of these existing resources.
- Many of the TAG recommendations are "no regrets" and address existing challenges.
- New partnerships and resources, such as LCCs, RISA at OSU, new DOI Climate Science Center partnership between CIG, U of Idaho, and U of Oregon.
- Opportunity to develop better tools for evaluating sustainability. As each strategy evolves into specific actions to adapt to climate change, the actions and alternatives can be evaluated against the Sustainability Principles to better understand long-term impacts.
- Align state agency mission statements.
- Minimize near- and long-term economic risks of not taking any action to prepare for and adapt proactively to climate change.

[1] See the report at: http://americasclimatechoices.org/

5. Recommended Adaptation Strategies and Resilience Actions

The TAG developed strategies and actions for each of the eight priority planning areas:

- Water supply
- Water quality
- Floodplain management
- Sea Level Rise
- Energy
- Commerce and Ports
- Transportation
- Land Use

These recommendations are outlined in Table 1. Actions that have been identified may require partnerships at different government levels.

Table 1: Built Environment, Infrastructure, and Communities TAG – Recommended Strategies and Actions

	Strategies	Recommended Actions
WATER SUPPLY (see Appendix B for more detail)		
1	Determine water availability and demand in high-priority basins.	a. Improve statewide water availability and supply and demand forecasting. *(high priority)* b. Develop water budgets in basins that will be impacted by climate change. *(high priority)* c. Clarify water rights and claims through streamlined judicial processes or non-judicial settlement agreements to enable more accurate supply and demand forecasting. (*high priority*)
2	Develop and implement water strategies to manage supply and demand in a climate-changed future.	a. Transition from watershed planning to implementation in high-priority climate change-affected basins: evaluate options to manage supply and demand, exploring a full range of options, including an increased use of water masters (high priority) b. Prioritize low-cost, no regrets options such as conservation, efficiency (i.e., demand management), and expanded use of non-potable water (high-priority strategy, suite of options available). c. Evaluate options such as new supply, timing, and transfers (high-priority strategy, suite of options available). Emphasize water supply options that provide in-stream and out of stream benefits. d. Improve legal and fiscal framework for water banking. e. Improve supply for streamflow mitigation and use through aquifer storage and recovery (ASR) program. f. Obtain water savings through green building legislation, building code updates, and tax holidays.

	Strategies	Recommended Actions
		g. Discourage use of turf grass and other high-water-demand landscaping. h. Develop industrial and agricultural conservation and efficiency standards and continue to improve municipal conservation and efficiency.
3	Integrate climate change into policy and planning efforts.	a. Integrate water supply considerations into land use planning in high-priority basins. *(high priority)* b. Map critical source water and groundwater infiltration areas in order to identify and protect them (for example, through requiring their protection in comprehensive plans). c. Update the definition of "drought" and remove barriers to drought relief to better reflect climate change.
4	Increase monitoring and mapping to better understand the effects of climate change.	a. Increase water use monitoring. *(high priority)* b. Increase water rights mapping. *(high priority)* c. Increase surface and groundwater monitoring. *(high priority)* d. Create and utilize data integration tools. Ensure all data is available in accessible digital formats (GIS).
5	Increase resilience through building and site design.	a. Encourage local storage of rainwater as a component of building design.
WATER QUALITY		
6	Identify areas of potential impacts to water quality.	a. Work with the UW Climate Impacts Group and other experts to determine the priority areas where climate change has a high likelihood of affecting ground and surface water quality using appropriate scenarios. NOTE: There is a need to discern when historical paradigm is not best the indication for the future; for example, when determining 7Q10 low flows or applying temperature water quality standards. b. Update the hydrologic models used in stormwater systems and site design in priority areas.
7	Enhance and expand water quality monitoring strategies. Evaluate changes in priority areas identified in 6a, as funding allows.	a. Develop an integrated groundwater monitoring network to monitor trends and changes in water quality over time in priority areas. b. Monitor water quality in coastal areas at risk for saltwater intrusion and inundation (see Sea Level Rise). c. Integrate climate change assessment needs into Ecology's surface water flow and water quality monitoring network. d. Identify and fund monitoring, modeling, and research needs to evaluate emerging and cumulative impacts of climate change.
8	Create climate-ready utilities.	a. Review the report of EPA's Climate Ready Water Utilities Working Group to determine what recommendations the state may want to adopt. b. Provide water utilities and local governments the resources, tools, and guidance to evaluate risk and vulnerability for water and wastewater systems c. Consider age of facilities and length of useful life. d. Provide utilities the tools needed to increase use and reuse of

	Strategies	Recommended Actions
		non-potable water supplies.
9	Require consideration of the impacts of climate change in the planning and design of water and wastewater infrastructure facilities that are funded by the state, including stormwater facilities	a. When giving state money for water or wastewater projects, ensure climate impacts are considered in planning and design. b. Provide guidance on how to consider climate change impacts in the planning and design of water and wastewater projects. c. Develop guidance on evaluating risk and vulnerability to climate change impacts. d. Leverage federal and other funding options for upgrading emergency sources of supply. e. Include in local risk analyses an assessment of stormwater system capacity to identify priorities for system retrofits in priority areas/basins (6a above).
10	Continue to promote low-impact development (LID) and best management practices (BMPs) for stormwater	a. Continue to incorporate LID practices into stormwater permitting and strengthen stormwater control requirements and incentives for maximizing groundwater infiltration (see Maryland's stormwater law). b. Retain native vegetation on a landscape scale rather than on individual sites. Retain or increase canopy cover of urban and community forests. c. Encourage biofiltration, green roofs, porous pavement, vegetated roofs, and water harvesting. d. Consider retrofitting existing structures to incorporate LID practices. e. Provide information and examples of LID BMPs and link with existing initiatives (e.g., Bullitt Foundation million gallon cistern, Gates Foundation green roof, BMPs). f. Encourage and support use of nonmotorized transportation and alternatives to single-occupancy vehicle transportation. g. Green infrastructure: restoring in a sensible way the predevelopment conditions. Develop ways to retrofit into existing community.
11	Continue to promote use of reclaimed water.	a. Create incentives for use of reclaimed water where appropriate. b. Consider potential issues and concerns with water rights, in-stream flow, and water quality. c. Consider the energy/water nexus (energy requirements) when evaluating reclaimed water projects.
12	Encourage use of grey water (DOH).	a. Develop a clearinghouse to provide information and resources to local governments, developers, and others on safely and effectively using grey water. Include good examples of effective grey water projects.
13	Use the existing triennial process and permitting cycles to adapt water quality standards and permits to climate change over time.	a. Prioritize areas (6a above) where standards may need to be reviewed to reflect the changing climate. As climate change occurs, if the capacity of the environment is no longer able to meet current standards as a result of warming trends, water quality standards may need to be addressed. NOTE: One of the challenges is discerning the effects of climate change given the

	Strategies	Recommended Actions
		influences of human water management decisions (e.g., climate change should not be used as an excuse to downgrade water quality requirements). b. Consider likely climate scenarios (6a above) in reviewing standards. c. As standards are adjusted over time in response to climate change, adjust permits accordingly. d. Assess the stormwater regulatory framework (e.g., NPDES permits) in priority areas (6a above) for modification as hydrologic conditions change.
FLOODPLAIN MANAGEMENT		
14	Identify changes in future flood risk due to climate change by basin.	a. Work with the Climate Impacts Group, hydrologists, and other experts to identify where climate change will likely result in greater flood risks from changes in hydrology and more pronounced channel migration.
15	Develop tools to evaluate risk and vulnerability.	a. Work with FEMA on revising the data used to map flood hazard areas to incorporate anticipated future flood risk due to climate change. b. Provide interim tools/guidelines for local governments to consider future flood risk due to climate change until better mapping and information is developed.
16	Require consideration of changing flood risk in management of state and local government infrastructure.	a. Consider changes in future flood risk when planning, siting, and designing public infrastructure, including water supply, stormwater, wastewater, and roads.
17	Provide communities the tools to minimize future risks of flooding due to climate change impacts.	a. Where changes to flood elevation and channel migration are anticipated, work with local communities to minimize risk and accommodate natural processes through floodplain management (e.g., protecting and restoring floodplains, setting back levees, and protecting and restoring wetlands) and shoreline regulation. b. Incorporate changes in flood risk into policies and planning efforts, such as Flood Hazard Management Plans, Critical Areas Ordinances, and Shoreline Master Plans. c. Ecology will work with stakeholders to identify a dedicated fund source for FCAAP, so that grants for planning and implementation can be available to small communities with increased flood risk due to climate change. d. In certain highly developed areas, have regional dialog to consider environmental trade-off for areas we need to defend rather than developing natural areas; conduct a risk assessment.
SEA LEVEL RISE		
18	Develop and share information resources on sea level rise.	a. Characterize and map sea level rise vulnerability for all marine shorelines, including outer coast. b. Identify and assess what has been done, to provide examples

	Strategies	Recommended Actions
		and the starting point for further work. Obtain LIDAR mapping of all coastal areas. c. Obtain high-accuracy elevation benchmarks to support sea level monitoring. d. Identify scope, responsibilities, and timeframe to get this accomplished and share statewide.
19	Address sea level rise in land use and infrastructure planning and permitting.	a. Develop a single state location for climate change information to encourage optimal use in local planning updates: well-maintained, comprehensive, user-friendly website. b. Require that sea level rise and other climate change impacts be considered in future Comp Plan updates. This would include Capital Facilities Planning (updated annually). c. Require sea level rise be considered in Shoreline Master Plan updates and incorporated as data become available Promote “Green shoreline” stabilization alternatives to bulkheads. Armoring can directly impede adaptation, by starving the beach of new material. Property owner concerns about shoreline stability will likely increase. **Green shorelines** use vegetation and natural materials to reduce negative impacts on coasts and near shore habitats while protecting property. d. Identify feasible approaches to avoid or minimize hardening, especially on Puget Sound (localized sources of beach material). e. Streamline permitting for “green” projects. Tendency is to streamline permitting for known projects and “replacement in kind.” Greater hurdles are common for innovative approaches such as replacement of bulkhead with “green” stabilization. Actions may include changing statutes (parallel with existing streamside fish habitat project streamlining), providing design manual, and/or coordinated interagency permitting.
20	Address sea level rise in coastal facility planning and design.	a. Provide information, tools, and guidance on how to address the issue of considering sea level rise in planning and design of public infrastructure. b. Avoid mandates like a set sea level elevation for facility planning, due to significant uncertainty in science and wide variation of settings and management approaches. c. Develop a central clearinghouse to share information. d. Require sea level rise and climate change consideration in design of state-funded facilities: i. Add to statute or agency requirements for Centennial and other ECY funds, PWTF, etc. ii. Good guidance will be vital (perhaps same guidance as in strategy #1). iii. Allow creative approaches, such as demonstration projects, that do not set precedent for future decisions. e. Develop guidance on incorporating consideration of sea level rise and climate change in facility design: highlight key

	Strategies	Recommended Actions
		considerations of facility life, criticality, and vulnerability based on available science. Provide links to good examples and models (especially for smaller jurisdictions).
21	Increase monitoring and mapping to better understand the rate of sea level rise.	a. Monitor saltwater intrusion and inundation of freshwater areas. b. Expand monitoring and mapping of sea level rise and evaluate the impacts to the shoreline, such as changes in erosion and unstable bluffs.
ENERGY		
22	Identify vulnerabilities.	a. Identify vulnerabilities of power transmission due to extreme heat and other changes. b. Analyze vulnerabilities of power facilities, specifically for hydro and wind. c. Research and project future wind patterns for facility siting. d. Analyze potential effects of reduced electricity reliability during winter. e. Assess environmental impacts from climate change in siting and relicensing of new and existing energy facilities. f. Identify how state renewable energy goals could be impacted from future climate impacts.
23	Diversify energy resources.	a. Prioritize and promote conservation and efficiency as the least costly, most immediately available alternative to minimize the need for maintaining existing polluting energy sources. b. Construct more diverse, renewable generation facilities. c. Review standards from I-937 going forward fifty years. d. Construct more generation, prioritizing and incentivizing well-sited renewables such as wind and solar. e. Create additional transmission capacity. f. Encourage the development of distributed generation near and within load centers, to increase reliability by having redundant systems and to reduce risks associated with the long-distance transmission of energy. g. Develop a detailed climate vulnerability assessment and adaptation plan for Washington's transmission infrastructure.
24	Increase resilience to extreme weather events and demands from population increases (includes power and information systems).	a. Construct stronger, more resilient transmission and distribution systems, through undergrounding, redundancy, stronger poles/equipment, etc., to protect equipment from key weather affects. [Utility and WUTC action required] b. Protect infrastructure from flood impacts. Consider relocation to less vulnerable locations in longer term. c. Strengthen response and recovery capabilities [EMD and state agencies could expand resource capabilities to aid utilities, conduct exercises to validate capabilities.] d. Expand redundancy in transmission and storage. e. Incentivize backup systems for schools, clinics, and emergency shelters. Prepare for supply interruptions. f. Encourage the development of distributed generation near and

	Strategies	Recommended Actions
		within load centers; to increase reliability by having redundant systems, and to reduce risks associated with the long distance transmission of energy g. Encourage building practices (including materials selection, orientation, vegetation type/and placement, use of natural lighting, etc.) that will reduce energy demand from new construction and in retrofitted buildings. h. Reduce impacts associated with urban heat island effect (urban forestry programs, open space areas, etc.) in urban areas. i. Plan for reduced electricity reliability, especially in winter. j. Encourage water-efficient cooling systems at existing power plants that need them.
25	Increase resilience to climate changes in housing and site design.	a. Increase end-use efficiency in residential and commercial buildings b. Encourage local storage of rainwater as a component of building design. c. Discourage use of turf grass and other high-water-demand landscaping. Encourage low water use landscapes that allow water to infiltrate. d. Increase energy efficiency in buildings. Design and retrofit buildings to use less energy: weatherize, better insulation, passive solar, natural lighting, ventilation, etc. e. Identify and encourage the use of building materials that reduce reflectivity and therefore energy demand for heating and cooling. f. Identify and encourage the use of building practices that reduce contribution to the urban heat island effect in both new construction and retrofit of existing buildings. g. Increase energy use efficiency. Use energy efficient appliances (Energy Star), lighting, etc. h. Modify regulatory codes to address urban heat island effect and stormwater management based on climate issues and population densities. i. Encourage "smart" buildings and appliances that can reduce power consumption during high demand periods. j. Ensure that future updates of the State Energy Code are reflective of future conservation needs; adopt codes accordingly
26	Address energy storage/ capacity and timing.	a. Assess vulnerability to heat waves in generation, transmission, and delivery systems. b. Reduce electrical demand at time periods when hydropower generation capacity is reduced. c. Construct more generation (renewable—less water dependent, dispersed renewable generation) [Utility/Industry actions required, WUTC may have some influence] d. Assess whether decentralized power generation reduces risk. e. Construct more transmission and a smarter transmission grid

Strategies		Recommended Actions
		[Utility/Industry actions required, WUTC may have some influence, Governor's office may have some federal influence] f. Ensure future updates of the State Energy Code are reflective of future conservation needs; adopt codes accordingly.
TRANSPORTATION		
27	Identify risks and vulnerabilities to all transportation modes.	a. WSDOT/FHWA is in the process of conducting a vulnerability assessment that includes WSDOT-owned facilities and modes; includes ferries, state-owned rail and airports. b. Conduct risk assessment for rail, Sound transit, BNSF, and others. There are multiple owners for these without a single point of contact. c. Air. d. Barge. e. Pipelines. f. Recommend UTC and USDOT conduct risk assessment for regulated utilities (rail and pipelines). a. Risk of rail to heat effects b. Rail lines in vulnerable areas along shoreline g. Provide information to state and local governments on risk assessment.
28	Increase transportation system redundancy to improve resiliency.	a. Coordinate and integrate emergency evacuation procedures between adjacent cities and between adjacent counties. b. Multiple mode redundancy. c. Decrease reliance on GHG producing modes and technologies. d. Increase mass transit, especially electrified. e. Protect critical evacuation routes or create alternate paths that avoid the impact of hazards. f. Raise and/or reinforce harbor infrastructure. g. Protect bridge piers and abutments. h. Increase culvert capacity in a manner that is compatible with maintaining or expanding effective fish passages. i. Upgrade drainage systems.
29	Improve information.	a. Expand systems for monitoring scour of bridge piers and abutments. b. Increase monitoring of land slopes, stormwater runoff, and drainage systems. c. Consider the changing storm patterns to make sure facilities are adequate to handle runoff. See Floodplain section d. Increase monitoring of real-time flood levels and storm surge and provide messaging to public.
30	Create statewide policy to guide private and local actions.	a. Return some coastal and floodplain areas to nature. b. Restrict development in floodplains and vulnerable coastal areas. c. Determine threshold for when state will not invest in at-risk locations; tie to project life.
31	Other	a. Develop modular traffic and signing features for easier

Strategies		Recommended Actions
		replacement/repair.
COMMERCE AND PORTS		
32	Increase resilience to changes in sea level rise, precipitation changes, increased temperatures, glacial melting, and decreased summer river flows.	a. Determine critical shipping channels and their vulnerability to riverbed aggradation. b. Identify options to respond to changed conditions. c. Evaluate need for restrictions on shipping due to channel depths, impacted inland waterways. and rivers. d. Evaluate impacts of increased dredging on critical shipping channels.
33	Increase resilience to sea level rise and higher river flows in winter due to potential flooding.	a. Determine vulnerability to flooding/inundation at port facilities. b. Evaluate need to increase protection of ports and associated infrastructure such as docks, roadbeds, and bridge abutments near ports and marinas. c. Consider strengthening existing dike and levee systems and restoring natural floodplains to mitigate flow changes. d. Improve early warning systems and weather forecasts to allow on-site protections to be engaged in advance of emergency. e. Coordinate to streamline GMA, Shoreline, and Critical Area regulations to address existing facilities and their associated infrastructure as essential public facilities. f. Consider relocation where channel migration occurs and/or where existing river channels can no longer be reasonably defended. g. If relocation is chosen, determine where or whether relocation is feasible within the existing community. h. Develop balance within regulations between marine trade and industry areas with natural areas and their buffers. i. In considering port facilities, recognize the links of their support facilities, such as rail, warehouses, commerce, and roads. j. Integrate port plans with local planning and require consideration of sea level rise. Consistency with adjacent local jurisdictions is necessary.
34	Increase resilience to sea level rise in coastal facility planning, siting, and design.	a. Examine all modal options to move goods to determine if climate change impacts will affect mode choice, for example rail vs. barge. b. Develop guidance on including sea level rise and climate changes in facility design: highlight key considerations of facility life, criticality, and vulnerability based on available science. c. Develop guidelines on selected relocation of facilities to avoid impacts: strategic disinvestment. d. Develop decision processes to determine facility location and how/where we invest state funds.
LAND USE		
35	Leverage existing regulatory processes to adapt to climate change.	a. Provide climate change impact assessments and maps across the state on a basin-by-basin basis, using consistent data from CIG (e.g., CIG scenarios).

	Strategies	Recommended Actions
		b. Require local governments to update countywide and multicounty planning policies (under the GMA) to include climate change adaptation issues. c. Amend GMA and SMA to require climate change adaptation planning using impact assessment information (state provides regional framework and basic information, local governments consider and make decisions). d. Amend GMA to require designation of "climate change risk areas." e. Require that urban growth area expansions must consider all climate change impacts, including likely future migration of floodplains. f. Consider a time horizon longer than the 20-years currently typical under the GMA when considering urban growth area boundary expansions or long-term infrastructure investment decisions, incorporating anticipated climate change impacts (e.g., sea level rise considerations). g. Encourage counties with commercial-scale wind and solar energy potential to develop permitting processes to streamline their deployment while still providing adequate environmental and land use protections. h. Encourage counties and cities to plan for a wide variety of energy facilities, with an emphasis on well-sited renewable energy sources. i. Provide timely updates of the state building codes to facilitate greater adaptation and mitigation measures in the building sector; utilize technical advisory groups to address green building standards as related to land use. j. Establish benchmarks local governments can use to determine what levels of development are acceptable in climate change risk areas until anticipated impacts occur. k. Provide a consensus planning forecast of the changing environmental conditions that include projected impacts (e.g., precipitation changes). l. Encourage "Complete Streets," with a full range of motorized and nonmotorized options. **Complete Streets are streets for everyone**. They are designed and operated to enable safe access for all users. Pedestrians, bicyclists, motorists, and transit riders of all ages and abilities must be able to safely move along and across a complete street. m. Urban forestry: increase tree cover, use for shading, etc., in balance with solar access. Restore funding for the Evergreen Communities Act to develop best practices and model regulations and community forestry management plans.
36	Address climate change impacts in local land use	a. Info access: the state should provide a single location for climate change information to encourage optimal use in local planning

	Strategies	Recommended Actions
	planning.	updates (well-maintained, comprehensive, user-friendly website). b. Prioritize “green shoreline” stabilization alternatives over bulkheads. (Armoring can directly impede adaptation by starving the beach of new material. Property owner concerns about shoreline stability will likely increase.)
37	Increase carbon storage (carbon sequestration)	a. Encourage and facilitate efforts to maintain or increase carbon sequestering land uses; for example, preservation of forest or agricultural land uses. b. Enhance Green Infrastructure to provide environmental and social services. **Green infrastructure** encompasses the preservation and restoration of natural landscape features – forests, wetlands, floodplains, natural drainage features. At the site scale, it involves low-impact development (LID) and sustainable building features such as rain gardens, green roofs, permeable pavement, rainwater harvesting, etc. c. Develop methods to retrofit into existing community. d. Preserve resource lands (agricultural and forestry resource lands of long-term commercial significance. e. Enhance urban and community forestry to address temperature issues, air quality, etc.
38	Address increased fire potential.	a. When considering potential impacts on wildland/urban interface areas caused by extreme temperature changes/increases, local jurisdictions should give consideration to adoption of the Wildland/Urban Interface Code (WUI Code). This is currently in WAC as Appendix K of the 2009 Washington State Fire Code. WAC 51-54-4800 is available for voluntary adoption by local jurisdictions and has currently been adopted by two counties: Kittitas and Yakima. This voluntary code section mandates specific regulation regarding vegetation management plans, fire danger rating systems, and water supplies for development, among other approaches. b. Local fire services may be unable to respond to increasing wildland/urban interface zone fires, likely to be exacerbated as a result of higher temperatures as projected over the next 40 to 80 years. This will be due to lack of water and other resources to fight wild fires, as well as dramatic and unsustainable cost increases that will drain public financial resources.
39	Provide state predictability.	a. Identify state funding priorities and limits, but not control local responses. (At what point will the state end funding in certain locations due to the risks associated with climate change? How will this affect local governments?)

Strategies		Recommended Actions
40	State Environmental Policy Act (SEPA)	a. Use SEPA during non-project review of comprehensive plans and development regulations to evaluate climate change impacts. b. During project review, consider climate change impacts when appropriate (potential impacts from the project that may exacerbate climate change impacts; potential climate change impacts that may affect the project). c. Amend SEPA or WAC to specifically identify climate change-related issues to be considered via SEPA, including SLR for coastal projects/plans. d. Nexus and proportionality must be considered when applying mitigation standards to projects
41	Other	a. Increase flood insurance rates to reflect actuarial costs. b. Shift greater share of insurance risk to customers; create pricing incentives to reduce exposure to risks. c. Identify social equity issues and how to best address them (e.g., a disproportionately high number of low-income people may be affected by increasing flood risks, and they may have fewer opportunities to relocate out of existing or enlarged floodplains). d. Determine role of regional organizations.

Discussion on Implementation

The state agency plan will need to work on several areas, including integration of recommendations, clear delineation of roles and responsibilities across state agencies and vertically through different levels of government, identification of funding mechanisms, and legal and regulatory changes. This work will be challenging and will require candid, plain language that exposes policy and programs that conflict.

Unclear or conflicting mandates on state agencies may undermine our ability to clearly outline an integrated approach. For example, TAG 1 members discussed shoreline armoring. We talked about places where it may make sense to limit or prohibit armoring, and places the state may want to promote armoring to save infrastructure. To assist in resolving this conundrum, it may be important to develop criteria—such as habitat value and population density—derived from a sustainable vision of economic/social/environmental priorities. Private property ownership, local land use authority, and state authority are immediately drawn into the discussion, along with the jurisdictional variations (one town may allow bulkheads and the next town may ban them). Incentives and regulatory controls are two of the primary tools. However, the challenge is in reaching a coordinated approach that all levels of government and society can support or adhere to. Other jurisdictions may provide an example of how to address these issues. For example, the Swinomish Action Plan has an extensive discussion on this issue.

Several key elements of the state strategy are in place today! TAG 1 members strongly endorse the concept that we must leverage what we currently have in place. We don't want to undermine essential programs—we want to see where they may need to be enhanced or where coordination is needed to improve their ability to respond to climate changes.

The state's integrated approach will be used to develop more effective and efficient:

- Infrastructure investment decisions.
- Regional transportation services and response coordination.
- Water and waste water management.
- Diking programs and flood protection programs.
- Habitat preservation, research, and mitigation coordination.
- Local and regional utilities coordination.
- Emergency planning and response.

Opportunities to leverage existing programs—maximizing the state's current response mechanisms:

- Risk management and coordinated response strategies for seismic, tsunami, wildfire, flood, and severe storm impacts fit naturally with climate change preparation planning.
- Communication and public education programs at all levels that build public knowledge, readiness, and willingness to prepare.
- Research.
- Federal leadership, British Columbia, regional research and programs.
- Tribal partners.

6. Concluding Remarks and Next Steps

The scope of TAG 1's efforts—communities, infrastructure, and the built environment —encompassed a diverse array of interests and disciplines. The team was inspired and compelled by the recognition that while individual interests acting alone may find it difficult to achieve meaningful, sustainable results, the coordinated adaptation strategies of many are necessary to produce meaningful results.

The state should ensure the provision of baseline information—presented in a clear, concise, and easy to understand manner that is scientifically derived or based on science supported by Washington State—to assist citizens, businesses, and local governments in making informed decisions regarding adaptation to climate change. Information should be shared to assist entities that need more focused analyses and assessments. Such information should be provided at a scale that is useful and meaningful for both planning and investment purposes.

Important next steps to implementing any of TAG 1's recommendations include the development of communication and education materials so the public and decision makers can be well informed to make climate-ready decisions. It is also important to identify and leverage existing tools and resources, such as the EPA Climate Ready Water Utilities Toolbox and Climate Ready Water Utilities Working Group report and the Swinomish Climate Change Initiative: Climate Adaptation Action Plan.

Guidance for Integration

- Consider economic impacts; state, regional, and local embedded cultural values when choosing strategies and the impact of those strategies to existing and long-term ability to respond to change.
- Begin with interim tools and local information.
- Caution—avoid negative unintended consequences. Think through how recommendations can be misused.

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Appendix B1-A: Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts

Prepared by the University of Washington Climate Impacts Group

December 16, 2010

The information provided below is largely assembled from work completed for the 2009 Washington Climate Change Impacts Assessment. Other sources have been used where relevant, but this summary should not be viewed as a comprehensive literature review of Pacific Northwest (PNW) climate change impacts. Confidence statements are strictly qualitative with the exception of IPCC text regarding rates of 20th Century global sea level rise. Note that periods of months are abbreviated by each month's first letter, e.g., DJF = Dec, Jan, Feb.

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Temperature	Increasing temperatures expected through 21st century	Projected multi-model change in average annual temperature (with range) for specific benchmark periods: • 2020s: +2°F (1.1 to 3.4°F)** • 2040s: +3.2°F (1.6 to 5.2°F) • 2080s: +5.3°F (2.8 to 9.7°F) These changes are relative to the average annual temperature for 1970-1999. The projected *rate* of warming is an average of 0.5°F per decade (range: 0.2-1.0°F). ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected warming by the end of this century is much larger than the regional warming observed during the 20th century (+1.5°F), even for the lowest scenarios.	Warming expected across all seasons with the largest warming in the summer months (JJA) Mean change (with range) in winter (DJF) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.1°F (0.7 to 3.6°F)** • 2040s: +3.2°F (1.0 to 5.1°F) • 2080s: +5.4°F (1.3 to 9.1°F) Mean change (with range) in summer (JJA) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.7°F (1.0 to 5.3°F)** • 2040s: +4.1°F (1.5 to 7.9°F) • 2080s: +6.8°F (2.6 to 12.5°F)	High confidence that the PNW will warm as a result of increasing greenhouse gas emissions. All models project warming in all scenarios (39 scenarios total) and the projected change in temperature is statistically significant.	Mote and Salathé 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Precipitation *(extreme precipitation addressed in separate field)*	A small increase in average annual precipitation is projected (based on the multimodel average, Mote and Salathé 2010), although model-to-model differences in projected precipitation are large (see "Confidence"). Potentially large seasonal changes are expected.	Projected change in average annual precipitation (with range) for specific benchmark periods: • 2020s: +1% (-9 to 12%)** • 2040s: +2% (-11 to +12%) • 2080s: +4% (-10 to +20%) These changes are relative to the average annual temperature for 1970-1999. ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected increase in average annual precipitation is small relative to the range of natural variability observed during the 20th century and the model-to-model differences in projected changes for the 21st century	*Summer:* Majority of global climate models (68-90% depending on the decade and emissions scenario) project decreases in summer (JJA) precipitation. Mean change (with range) in JJA precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: -6% (-30% to +12%) ** • 2040s: -8% (-30% to +17%) • 2080s: -13% (-38% to +14%) *Winter:* Majority of global climate models (50-80% depending on the decade and emissions scenario) increases in winter (DJF) precipitation. Mean change (with range) in DJF precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: +2% (-14% to	Low confidence. The uncertainty in future precipitation changes is large given the wide range of natural variability in the PNW and uncertainties regarding if and how dominant modes of natural variability may be affected by climate change. Additional uncertainties are derived from the challenges of modeling precipitation globally. Model to model differences are quite large, with some models projecting decreases in winter and annual total precipitation and others producing large increases. Expect that the region will continue to see years that are wetter than average and drier than average even as that average changes over the long term.	Mote and Salathé 2010; Salathé et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
				+23%)** • 2040s: +3% (-13% to +27%) • 2080s: +8% (-11% to +42%)		

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Extreme precipitation	Precipitation intensity may increase but the spatial pattern of this change and changes in intensity is highly variable across the state.	State-wide *(Salathé et al. 2010)*: More intense precipitation projected by two regional climate model simulations but the distribution is highly variable; substantial changes (increases of 5-10% in precipitation intensity) are simulated over the North Cascades and northeastern Washington. Across most of the state, increases are not significant. For sub-regions *(Rosenberg et al. 2010)*: Projected increases in the magnitude (i.e., the amount of precipitation) of 24-hour storm events in the Seattle-Tacoma area over the next 50 years are 14.1%-28.7%, depending upon the data employed. Increases for Vancouver and Spokane are not statistically significant and therefore cannot be distinguished from natural variability.	Projected increases in the magnitude of 24-hour storm events for the period 2020-2050 for the Seattle-Tacoma area (14.1 to 28.7%) is comparable to the observed increases for 24-hour storms over the past 50 years (24.7%) *(Rosenberg et al. 2009).*	The ECHAM5 simulation produces significant increases in precipitation intensity during winter months (Dec-Feb), although with some spatial variability. The CCSM3 simulation also produces more intense precipitation during winter months despite reductions in total winter and spring precipitation *(Salathé et al. 2010)*	Low confidence. Anthropogenic changes in extreme precipitation difficult to detect given wide range of natural precip variability in the PNW. Computational requirements limit the analysis of sub-regional impacts within WA to two scenarios, reducing the robustness of possible results. Simulated changes are statistically significant only over northern Washington.	Salathé et al. 2010 Rosenberg et al. 2009 Rosenberg et al. 2010
Extreme heat	More extreme heat events expected	Generally projecting increases in extreme heat events for the 2040s, particularly in south central WA and the western WA lowlands *(Salathé et al. 2010).*** Changes in specific regions vary with time period (2025, 2045, and 2085), scenario (low, moderate, high), and region (Seattle, Spokane, Tri-Cities, Yakima) but all four regions and all scenarios show increases in the mean annual number of heat events, mean event duration, and maximum event duration *(Jackson et al. 2010, Table 4).*	Projected increases in number and duration of events is significantly larger than the number and duration of events between 1980-2006 (specific values vary with location, warming scenario, and time period). In western Washington, the frequency of exceeding the 90th percentile daytime	n/a (relevant to summer only)	Medium confidence. There is less confidence in sub-regional changes in extreme heat events due to the limited number of scenarios used to evaluate changes in extreme heat events in Jackson et al. 2010 (9 scenarios) and Salathé et al. 2010 (2 scenarios), although confidence in warmer summer temperatures overall is high (see previous entry for temperature).	Salathé et al. 2010 Jackson et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		---------------------------- *** Definitions of extreme heat varied between the two studies cited here. Salathé et al. 2010 defined a heat wave as an episode of three or more days where the daily heat index (humidex) value exceeds 90°F. Jackson et al. 2010 defined heat events as one or more consecutive days where the humidex was above the 99th percentile.*	temperature (Tmax) increases from 30 days per year in the current climate (1970-1999) to 50 days per year in the 2040s (2030-2059).			
Snowpack (SWE)	Decline in spring (April 1) snowpack expected	The multi-model means for projected changes in mean April 1 SWE for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: -27% (B1), -29% (A1B) • 2040s: -37% (B1), -44% (A1B) • 2080s: -53% (B1), -65% (A1B) All changes are relative to 1916-2006. Individual model results will vary from the multi-model average.	Projected declines for the 2040s and 2080s are greater than the snowpack decline observed in the 20th century (based on a linear trend from 1916-2006).	n/a (relevant to cool season [Oct-Mar] only)	High confidence that snowpack will decline even though specific projections will change over time. Projected changes in temperature, for which there is high confidence, have the most significant influence on SWE (relative to precipitation).	Elsner et al. 2010
Streamflow	Expected seasonal changes include increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow dominant and rain/snow mix (transient) basins, and decreases in summer streamflow.	The multi-model averages for projected changes in mean annual runoff for Washington state for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: +2% (B1), 0% (A1B) • 2040s: +2% (B1), +3% (A1B) • 2080s: +4% (B1), +6% (A1B)	During the period from 1947-2003 runoff occurred earlier in spring throughout snowmelt influenced watersheds in the western U.S. *(Hamlet et al. 2007)*.	Projected changes in mean cool season (Oct-Mar) runoff for WA state: • 2020s: +13% (B1), +11% (A1B) • 2040s: +16% (B1), +21% (A1B) • 2080s: +26%(B1), +35%	*Regarding changes in total annual runoff:* There is high confidence in the direction of projected change in total annual runoff but low confidence in the specific amount of projected change due to the large uncertainties that exist for changes in winter (Oct-Mar) precipitation. The large	Elsner et al. 2010 Hamlet et al. 2007 Mantua et al. 2010 Tohver and Hamlet 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
	Increasing risk of extreme high and low flows also expected. In all cases, results will vary by location and basin type.	All changes relative to 1916-2006; numbers rounded to nearest whole value *(Elsner et al. 2010)* The risk of lower low flows (e.g., lower 7Q10** flows) increases in all basin types to varying degrees. The decrease in 7Q10 flows is greater in rain dominant and transient basins relative to snow-dominant basins, which generally see less snowpack decline and (as a result) less of a decline in summer streamflow than transient basins. *(Mantua et al. 2010; Tohver and Hamlet 2010)* Changes in flood risk vary by basin type. Spatial patterns for the 20-year and 100-year flood ratio (future/historical) indicate slight or no increases in flood risk for snowmelt dominant basins due to declining spring snowpack. There is a progressively higher flood risk through the 21st century for transient basins, although changes in risk in individual transient basins will vary. Projections of flood risk for rain dominant basins do not indicate any significant change under future conditions, although increases in winter precipitation in some scenarios nominally increase the risk of flooding in winter. *(Tohver and Hamlet 2010, in draft)*		(A1B) Projected changes in mean warm season (Apr-Sept) runoff for WA state: • 2020s: -16% (B1), -19% (A1B) • 2040s: -22% (B1), -29% (A1B) • 2080s: -33%(B1), -43% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value. *(Elsner et al. 2010)*	uncertainties in winter precipitation are due primarily to uncertainty about the timing of, and any changes in, dominant models of natural decadal variability that influence precipitation patterns in the PNW (e.g. the Pacific Decadal Oscillation) as well as changes in precipitation caused by climate change. *Regarding streamflow timing shifts:* There is high confidence that peak streamflow will shift earlier in the season in transient and snow-dominant systems due to projected warming and loss of April 1 SWE. There is less confidence in the specific size of the shift in any specific basin given uncertainties about changes winter precipitation *(see previous comment)*. *Regarding summer streamflows:* Overall, there is high confidence that summer streamflow will decline due to projected decreases in	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		--------------------------- *** 7Q10 flows are the lowest stream flow for seven consecutive days that would be expected to occur once in ten years.*			snowpack (relevant to snow dominant and transient basins) and increasing summer temperatures (relevant to all basin types). There is medium confidence that late summer streamflow will decline given 1) the sensitivity of late summer streamflow to uncertain precipitation changes, and 2) uncertainties about if and how groundwater contributions in any given basin may affect late summer flows. For all changes in streamflow, confidence in *specific* projected values is low due to high uncertainty about changes in precipitation and decadal variability.	
Sea level	Varying amounts of sea level rise (or decline) projected in Washington due to regional variations in land movement and coastal winds.	Projected global change (2090-2099) according to the IPCC: 7-23", relative to 1980-99 average *(Solomon et al. 2007)*** 2050: Projected medium change in Washington sea level (with range) *(Mote et al. 2008)*: • NW Olympic Pen: 0" (-5-14")	Relative change in Washington varies by location. Globally, the average rate of sea level rise during the 21st century very likely‡ (>90%) exceeds the 1961-2003 average rate (0.07 ± 0.02 in/year) *(Solomon et al. 2007)*	Wind-driven enhancement of PNW sea level is common during winter months (even more so during El Niño events). On the whole, analysis of more than 30 scenarios found minimal changes in average wintertime northward winds in the PNW. However, several models produced strong increases. These potential increases contribute to the upper estimates for WA sea level	High confidence that sea level will rise globally. Confidence in the amount of change at any specific location in Washington varies depending on the amount of uncertainty associated with the global and local/regional factors affecting rates of	Mote et al. 2008 Solomon et al. 2007

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		• Central & So. Coast: 5" (1-18") • Puget Sound: 6" (3-22") 2100: Projected medium change in WA sea level (with range) *(Mote et al. 2008)*: • NW Olympic Peninsula: 2" (-9-35") • Central & So. Coast: 11" (2-43") • Puget Sound: 13" (6-50") ---------------------------- *** Since 2008, numerous peer-reviewed studies have offered alternate estimates of global sea level rise. The basis for these updates are known deficiencies in the IPCC's 2007 approach to calculating of global sea level rise, including assumptions of a near-zero net contribution from the Greenland and Antarctic ice sheets to 21st century sea level rise. A comparison of several studies in Rahmstorf 2010 (Figure 1) shows projections in the range of 1.5ft to over 6ft. Overall, recent studies appear to be converging on projected increases in the range of 2-4ft (e.g., Vermeer and Rahmstorf (2009), Pfeffer et al. 2008, Grinsted et al. 2009, Jevrejeva et al. 2010).*	---------------------------- *‡ = as defined by the IPCC's treatment of uncertainties (Solomon et al. 2007, Box TS1)*	rise. *(Mote et al. 2008)*	sea level rise. Regionally, there is high confidence that the NW Olympic Peninsula is experiencing uplift at >2 mm/yr. There is less confidence about rates of uplift along the central and southern WA coast due to sparse data, but available data generally indicate uplift in range of 0-2mm/yr. There is high uncertainty about subsidence, and rates of subsidence where it exists, in the Puget Sound region. Although annual rates of current and future uplift and subsidence (a.k.a. "VLM") are well-established at large geographic scales, determining rates at specific locations requires additional analysis and/or monitoring. Uncertainties around future rates are unknown and would be affected by the occurrence of a subduction zone earthquake.	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Wave Heights	Increase in "significant wave height" ** expected in the near term (through 2020s) based on research showing that a future warmer climate may contain fewer overall extra-tropical cyclones but an increased frequency of very intense extra-tropical cyclones (which may affect the extreme wave climate). ------------------ *** "Significant wave height" is defined as the average of the highest 1/3 of the measured wave heights within a (typically) 20 minute period*	Based on extrapolation of historical data[‡] and assumptions that the historical trends continue into the future, the 25, 50, and 100 year significant wave height events are projected to increase approximately 0.07m/yr (2.8 in/yr) through 2020s. ---------------------------- *‡ the five highest significant wave heights measured at Washington NDBC Buoy #46005 (at the WA/OR border)*	Projected changes through 2020 are comparable to the observed increase in the average of the five highest significant wave heights for the mid 1970s-2007 (0.07m/yr, or 2.6 in/yr). *More on past changes:* Over the last 30 years, the rate of increase for more extreme wave heights has been greater than the rate of increase in average winter wave height. For the WA/OR outer coast (mid 1970s-2007): • The average of all winter significant wave heights increased at a rate of 0.023m/yr (0.9 in/yr) • Annual maximum significant wave height increased 0.095m/yr (3.7 in/yr).	These findings relate to the winter season (Oct-March), which is the dominant season of strong storms	*Regarding general trend:* There is low confidence that significant wave height will increase given the dependence of this increase on a limited number of studies showing potential increases in the intensity of the extra-tropical cyclones that can affect the extreme wave climate. *Regarding specific projected increases in wave height:* There is low confidence in the calculated trend for 25, 50, and 100 year significant wave height events given that this calculation is based on extrapolation of historic data and assumptions of continued historical trends rather than physical modeling.	Ruggiero et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Sea surface temperature (SST)	Warmer SST expected	Increase of +2.2°F projected for the 2040s (2030-59) for coastal ocean between 46°N and 49°N. Changes are relative to 1970-99 average.	Projected change is substantially outside the range of 20th century variability.	*No information currently available*	Medium to low confidence in the degree of warming expected for the summertime upwelling season. Global climate models do not resolve the coastal zone and coastal upwelling process very well, and uncertainty associated with summertime upwelling winds also brings uncertainty to coastal SSTs in summer.	Mote and Salathé 2010
Coastal upwelling	Little change in coastal upwelling expected	The multimodel average mean change in winds that drive coastal upwelling is minimal	Comparable to what has been observed in the 20th century	Little change in seasonal patterns.	Low confidence given the fact that this hasn't been evaluated with dynamical downscaling of many climate model scenarios at this point.	Mote and Salathé 2010
Ocean acidification	Continuing acidification expected in coastal Washington and Puget Sound waters	The global surface ocean is projected to see a 0.2 - 0.3 drop in pH by the end of the 21st century (in addition to observed decline of 0.1 units since 1750) (Feely et al. 2010). pH in the North Pacific, which includes the coastal waters of Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO2 to 560 and 840 ppm, respectively (Feely et al. 2009). pH in Puget Sound is projected to decrease, with ocean acidification	Projected global changes are larger than the decrease of 0.1 units since 1750, and greater than the trend in last 20 years (0.02 units/decade). The observed decrease of 0.1 units since 1750 is equivalent to an overall increase in the hydrogen ion concentration or "acidity" of about 26%.	The contribution of ocean acidification to Dissolved Inorganic Carbon (DIC) concentrations within the Puget Sound basin can vary seasonally. Ocean acidification has a smaller contribution to the subsurface increase in DIC concentrations in the summer (e.g., 24%) compared to winter (e.g., 49%) relative to other processes (Feely et al. 2010).	For global changes, confidence that oceans will become more acidic is high. Results from large-scale ocean CO_2 surveys and time-series studies over the past two decades show that ocean acidification is a predictable consequence of rising atmospheric CO_2 that is independent of the uncertainties and outcomes of climate change (Feely et al.	Feely et al. 2009 Feely et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		accounting for an increasingly large part of that decline. Feely et al. 2010 estimated that ocean acidification accounts for 24-49% of the pH decrease in the deep waters of the Hood Canal sub-basin of Puget Sound relative to estimated pre-industrial values. Over time, ocean acidification from a doubling of atmospheric CO2 could account for 49-82% of the pH decrease in Puget Sound subsurface waters.			2009). For Puget Sound, estimates of the contribution of ocean acidification to future pH decreases in Puget Sound have very high uncertainty since other changes that may occur over the intervening time were not taken into account when calculating that estimate (a percentage) (Feely et al. 2010).	

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Appendix B1-B: Detailed Water Supply Strategies and Actions

Principles for Prioritizing Water Supply Strategies

1. An accurate assessment of current and future water supply and water demand should inform all water management decisions.
2. The full range of alternatives available for meeting the demonstrated water supply shortfall must be evaluated.
3. Water supply and demand should be managed and addressed using the most cost-effective tools that benefit communities, the environment, promote economic vitality, and that can be readily adapted to meet changing circumstances.
4. Beneficiaries of water management services and supply projects should pay for an equitable share of the costs.
5. Public involvement should be a priority during each stage of the evaluation of a new water supply project.
6. Prioritize strategies that help the state meet legal/regulatory obligations including recovery of ESA listed species, water quality standards, etc.
7. Prioritize strategies that utilize green infrastructure and efficiency measures as a core component to water quality and management.

Recommended Strategies and Actions

1. Determine water availability and demand in high priority basins

a) Improve statewide water availability and supply and demand forecasting *(high priority)*

Ecology is preparing a description of surface water and where feasible, groundwater, availability throughout Washington. The document will describe where and when water is available, the multiple factors that affect availability, and potential options for obtaining future water rights. Ecology is currently conducting a detailed assessment of water supply and demand forecasting in the Columbia basin. This work could be expanded to cover all areas of the state. There are many existing studies and plans to draw from on the west side of the state. Rather than recreate the wheel, Ecology would maximize the use of existing resources and information. Discussion will also involve GHG implications of energy intensive plans to bring water to basins where there is currently not enough water available to meet forecasted demand.

b) Develop water budgets in basins that will be impacted by climate change *(high priority)*

Obtain basin water budget information needed to understand hydrologic systems in areas where information is lacking. This information could be used to identify future supply problems, support mitigation plans and reclaimed water projects, assist water banking and stormwater management, and identify areas where further water development (aquifer storage and recovery, off channel storage) would be acceptable. As an additional resource, some watershed plans adopted under Chap 90.82 RCW may also have relevant information and studies assessing water availability where such information was previously lacking. This approach differs from 1.1.1 in that it is more local: a WRIA by WRIA approach will be taken where feasible given aquifer connectivity. Barriers and resiliency will also be part of the discussion.

c) **Clarify water rights and claims through streamlined judicial processes or non-judicial settlement agreements to enable more accurate supply and demand forecasting (*high priority*)**
Increase adjudication of water rights and claims to determine legally allocated water in select basins via performing more adjudications, streamlining the adjudication process, and/or creating water courts. Desired end result could also be achieved by entering into more non judicial settlement agreements. Pursue the quantification of federal reserve rights where feasible.

2. Develop and implement water strategies to manage supply and demand in a climate changed future

a) **Transition from watershed planning to implementation in high priority climate change affected basins - evaluate options to manage supply and demand exploring a full range of options including an increased use of water masters (*high priority*)**
Compile and integrate data of existing water use (both instream and out of stream), current ground and surface water supplies, information in locally adopted watershed plans, and anticipated future demands based on climate change and other factors (e.g. full inchoate water rights build out in incorporated areas). Incorporate data from OCR's 2011 Supply and Demand Forecast and information from Chap. 90.82 RCW watershed plan development activities. Identify gaps.

Increase the amount of water masters. The Water Resources Program does not have enough water masters to effectively deal with statewide water use compliance and enforcement needs.

b) **Prioritize low-cost, no regrets options such as conservation, efficiency (demand management) and expanded use of non-potable water (high priority strategy, suite of options available)**

i. **Expand the use of non-potable water supplies**
Implement strategies to conserve, be more efficient and expand use of reclaimed water and non-potable water supplies for non-potable uses. These strategies can be an essential component of meeting water demand in a climate changed future.

Propose legislation or develop an Ecology issued Interpretive Statement to allow the beneficial use of unpermitted stormwater as part of a stormwater management project (stormwater management often involves beneficial use so the two are not mutually exclusive) provided the use of stormwater in the stormwater management plan meets certain conditions (essentially serves to mimic the natural hydrograph).

ii. **Decrease demand through demand side efficiency and demand management**
Implement a new rebate or grant program to help pay for WaterSense certified water efficiency plumbing fixture replacement and for landscape conversion to low water use types. Ask other organizations (i.e. Partnership Water Conservation) to administer program.

Establish grant/loan program for privately-owned water systems to install source/service meters. As a condition of loan/grant, require that they demonstrate financial capacity/viability.

c) Evaluate options such as new supply, timing and transfers (high priority strategy, suite of options available)

i. **Emphasize water supply options that provide instream and out of stream benefits**
Address statewide water supply and demand issues that complement the work the Office of the Columbia River is doing on the eastside of the State.

Propose a budget add for a desalination study for water-scarce coastal area(s) where new water from a desalination project would replace diversion of water from an over appropriated source to benefit ESA listed fish species.

d) Improve legal and fiscal frameworks for water banking
Propose legislation and pursue rulemaking to seed funds for regional water banks, provide guidance for creation of banks for statewide consistency and mitigation, charge cost recovery fees for transaction costs, create revolving accounts for funds to purchase water and receive funds for mitigation payments.

e) Improve supply for streamflow mitigation and use through aquifer storage and recovery (ASR) program
Supplement the state water plan and water supply action items with a deliberate effort to identify and evaluate the feasibility of ASR opportunities throughout the state. This action entails conducting a statewide assessment to identify viable aquifer recharge and recovery projects that provide the greatest benefit. Opportunities to integrate stormwater management and wetland restoration practices into aquifer recharge and baseflow augmentation efforts would also be considered where appropriate.

f) Obtain water savings through green building legislation, building code updates and tax holidays
Propose legislation to authorize Ecology and General Administration to work together to develop rules that would require public buildings to integrate water saving strategies in addition to their existing requirement to comply with green building standards. This effort could be broadened to address sustainable sites and heating, cooling and energy water related issues.

Amend RCW 36.70A to encourage local governments to adopt ordinances that require low water use developments. Encourage local governments to offer incentives to these types of developments. Use WaterSense certified single-family housing concept.

Option A: Amend/update RCW 19.27.170 to mandate water efficiency standards. Develop legislation that would allow a 2-year pilot program under this code with public buildings. The pilot phase will allow for evaluation of feasibility and identify issues that could be modified in official code change. Option B: Amend code or update RCW 19.27.170 (water conservation performance standards, state building code) to mandate/phase in WaterSense and other water efficiency standards. Could start with new state funded building only and phase in other new construction.

Support efforts to mandate rainwater harvesting in urban areas with supply and/or stormwater management issues via locally administered building, health or other relevant ordinance or code amendments.

Under Washington law, purchases of personal property are subject to sales taxes. Implement a sales tax holiday (a temporary period such as one week for example) during which purchases of certain items are exempt from the sales taxes.

g) Develop industrial and agricultural conservation and efficiency standards and continue to improve municipal conservation and efficiency
There are currently municipal conservation standards but no similar standards for the industrial and agricultural sector.

3. Integrate climate change into policy and planning efforts

a) Integrate water supply considerations into land use planning in high priority basins *(high priority)*
Develop recommendations for research, legislation, and, if needed, regulations that address changes in hydrology at the subbasin scale. Consider integrating water resource management tools, stormwater management and land use.

b) Map critical source water and groundwater infiltration areas in order to identify and protect them (e.g. through requiring their protection in comprehensive plans)

c) Update the definition of drought and remove barriers to drought relief to better reflect climate change
Remove the 10 percent cap for non-agriculture uses for emergency drought relief.

Clarify and explain to stakeholders that the definition of “normal” in the context of drought conditions would be better based on a 30-year running mean, instead of the mean of the entire historic record.

4. Increase monitoring and mapping to better understand the effects of climate change

a) Increase water use monitoring *(high priority)*

Enhance and improve water use monitoring throughout the state. Monitor and quantify new water uses including water rights permitting actions and permit-exempt uses (new and existing where appropriate using building permits or other appropriate data). Compare water use to water rights. Increase compliance and enforcement.

b) Increase water rights mapping *(high priority)*

Digitize all water rights and claims records in the state. Each record (points of diversion or withdrawal and place of use) will be mapped using GIS software. The records will be mapped as recorded on the water right documents (as opposed to field verification). Ecology currently has approximately 35% of the water rights records mapped and this action item will continue this effort. Other items could also be mapped (such as instream flow indicators) to make this more comprehensive. See also PAWG 1.1 and 1.3 (water supply availability and supply and demand forecasting).

c) Increase surface and groundwater monitoring *(high priority)*

Setting instream flows, salmon restoration activities, and other water management strategies demand an effective gaging network. Stream gaging is in high demand across the state but there are insufficient resources to meet needs. Climate change will exacerbate the need for an effective gaging network. Ecology's Watershed Advancement Group (WAG) sanctioned the development of a Statewide Stream Gaging Strategy in late 2007. The outcomes of or recommendations from this strategy should guide this action.

In 2008 Ecology drafted recommendations for a basin-specific ambient groundwater monitoring program that covers all areas of the state. Recommendations included assessment of current monitoring efforts, capture of available and useful data into Ecology's environmental database, improving database usability, establishment of additional monitoring locations, and ongoing assessment of monitoring results. Monitoring efforts could utilize data loggers for continuous water level measurements.

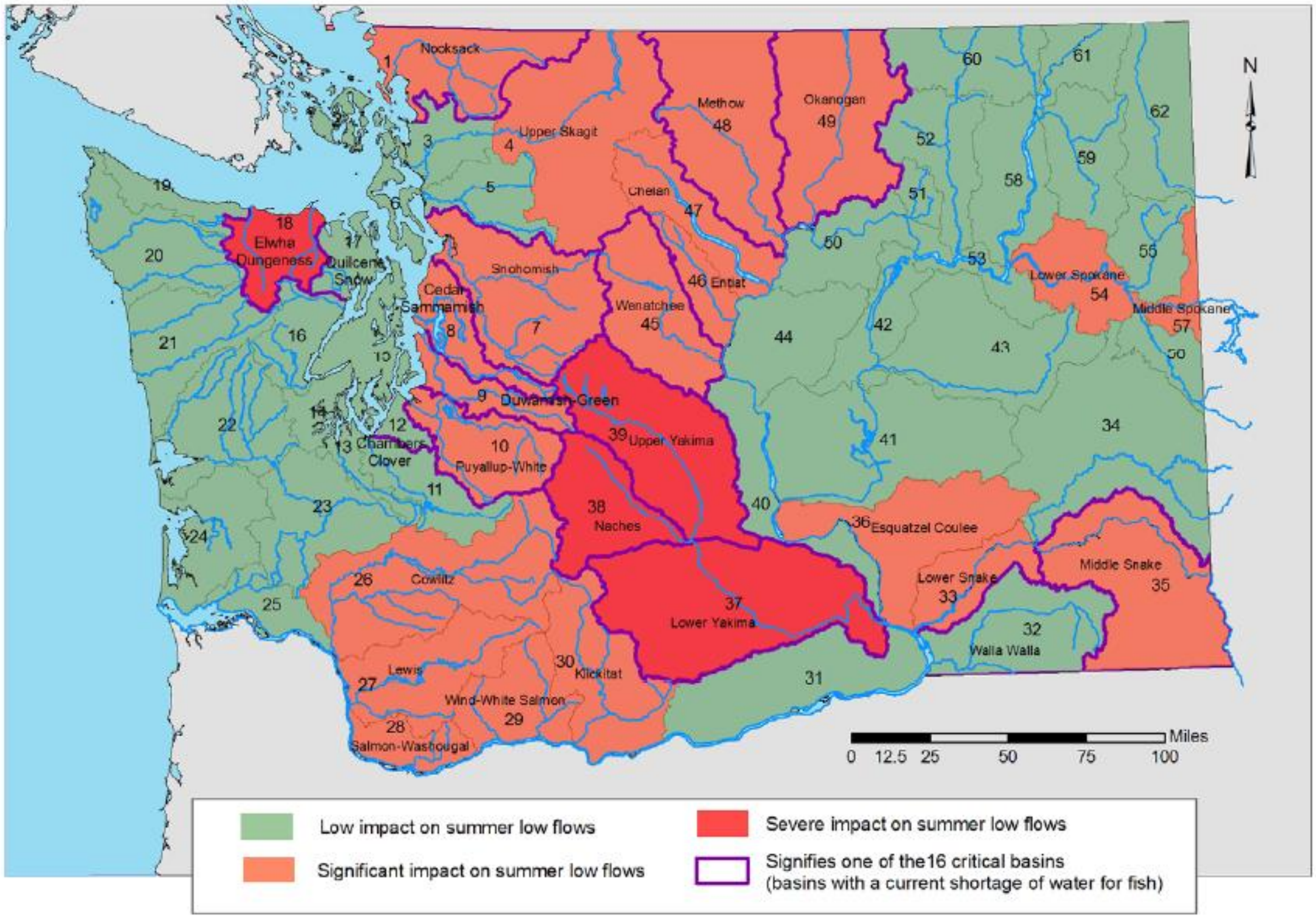
A combination of temporary and full-time staff could collect static water levels (SWLs) of wells for one week prior to irrigation season and one week after across the state. Other time would be spent obtaining access to monitoring locations, coordination with local other agencies collecting data, training, mapping out routes and then entering and evaluating data. One FTE at each region could be in charge of regional water level monitoring program.

d) Create and utilize data integration tools. Assure that all data is available in accessible digital formats (GIS)

Build information management tools to integrate water resources data and information.

Appendix B1-C: Impacts to summer flows by Water Resource Inventory Areas (WRIA)

2040 Projected Climate Change Impact on Summer Flows by WRIA



Appendix B1-D: Invited participants and reviewers

Built Environment, Infrastructure and Communities

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Milt Doumit	Verizon
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Eric Lohnes	Building Industry Assoc. of Washington
Sandy Mackie	Association of Washington Businesses
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Appendix B1-E: Excerpt from *Decision Frameworks For Effective Responses To Climate Change*

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Climate change is often characterized as a complex problem because it lacks both a definitive assessment and a clear point at which the problem is solved (Rittel and Webber, 1973; Dietz and Stern, 1998). Complex problems involve intense conflicts over definitions of the problem, objectives, and even what issues and topics are relevant to the decision. They also confront significant uncertainty, so that parties involved in problem solving must rely on highly imperfect, often conflicting information about what is known and not known. Even more difficult, values are intertwined with assessments of fact. Complex problems are commonly thought of as unique; although some aspects of the problem may have been seen before, each complex problem involves a distinctive constellation of constituent problems, meaning that prior experience with other problems may offer little guidance. An iterative risk management framework with a heavy emphasis on learning and embedded in a distributed institutional capacity to make sensible reforms can help address such complex problems (NRC, 2009a).

DECISION FRAMEWORKS FOR EFFECTIVE RESPONSES TO CLIMATE CHANGE page 81 PREPUBLICATION COPY

FIGURE 3.3 An iterative risk management and adaptive governance approach for climate change at multiple levels of government, public and private sectors in which risks and benefits are identified and assessed, responses implemented, evaluated, and revisited in sustained efforts to develop more effective policies or to respond to emerging problems and opportunities.

This iterative risk management has several advantages for climate-related decisions. The approach emphasizes that:

- Action in the face of uncertainty is unavoidable. All assessment and management efforts involve uncertainty, and while it is important to assess and reduce uncertainties where possible, significant uncertainty can rarely be eliminated.
- Eliminating all potential risks is impossible. Even the best possible decision will entail some residual risk.
- Determining which risks are acceptable (and unacceptable) represents an integral part of the process of risk management. Different stakeholders will inevitably hold different views.
- Risk management actions can achieve an appropriate balance among the potential cost and benefits from the broadest range of potential outcomes, taking full consideration of available information on the likelihood of occurrence. These actions can be reassessed and rebalanced in an on-going process over time.

Appendix B2

Washington State Climate Change Response Strategy Topic Advisory Group (TAG) Report - TAG 2 Human Health and Security

Final Draft - January 27, 2011

Human Health & Security, Climate Change TAG
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1. Introduction

Describe the purpose and objectives of the TAG.

The human condition is inextricably linked to the natural environment. As such, we know climate change will impact population health. In 2007 the Preparation and Adaption Workgroup (PAWG) began work to determine the potential human health impacts associated with climate change in Washington and to make recommendations on minimizing these impacts. The work of the Human Health and Security Technical Advisory Group (TAG 2), directed by E2SSB 5560(2009), builds on the foundation of the PAWG report using new information from the Climate Impact Group(CIG) and others to continue refining assumptions and projections to inform strategies to bolster and build resilience across communities in the state.

The challenges we face as a result of climate change come at a time of unprecedented economic crisis and at a time when the entire public health system is in the process of examining and reshaping its approach to service. However, the impacts of climate change are not expected to introduce entirely new fields of work to public health, but rather are expected to exacerbate current conditions over a range of public health issues. As a result, the recommendations of the human health and security TAG focus on how to bolster existing systems and integrate climate considerations into a new and emerging public health system.

2. Overview of the Impacts of Climate Change

a) Summarize the observed and projected impacts of climate change relevant to the TAG (human health and security) using information from CIG and other published sources.

The key aspects of climate change being considered by TAG 2 are increasing temperature and changing weather patterns.

Increasing Temperature

Increasing temperatures are expected to bring about potentially harmful changes in local vegetation, disease vectors, and air quality. In addition, increasing temperatures will likely increase the incidence of drought in some areas, decrease water quality due to sea level rise and salt water intrusion into drinking water supplies, and potentially augment and impact the effect of urban heat islands.

Salathe et al (2009) performed two climate simulations for the state of Washington. These regional models were created based on large-scale global models using local topographical features at a smaller resolution. The two models (20km and 36 km grid spacing) were of a fine enough resolution to account for the differences in values of the mountains and coasts. Even though the results for temperature showed a considerable difference between the two models and between seasons, the results do suggest an increase in temperature across the state. The models predict an increase of as much as 5 degrees Fahrenheit (annual average) by 2059 during the summer in the southeastern portion of the state. Both models predict less warming along the coast during spring and summer.

Based on Pacific Northwest modeling of meteorological parameters and ambient air pollutants, Washington State can expect increase in ambient concentrations of ozone (Salathe et al, 2009). Projections suggest forest area burned by climate change influenced fires will at least double by 2050 (Littell et al, 2009) with a resulting increase in particulates. In addition, increases in temperature may also produce a longer pollen season and increase the allergenicity of some aeroallergens (Beggs, 2004; Shea et al 2008).

Changing Weather Patterns

Another potentially harmful impact of climate change to health and security is changing weather patterns including more frequent storms and varying precipitation patterns.

Changing precipitation patterns are expected to shift the state's water supply from sources supplied primarily by snow melt to those supplied primarily by rain. Timing of precipitation could contribute to more frequent flooding in some areas but also cause drought in others. The CIG projections for precipitation averaged over all models anticipate a small increase of 1 - 2%, but with changes toward wetter autumns and winters and drier summers. Increases in extreme high precipitation in western Washington and reductions in Cascades snowpack are consistent projections across all models. As a result of these changes, the April 1 snowpack is projected to decrease by 40% by the 2040s leaving sensitive watersheds, particularly in central and eastern Washington subject to drought (WACCIA, 2009).

At the same time, rising temperatures globally will result in higher sea-levels, and potentially increase the intensity of storm events such as storm surges. (Nicholls, 2004). Higher temperatures will lead to more rain-on-snow events; a major trigger of the periodic river flooding that is already a frequent occurrence in the state. (Hoo and Sumitani, 2005). More frequent storms coupled with sea level rise will have significant impacts on coastal areas as well as flooding and power outages throughout the state. Sea level rise may also potentially affect drinking water quality as the result of sea water intrusion, raising additional water supply issues.

b) Describe the implications of climate change for the topic area (human health and security) and the TAG specific perspective on those impacts.

Heat related health outcomes – The National Institute of Environmental Health Sciences reports that extreme heat events cause more deaths annually in the US than all other extreme weather events combined. These deaths are likely under-reported due to the broad range of health problems which can be caused by excessive heat. In addition to heat stress and heat stroke, excessive heat can also lead to health complications such as heart attack, stroke, and respiratory illness, especially in sensitive populations like the elderly and the young. Temperatures are projected to rise across Washington State and the greatest impacts from heat events can be expected in cities with milder summers, less air conditioning and higher population density.

The numbers of excess deaths due to extreme heat events were projected using statistical modeling for four areas of Washington State: the greater Seattle area (King Pierce and Snohomish counties), Spokane County, the Tri-Cities and Yakima County. This analysis found that mortality rises significantly after heat waves lasting three or more days. It was estimated for ages 45+ that there may be as many as 211 excess deaths from all non-traumatic causes from thermal stress in the greater Seattle area by 2025 and just under 1000 by 2085. Spokane, Tri-Cities, and Yakima may have as many as 31 excess heat-related deaths for ages 45+ for all non-traumatic causes by 2025 and 76 by 2085(Jackson et al, 2009)

Respiratory and cardiovascular disease – Rates of mortality from respiratory and cardiovascular disease are expected to increase due to declining air quality and increasing temperatures. Contributing factors include increases in summertime ozone concentration, increases in pollen/fungal spores, and increases in particulate matter due to wildfires.

The National Mortality and Morbidity Air Pollution Study has identified a number of acute and chronic respiratory and cardiovascular (heart disease and stroke) health risks from exposure to these airborne contaminants (Dominici et al, 2003). Increased exposure to ozone and particulate matter (PM) air pollution have been implicated in premature death in adults, increased rates of infant mortality, worsened asthma or chronic obstructive pulmonary disease (COPD) in children and the elderly, low birth weight or prematurity in newborns, and increased incidence of serious respiratory infections, lung cancer, heart attack and stroke. Asthma and other allergic diseases such as seasonal allergic rhinitis ("hay fever") have increased in the population in the last decades and pollen is an important trigger for asthma and allergic symptoms. Ozone and PM are also asthma "triggers" and have been implicated in the development of asthma in children. It has been argued that the climate change that has already occurred may explain some of the rise in asthma incidence (Beggs and Bambrick, 2005). In addition, studies suggest co-exposure to allergens and air pollutants increase the potential for allergic symptoms to develop and may also increase the severity of response (Wyler et al., 2000; Shea et all, 2008).

These air pollution related morbidities are important public health priorities in Washington State. In 2008, heart disease was the leading cause of death in Washington State residents over 65 years of age (Center for Health Statistics, Washington State Department of Health, December 2009). Prematurity and low birthweight were the third leading causes of infant mortality in Washington State in 2008 (Center for Health Statistics, Washington State Department of Health, December 2009). Washington's adult asthma rate is higher than the United States average and 1 in 9 households (with children) have at least one child with asthma (The Burden of Asthma in Washington State: 2008 Update, May, 2009). Asthma costs in medical expenditures and lost productivity are already more than $400 million every year (The Burden of Asthma in Washington State, June 2005).

In general, worsening air quality will have a disparate impact on elderly, young, urban and rural poor (due to lack of access to chronic condition care and urban hotspots for ozone/particulate matter, rural hotspots for wildfire impacts.) Also, there will be relatively higher exposure for individuals who spend more time outside such as the homeless, children active in sports, and outdoor laborers. People with existing respiratory or heart problems will also be at increased risk (Climate Change and Health Effects, EPA, 2010)

Infectious Disease – Climate change is expected to bring emerging zoonotic diseases to Washington. Flooding may contaminate wells and food supplies, as well as create other unsanitary conditions, causing an increase in infectious disease. The large number of climate sensitive variables in infectious and vector-borne disease transmission makes the modeling of the effects of climate change very complex and less certain. What follows is a list of some variables and how they are projected to impact disease as a result of climate change.

- **Snowpack -** The amount of accumulated snowpack each year plays a role in the amount of water readily available for irrigation as well as excess flooding, which can create abundant mosquito habitat. Longer, drier summers and changing distribution patterns of vertebrate hosts could increase the distribution range of *Dermacentor* ticks, which are capable vectors of several pathogens, including Rocky Mountain spotted fever, tularemia, and Q fever, as well as causing tick paralysis. Milder winters in western Washington could cause an increase of *Ixodes pacificus* tick populations, which is the western US's Lyme Disease vector.
- **Mosquito borne diseases -**Should climate change result in longer warmer seasons, the state could see occasional local transmission of malaria occur, similar to what California has experienced. The introduction of exotic mosquito-borne diseases remains a concern. The recently introduced species, *Ochlerotatus japonicus*, is a known vector of filariasis and has been shown to transmit West Nile virus (WNV) in the laboratory. Global travel has increased the very real threat of introducing other diseases such as Rift Valley fever and Japanese Encephalitis. Other arboviral diseases that have occurred in Washington State and that may be sensitive to climate change are Western Equine Encephalitis and St. Louis Encephalitis, though no cases have been reported since 1988 (Washington State Department of Health, 2008).
- **Waterborne illnesses –** With increased frequency of flooding events comes potential increases in risk of waterborne illnesses. Outbreaks of waterborne diseases frequently follow heavy precipitation (Curriero et al., 2001; Thomas et al., 2006), hurricanes (Setzer and Domino, 2004) and flooding (Wade et al., 2004). Both surface water and ground water used for drinking may be affected (Rose et al., 2000), though generally surface water contamination is the greater risk. Sea water intrusion could also negatively impact water quality, particularly in coastal areas, causing further water supply problems/issues.
- **Deforestation -** The potential of increased forest decimation through beetle infestations with the subsequent increasing risk of severe forest fires will impact the habitat and distribution of

rodent populations, which would in turn impact the risk of exposure to the diseases they can carry, such as hantavirus.

- **Foodborne illnesses -** Research shows a significant correlation of foodborne illnesses with ambient temperature at the time of illness and with the previous week's temperature. Depending on the type of foodborne illness, for every degree centigrade rise in temperature, results showed 2.5 - 6% relative increase in risk of foodborne illness (Lake, IR, et al Epidemiol Infect, 2009).

<u>Injury</u> - Injuries are expected to increase due to severe weather events such as storms and flooding. Furthermore, power outages in the aftermath of severe weather events can contribute to injury from carbon monoxide poisoning when people use generators or barbeques indoors for cooking and alternative sources of heat.

The number of people killed by climatic, hydrological, and meteorological disasters in 2009 was the highest of the last decade, with 147,722 deaths reported worldwide. Scientific evidence supports that global warming will be accompanied by changes in the intensity, duration and geographical extent of weather and climate extreme events; therefore, the threat to human health and well being from such events as hurricanes, wildfires, flooding and tornadoes is likely to continue, and perhaps worsen. (IWGCCH, 2010)

<u>Mental Health</u> – Projected increases in extreme weather events are anticipated to bring associated increases in mental health impacts. The most common mental health conditions associated with extreme weather events are expected to be post traumatic stress disorder, depression, sleep difficulties, social avoidance, and drug or alcohol abuse. In addition, individuals being treated for mental illness are at greater risk during heat events because some drugs interfere with the body's ability to regulate temperature.

Extreme weather events potentially create both short and long term mental health and stress impacts. The severity of mental health impacts following an extreme climate event will depend on the degree to which there is sufficient support capacity, both during and following the event. During the recovery period, mental health problems and stress related disorders can arise from geographic displacement, loss of property, death or injury of loved ones, and the stress involved with recovery efforts. Furthermore, the chronic stress-related conditions and disorders resulting from severe weather events may lead to additional negative health effects. (IWGCCH, 2010)

Ultimately, the effects of migration, unemployment, cost of living, and reduced services is experienced by individuals in terms of their ability to cope in their daily lives; psychological stress has been defined as occurring when "an individual perceives that environmental demands tax or exceed his or her adaptive capacity" (Cohen et al., 1995) The effects of stress on illness are well established; stress effects immune and inflammatory responses and is implicated in cardiovascular disease, depression, infectious disease, and others. (Cohen et al., 2007) Anecdotal information coming from New Orleans indicates that one of the most lasting challenges facing the public health system in the aftermath of Hurricane Katrina has been meeting mental health needs.

3. Key Risks and Vulnerabilities

For all projected health impacts, the most vulnerable populations are children, elderly and people with existing respiratory, cardiovascular or other chronic disease. People who work outdoors will also be especially vulnerable to effects of heat.

Western Washington, particularly the greater Seattle area, is expected to see a higher level of mortality from heat events than Eastern Washington, even with population taken into account. There are several possible reasons for this projection including the urban heat island effect being much stronger in more densely populated areas, economic inequality being greater in urban portions of Seattle, and greater levels of residential air conditioning existing in Eastern Washington. (Jackson et al, 2009).

People living near the coast or near rivers likely to flood are at greater risk from extreme weather events, erosion, flooding, and salt water intrusion into drinking water supplies. They are also at greater risk from mental stress caused by displacement.

Another vulnerable group will be non-English speaking populations. Public health outreach and communication efforts will be critical in order to inform and educate non-English speakers how to prevent injury and illness associated with extreme weather events, poor air quality, and infectious diseases.

Finally, socioeconomically disadvantaged populations have few resources for adapting to a changing environment; the poor are most vulnerable not only to the direct health impacts of our changing climate but to indirect health impacts as well, namely increased economic pressures leading to worsened health care access and public safety, and increased stress and illness.

4. Unifying Themes and Overarching Strategies to Prepare for and Adapt to Climate Change.

a) What are the key elements of a successful strategy? What are the key principles that inform the development of the strategies?

b) What are the criteria for prioritizing strategies?

The Human Health and Security TAG identified these guiding principles for identifying and prioritizing recommendations:

- Bolster community adaptation and resilience capacities by enhancing existing systems and tools.
- Provide multiple benefits to a community rather than being narrowly focused

- Protect the health of the most vulnerable segments of the population.
- Promote and support local community action.
- Result in systems that are flexible enough to effectively respond to new and/or changing climate predictions and impacts.
- Link strategies and initiatives to directions and efforts coming from the federal government

c) What are the priority strategies, overarching strategies, and themes?

TAG 2 identified several overarching themes for recommended strategies and actions necessary for adaption and prevention of all projected impacts. These themes include surveillance, communication and education, and mitigation of the disproportionate impacts to the poor.

Surveillance – To prepare and adapt to the anticipated as well as unanticipated, effects of climate changes upon the residents of Washington State, critical public health surveillance systems will need to be enhanced. The ongoing and systematic collection of data is critical for monitoring changes in the magnitude of current public health threats and early detection of new or emerging threats. Both the PAWG and TAG 2 identified three areas where surveillance systems are critically important to public health preparation and adaptation.

- Zoonotic Disease Surveillance
- Air Quality Monitoring
- Notifiable Conditions Surveillance

Communication – Outreach and education is a core function of public health prevention work. We need to integrate climate change discussion into public health's existing priorities. We know that single messages will not work for all populations/audiences, nor will single-pronged methods of delivery. Therefore, as with the above recommendation, we encourage analyzing how climate change can be messaged at the same time agencies are considering how best to communicate their intervention (e.g. preventing heat stress) to targeted audiences.

Social Equity – Both the PAWG and the TAG recognized that the health impacts of climate changes will fall disproportionately on those in lower socio-economic brackets. Low income individuals, people of color and those with limited English proficiency often experience higher rates of chronic stress and have poorer health outcomes regardless of the stressor. These individuals also typically experience poorer existing health conditions, more barriers to health care, unstable employment, and lower quality housing. In addition the poor are more likely to lack access to healthy food, have fewer transportation options, and live in neighborhoods with lower social and financial capital, higher crime rates, and more safety concerns. As a result of infrastructure deficits in these areas, climate change effects are likely to exacerbate one or more of the above factors, or multiply the outcome between one or more factors that may further reduce the ability and adaptive capacity of individuals and communities to cope with climate change effects.

5. Recommended Adaptation Strategies and Resilience Actions

a. Identify key barriers or opportunities for taking action to address climate change impacts

The general response strategies needed to prepare and adapt for the health implications of climate change fit well within existing core public health activities and services. The key barrier currently facing the public health system is the economic situation that has had a significant negative impact on the current ability to deliver services, not to mention the ability to address new threats to public health. Local and state funding for public health has been rapidly eroding, resulting in the loss of trained public health professional staff ranging from 25 - 40% in some jurisdictions and compromising our overall public health system's ability to respond to critical health issues.

In response to the dual challenges of a severe funding crisis and a change in the nature of preventable disease and illness in our state the Secretary of Health formed a workgroup in 2010 to look at reshaping the governmental public health system in Washington and develop an *Agenda for Change*. Given the outlook for a slow economic recovery, TAG 2 recommends that response strategies that address the projected health implications of climate change fit within the overall context of the *Agenda for Change*, rather than create a stand-alone climate change response strategy. TAG 2 also believes that since the underlying causes of climate change are not fully embraced by all, fitting our recommended strategies into core public health efforts may be the most effective means to move forward to prepare communities to address the potential implications of climate change.

The overarching objectives contained in the *Agenda for Change* include:

- "Focus our communicable disease capacity on and enhance the most effective and important elements of prevention, early detection, and swift responses to protect people from communicable diseases and other health threats."
- "Focus on policy and system efforts to foster communities and environments that promote healthy starts and ongoing wellness, prevent illness and injury, and better provide all of us the opportunity for long, healthy lives."
- "With healthcare reform, it is time for public health to more effectively and strategically partner with the healthcare system to improve access to quality, affordable, and integrated health care that incorporates routine clinical preventive services and is available in rural and urban communities alike."

b. What initiatives, policies, programs and tools are already in place to prepare for and adapt to climate change?

Climate change is expected to increase a number of public health challenges that already exist - disease, injury, and mental health impacts related to flooding, drought, and extreme temperature. As such, the public health system and its partners already have numerous programs and initiatives in place to assist communities prepare for and respond to public health issues. The real challenge and opportunity is in expanding existing initiatives to fill any gaps and then to work creating messaging and informational links that connect these existing adaptation and preparation activities to the broader climate change and public health discussion.

Some of the existing programs already in place include:

Air Quality –

- The Department of Ecology and its partners operate a network of PM2.5 and ozone monitors throughout Washington State. There are currently 11 official Ecology network ozone monitors and nearly 60 PM2.5 monitors as well as other monitors that are not part of the official network. Nearly all these stations provide near-real-time data on air quality conditions and can be accessed via Department of Ecology's website.

- NW-AIRQUEST (Northwest International Air Quality Environmental Science and Technology Consortium, http://lar.wsu.edu/nw-airquest/) is a consortium of U.S. and Canadian federal, state, tribal, and local government agencies and universities in the Pacific Northwest that seeks to maintain and enhance a sound scientific basis for air quality management decisions in the region. NW-AIRQUEST has several tools that will be useful in understanding the impacts of climate change on the Pacific Northwest, including a regional Weather Research and Forecasting (WRF) meteorological model (http://www.atmos.washington.edu/mm5rt/), and the AIRPACT air quality model (http://lar.wsu.edu/airpact-3/introduction.html).

- EPA Region 10 convenes annual meetings of the program managers of the state and local air quality programs. This is a useful group for discussing and disseminating climate change issues in the Pacific Northwest region. Similarly, the Washington Air Quality Managers Group consists of the Washington Air Quality program managers and meets every 3-months.
- The American Lung Association in Washington provides regional air quality forecasts and an email alert service know as e-forecast. This is a tool to give residents of the Northwest fast, accurate notification when air quality has deteriorated and may affect health-sensitive people. It's called the Breathe Easy Network.

Thermal Stress –

- When heat advisories are issued by the National Weather Service, many local communities open cooling centers to accommodate those in need. One example is the city of Kirkland with their Kirkland residents can chill at Community Centers program.

- The Washington State Department of Health provides informational resources about precautions to reduce the risk of heat exhaustion and heat stroke.

Extreme Weather/Emergency Preparedness -

- The Washington State Department of Health actively works with water systems to help them prepare for both drought and flood response. Two important tools include the drought resource guide and the flood response guide.
- The Emergency Management Department provides valuable resources that address public health concerns in the Comprehensive Emergency Management Plan, the State Hazard Mitigation Plan and its foundation document the Hazard Inventory and Vulnerability Analysis. These plans are built on local input and help guide strategy for appropriate response when a variety of significant events occur. In addition FEMA has recently expanded their mapping capabilities through their RiskMAP initiative which allows them to provide both a broader and more detailed range hazard identification services.

Communicable Disease -

- Monitoring for vector borne diseases at the state and local level is accomplished through the Notifiable Conditions Surveillance system under (chapter 246-101 WAC) which directs health care providers, facilities, laboratories, veterinarians and others to notify public health authorities of cases of certain diseases or conditions. The state then forwards the reported data to the CDC monthly to be incorporated in national and international tracking.
- The Washington Tracking Network integrates environmental data about hazards and exposure with public health data to try and make connections to health outcome information.
- Mosquito Control Districts under chapter 17.28 RCW are special purpose districts which may be formed to directly control mosquitoes within their boundaries. Currently there are districts formed in, Adams, Benton, Franklin, Grant, Kittitas, Walla Walla, and Yakima Counties.

c. What additional strategies are needed to prepare for and adapt to a changing climate?

The work identified above is critically important to public health preparation and adaptation. TAG 2 wishes to emphasize that first and foremost current activities must be maintained and not diminished as we consider additional strategies to pursue. The additional objectives which follow take their origins from the *Agenda for Change*.

Objective: "Focus our communicable disease capacity on and enhance the most effective and important elements of prevention, early detection, and swift responses to protect people from communicable diseases and other health threats."

Strategy: Enhance surveillance and reporting systems in order to support early detection and swift response to emerging threats associated with climate change.

Action: As efforts to advance the *Agenda for Change* continue, the Public Health Improvement Partnership should focus efforts on maintaining and rebuilding the core capacity and systems that support our public health surveillance systems at the state and local levels.

Action: The Department of Health should focus future efforts in the development of their Environmental Public Health Tracking network on data and indicators which are linked to climate change and healthy communities issues. Specifically, targeting meaningful data sets that position us to better understand changes in zoonotic disease patterns and disease vectors, air quality conditions, and harmful algae blooms will assist our future efforts in preparing and adapting to climate change related conditions which can affect health.

Action: The Department of Health and the Washington Health Care Authority should make every effort to leverage the current federal efforts under National Health Care Reform to strengthen standardized electronic medical records as part of "meaningful use" infrastructure development. Using this federal initiative to enhance syndromic surveillance and electronic laboratory reporting should help to support the efforts needed to rapidly detect emerging health issues and position the health system for timely and effective community response actions.

Strategy: Enhance emergency planning efforts at the local level so that communities are able to quickly respond to climate change related conditions which have the potential to affect health.

Action: The Department of Health, University of Washington, and other state agencies should continue to look for funding opportunities that can support more localized forecasting and risk modeling for focused planning efforts that can address the potential health implications of climate change (e.g. extreme heat events; flooding and other extreme weather events; potential for increased forest fires, etc.). Localized forecasting and risk modeling will greatly enhance the ability of a community to be prepared to address the potential effects of climate change. As part of those efforts, updated census mapping of vulnerable populations will also assist in targeting resources during emergency response efforts.

Action: The Military Department - Emergency Management Division, should partner with the Department of Health and other state agencies to explore opportunities to bolster local emergencies response plans to specifically address projected climate change impacts for their local area. Whether projected local issues are associated with potential extreme heat events, or increased flooding due to sea level rise, local planning and preparedness will greatly influence the resiliency of a community to potential climate change related events.

Strategy: Enhance communication efforts in order to raise awareness about the potential health implications of climate change and support community engagement in preparation and adaptation efforts.

Action: The Department of Health, in collaboration with the Northwest Center for Public Health Practice and other academic practice partnerships, should develop a web-based resource hub aimed at providing information and technical resource links to the public health community for all aspects of climate change adaptation and preparedness. This type of resource would greatly enhance the ability of local communities to take advantage of all of the good work being conducted across the country on the health associated implications of climate change. This resource should be available in several languages to ensure it meets the needs of communities most at risk.

Action: The Washington State Public Health Association should be encouraged to dedicate time at the annual Joint Conference on Health as an important venue to raise awareness and engage the public health and health care community on the health implications of climate change. Another important aspect of this of engagement would be to raise awareness of the tools and opportunities for local communities to prepare for the various health implications of climate change. Examples would include health impact assessment tools and highlighting linkages between community planning, climate change, and public health.

Action: As opportunities arise the Department of Health, academic practice partnerships, and other public health organizations should pursue partnership with for-profit and non-profit organizations dealing with climate change to raise awareness and promote initiatives of the health implications of climate change.

Objective: "Focus on policy and system efforts to foster communities and environments that promote healthy starts and ongoing wellness, prevent illness and injury, and better provide all of us the opportunity for long, healthy lives."

Strategy: Encourage the Governor to pursue opportunities to enhance cross agency initiatives and actions to support healthy and sustainable communities, including those with connection to climate change adaptation and resiliency issues.

Action: The Governor's Natural Resources Cabinet should identify potential policy areas which link climate change impacts to both environmental and human health consequences (such as reduced Green House Gas emissions through land use and transportation, heat island mitigation, flood plain and low shoreline development) and develop policies and practices to limit or mitigate these areas of concern.

Strategy: Incorporate strategies that address the projected health implications of climate change into on-going efforts to address chronic disease and healthy community initiatives.

Action: The Department of Health should consider the health implications of climate change in their overall healthy community initiatives – leveraging the efforts of these various initiatives to address important chronic disease issues while at the same time addressing projected health implications of climate change.

Action: The Department of Health should pursue future funding opportunities (e.g. CDC Prevention Funds) to support the enhancement of critical public health infrastructure that is needed to promote healthy communities, including addressing the projected implications of climate change.

Objective: "With healthcare reform, it is time for public health to more effectively and strategically partner with the healthcare system to improve access to quality, affordable and integrated health care that incorporates routine clinical preventive services and is available in rural and urban communities alike."

Strategy: Work to ensure that all segments of a local community have access to care in response to climate change related events.

Action: The State of Washington, including the Department of Health, should support the capacity of local health jurisdictions to continue their work with the health care community to ensure access to quality, affordable, and integrated health care.

Strategy: Enhance awareness of the projected health implications of climate change and strategies to address those implications throughout medical system – including the mental health system.

Action: The Department of Health should pursue opportunities to engage, and disseminate information on the projected impacts of climate change on human health, with the Washington Medical Association, Department of Social and Health Services, UW Medical School and School of Public Health, Schools of Social Work at WSU, PSU and Eastern Washington University, as well as throughout the state's mental health system (RSNs). This should include efforts to raise awareness of the overarching mental health effects resulting from of the social and environmental disruptions associated with emergencies.

Action: During extreme weather events, and when possible in advance of predicted events, provider alerts should be disseminated to the medical and mental health communities, so they can be best prepared to serve members of their communities that may be adversely impacted.

d. Additional Considerations

The Human Health and Security TAG wishes to particularly emphasize that the health impacts of climate change will fall disproportionately on those in lower socio-economic brackets.

As stated earlier in this report, people who stand lower in society's hierarchy undergo more chronic stress and have worse health outcomes no matter what the stressor. They also typically experience poorer existing health conditions, more barriers to health care, unstable employment, and lower quality housing. In addition, the poor face more barriers to accessing healthy food, have more limited transportation options, and live in neighborhoods with lower social and financial capital, high crime rates, and unsafe built environments. There is also a greater likelihood that climate change effects will either exacerbate one or more of the above factors, or create synergies between factors that may further reduce the ability and adaptive capacity of individuals and communities to cope with climate change effects.

In light of the above, the Human Health and Security TAG recommends that in any and all follow-up action addressing the impacts of climate change, special consideration be given to the poor and disenfranchised members in our communities.

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Appendix B3

Washington State Integrated Climate Change Response Strategy

Photo Credit: Spencer Reeder

Interim Recommendations from
Topic Advisory Group 3
Species, Habitats and Ecosystems
(TAG3)

February 2011

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TABLE OF CONTENTS

I. INTRODUCTION

PURPOSE AND BACKGROUND

This document was prepared to inform the development of a statewide, integrated climate change response strategy, as required by state legislation passed in 2009. The Steering Committee guiding the development of that strategy formed four separate topic advisory groups (TAGs) to develop draft recommendations for different sectors; TAG3 was directed to consider impacts, key vulnerabilities and draft adaptation strategies for species, habitats and ecosystems across Washington. Approximately 30 individuals representing a range of organizations and perspectives participated in the TAG's work.

This report should be considered as interim. The recommendations presented represent the best thinking of the individuals participating in the TAG3 process at the time the report was drafted. While a number of experts were consulted during development, the limited time and resources available did not allow for extensive peer review of draft recommendations or iterative review and comment. Ultimately, development and implementation of an effective adaptation strategy will require more extensive participation by those charged with implementing and overseeing it. This will ensure that adaptation strategies reflect both scientific information and the management structure within which strategies will be carried out.

TAG3 GOALS AND ORGANIZATION

One of the first tasks of the TAG was to adopt two goals to guide its work: 1) Ensure the long-term viability of ecosystems in Washington, including ecosystem integrity, ecosystem services, and the ecological processes they depend on, and 2) Maintain biodiversity, with an awareness of the needs of climate-sensitive species.

The TAG also determined early in its process that since the specific ecological consequences from climate change will vary by ecosystems, adaptation strategies should also be evaluated separately for each major system. The TAG therefore elected to work in four separate subgroups; Marine/Coastal, Freshwater/Aquatic, Forests and Western Prairies, and Aridlands. Each group reviewed current scientific literature for observed and projected impacts from climate change and then identified a set of strategies and possible actions. Reports from each group are presented in Appendix A. The Science Summaries used to provide current and projected impacts were prepared by the National Wildlife Federation and are available in Appendix E, found in a separate document.

ADDRESSING CLIMATE IMPACTS TO SPECIES AND ECOSYSTEMS IS CRITICAL

Addressing impacts to species and ecosystems is a critical component of a comprehensive state adaptation strategy. Washington citizens rely on our many varied ecosystems for a wide range of benefits; for provisioning services such as clean water, fiber and food, for regulating services such as flood control and erosion control, pollination of crops, and cultural services such as outdoor recreation opportunities. Climate change puts our ecosystems, and the life supporting benefits they provide, at risk. Chapter II discusses in more depth the ecological consequences of projected climate impacts and how they may affect the delivery of ecosystem services to human communities, with examples of the economic costs which occur with the disruption of ecosystem services

KEY CONCEPTS[1]

There is no single best approach for developing adaptation strategies for species and ecosystems. Depending on any number of factors, conservation practitioners may opt for one of three basic conceptual approaches – resistance, resilience or response. TAG3 used each of these concepts (explained below) in developing the goals and priority strategies presented in this document.

- Resistance focuses on minimizing the impact of global climate change on a particular system, either by limiting local or regional climatic changes or minimizing the effect of changes that do occur. Examples from the built environment include using light-colored roofs to limit heating in cities or maintaining dikes and levees around low-lying cities to prevent flooding. Examples from the conservation world include maintaining or restoring riparian vegetation to reduce warming in cold water systems, or restoring wetlands to reduce drought and flooding.
- Resilience means that a population or system is able to bounce back to something like its previous state following disturbance or change, with ecological functions and processes still intact. Many of the recommended strategies to address the risks of catastrophic fire for both built and natural systems are focused on increasing the resilience of a system to recover from the disturbance.
- Response: There is some level of change beyond which a system becomes irrevocably altered. In these situations, management can focus on facilitating longer-term species or system responses to maintain desired resources or ecosystem services over time. A related concept is the idea of "preserving the canvas." The philosophy here is essentially one of facilitating natural responses to change rather than trying to maintain the status quo. Examples from the built environment include rolling easements and other mechanisms of managed retreat from sea level rise. Examples from the conservation world include maintaining ecosystem connectivity to support species range shifts or including likely future habitat in critical habitat designations.

[1] Additional definitions can be found in the glossary in Appendix D.

Another concept to consider in developing climate change adaptation strategies is the risk of maladaptation. Most adaptation actions require some sort of trade-off. When the negatives of an adaptation action or strategy outweigh the benefits, it becomes a maladaptation. Maladaptations may include: strategies that benefit one sector or community at the expense of others; strategies that decrease near-term harm but increase long-term vulnerability; strategies that result in increased greenhouse gas emissions or otherwise increase the rate or extent of global or regional change; economic actions or strategies that reduce incentives to adapt or set paths that limit choices available to future generations.

HOW THIS REPORT IS ORGANIZED

There are four chapters in the main body of the report: Chapter I introduces the report, Chapter II summarizes climate change impacts and consequences, and Chapter III includes recommended goals, priority strategies and near-term actions. Chapter IV introduces key issues which should be considered for further development in the context of the statewide integrated response strategy. The appendices provide further depth and background. Appendix A includes both narrative and tables describing adaptation strategies and actions for each of the four ecological systems. Appendix B is a summary of projected climate impacts for Washington, provided by the Climate Impacts Group. Appendix C includes information on prioritizing adaptation options, Appendix D is a glossary of key terms, and Appendix E contains the four science summaries which summarize climate impacts separately for each ecological system.

II ECOLOGICAL CONSEQUENCES OF CLIMATE CHANGE

Climate change has already led to demonstrable impacts to many species, habitats and ecosystems in Washington State. For example, sea levels have risen along our shores, threatening productive coastal ecosystems for our fish, shellfish, seabirds and other species. Summer temperatures in some rivers and streams already exceed temperature thresholds that are stressful or fatal for coldwater fish such as salmon and bull trout (Mantua et al. 2010). Temperatures are continuing to rise, and scientists estimate that, globally, approximately 20-30% of plant and animal species assessed to date could be at an increased risk of extinction if temperatures exceed 2.7°F to 4.5°F (IPCC 2007). These changes have the potential to fundamentally alter many ecosystems in the state, and dramatically affect the services and products they provide to human communities. The following section describes anticipated changes, the ecological impacts of those changes and some potential effects on ecosystem services.

Box 1. Examples of Ecosystem Services

Provisioning Services:
- Food production
- Fiber, timber, and fuel production
- Maintaining genetic resources

Regulating Services:
- Climate regulation (e.g., carbon storage, carbon sequestration; temperature regulation)
- Regulating river flows and groundwater levels
- Flood/storm protection
- Water filtration/water quality
- Preventing soil erosion
- Soil formation
- Habitat maintenance and regeneration
- Providing shade, shelter, refugia
- Insect/pest control
- Waste absorption and breakdown
- Maintaining the distribution, abundance, and effectiveness of pollinators

Supporting Services:
- Nutrient cycling (e.g., converting nitrogen, carbon, and phosphorus from unusable to usable forms)
- Maintaining soil fertility, health
- Water cycling

Cultural Services:
- Recreation Aesthetic value
- Education and research
- Maintaining tribal cultural practices

Adapted from UNEP 2006, Table 1.1; Ecosystem Services Project (2011); Batker et al. 2010, Table 1

ECONOMIC VALUE OF ECOSYSTEM SERVICES

Washington's diverse ecosystems, species, and habitats provide a complex range of goods and services, collectively referred to as "ecosystem services," that benefit Washington residents. These services include food production; fiber, timber, and fuel production; biodiversity; climate regulation (e.g., carbon storage, carbon sequestration; temperature regulation; storm protection; maintenance of soil fertility and health; water quality; spiritual and cultural sustenance, and recreation). A list of common ecosystem services is provided in Box 1. Although it is difficult to calculate the full economic value of many ecosystem services, the economic value associated with some aspects of ecosystem services have been calculated for Washington. For example:

- Habitat provided by marine and coastal ecosystems in Washington State sustain commercial and recreational fishing that directly and indirectly supported over 16,000 jobs and $540 million in personal income in 2006 (TCW Economics 2008).
- Washington's biodiversity supported hunting, fishing, and wildlife viewing activities that added nearly $3.1 billion to Washington's economy in 2006 (U.S. Department of the Interior 2006).

- Nitrogen removal by shellfish production in Oakland Bay (near Shelton, WA) provides approximately $77,000 and $650,000 in annual water quality treatment benefits for wastewater treatment facilities in the City of Shelton and the City of Olympia, respectively (Hudson 2010).
- One local study found that wetlands provide over $40,000 per acre of flood damage protection in Renton (Leschine, 1997). A recent pilot study for King County demonstrated that flood hazard reduction projects that widen the floodway of the Cedar River could avoid $468 to $22,333 per acre per year in damages to homes and county flood control facilities (Swedeen and Pittman, 2007).

A 2010 report on the annual value of ecosystem services in the Puget Sound watershed alone conservatively estimated the partial value of 14 ecosystem services at $9.7 billion to $83 billion annually (Batker et al. 2010). These services included gas and climate regulation, disturbance regulation (e.g., flood control), water supply, waste treatment, and habitat refugia.

HOW CLIMATE CHANGE DRIVERS MAY IMPACT ECOSYSTEMS AND THE SERVICES THEY PROVIDE

Provision of ecosystem services depends on preservation of key physical and ecological relationships within a system, much as the functioning of a car relies on a specific arrangement of car parts (Barclay et al. 2004). Climate change has the potential to impact many ecosystem services by affecting the key relationships that support those services. For example, coastal marshes act as important buffers against coastal erosion and infrastructure damage from storm surge. Sea level rise may "squeeze out" coastal marshes that do not have the ability to migrate inland in response to rising water levels (for example due to the presence of paved roads or other hard infrastructure), reducing and in some cases eliminating the natural protection they provide.

Research on Pacific Northwest climate change impacts by the University of Washington Climate Impacts Group (e.g., Climate Impacts Group 2009) and others have identified numerous climatic changes and associated impacts that are likely to have ecological consequences for Washington's ecosystems, species, and habitats and impact the ecosystem services they provide. Projected physical changes include, but are not limited to those on the following bulleted list. Box 2 describes examples of how ecosystem services will be affected by these changes.

PROJECTED PHYSCIAL CHANGES:

- **Increasing air temperature.** Global climate models project increases in average annual Pacific Northwest temperature (with range) of +2.0°F (+1.1 to 3.4°F) by the 2020s, +3.2°F (+1.6 to 5.2°F) by the 2040s, and +5.3°F (+2.8 to 9.7°F) by the 2080s, relative to 1970-1999. Warming is expected across all seasons with the largest warming expected in the summer months. (Mote and Salathé 2010)
- **Changes in annual and seasonal precipitation.** Projected changes in annual precipitation, averaged over all models, are small (+1 to +2% for much of the 21st century) but some models project a stronger seasonal precipitation cycle with wetter autumns and winters and drier summers. (Mote and Salathé 2010)
- **Declining snowpack**. April 1 snowpack is projected to decline in mid and low elevation basins as warmer cool season (Oct-March) temperatures cause more winter precipitation to fall as rain rather than snow and earlier spring snowmelt. Average April 1 snowpack is projected to decline -37% (for the B1 greenhouse gas emissions scenario) or -44% (for the A1B scenario) by the 2040s, and -53% (B1) or -65% (A1B) by the 2080s, relative to the 1916-2006 historical average. (Elsner et al. 2010)
- **Changes in the timing of streamflow runoff, low flows, and flood risk.** Declining winter snowpack, shifts to more winter rain, and earlier spring snowmelt are projected to shift the timing of peak spring runoff earlier into the year and reduce summer streamflows in transient (rain/snow mix) and snow-dominant watersheds. Low elevation rain-dominant basins are also likely to see lower summer streamflows as a result of warmer summer temperatures, although groundwater contributions to base streamflow may help offset declines in late summer streamflow. Flood risk increases in some basins, particularly transient basins west of the Cascades, and decreases in other basins, including east-side snowmelt dominant watersheds. In all cases, results will vary by location and basin type. (Elsner et al. 2010; Mantua et al. 2010; Tohver and Hamlet 2010)

Box 2. Examples of Impacts on Ecosystem Services

- **Impacts on food production,** due for example, to losses in spawning and breeding grounds for fish.
- **Impacts on fiber, timber, and fuel production** due for example, to shifts in commercial timber species, and losses from increased disturbances, such as fire.
- **Reduced water quality**, due for example, from lower flows and increased sediment and pollutant loads.
- **Impacts on water supply for communities, agriculture, and wildlife** due for example, from declining snowpack, reduced groundwater recharge, reduced contributions to summer streamflow in certain rivers and streams.
- **Reduced erosion and flood protection,** particularly in unstable areas after disturbance, or in areas where sea level rise reduces coastal habitats that usually provide buffering capacity.
- **Impacts on recreation** and related economic activities, such as fishing and snow skiing.
- **Impacts on culturally significant species, practices, sites of importance to tribes.**

- **Impacts on soil moisture.** Warmer temperatures, declining snowpack, and related changes in hydrology are projected to cause modest reductions overall in July 1 soil moisture, with more significant decreases projected in the Cascades and Olympic Mountains. Some areas in south central Washington may see slight increases in July 1 soil moisture as a result of increasing winter and spring precipitation in some climate scenarios. (Elsner et al. 2010)
- **Increasing summer water temperature.** Warmer summer air temperatures are projected to increase summer stream temperatures, likely reducing the quality and extent of freshwater habitat for coldwater adapted species such as salmon. The duration of periods that cause thermal stress and migration barriers for salmon is projected to at least double (under the B1 greenhouse gas emissions scenario) and perhaps quadruple (for the A1B scenario) by the 2080s for many streams and lakes. As with other hydrologic impacts, results will vary by location. (Mantua et al. 2010)
- **Increased risk of forest fires and impacts from insects such as the mountain pine beetle.** Due to increased summer temperature and decreased summer precipitation, the area burned by fire regionally is projected to double by the 2040s and triple by the 2080s (relative to 1916-2006). The probability that more than two million acres will burn in a given year is projected to increase from 5% (observed) to 33% by the 2080s. Primarily east of the Cascades, mountain pine beetles will likely reach higher elevations and pine trees will likely be more vulnerable to attack by beetles. (Littell et al. 2010)
- **Increasing sea level.** Sea level is projected to increase in Washington State although specific projections vary by location depending on differences in vertical land movement, the influence of onshore winds, and other factors. For the three regions analyzed in Mote et al. 2008, the projected medium change (with range) in Washington sea level in 2100 is +2" (-9 to +35") for the Northwest Olympic Peninsula, +11" (+2 to 43") for the central and southern coast, and 13" (+6 to 50") for Puget Sound. (Mote et al. 2008)
- **Potential for more extremes, including precipitation, heat, and coastal storms.** More intense precipitation is projected, although the spatial pattern of this change and the changes in intensity are 1) highly variable, and 2) not statistically significant for much of the state (Salathé et al. 2010). For extreme heat, the average annual number of heat events, average heat event duration, and maximum heat event duration are expected to increase in all scenarios and all four regions (Seattle, Yakima, Spokane, and the Tri-Cities region) evaluated by Jackson et al. 2010. Projected intensification of mid-latitude[2] winter season storm tracks is likely to increase coastal storm intensity (i.e., precipitation and winds) (Ulbrich et al. 2008).
- **Increasing ocean acidification.** The pH in the North Pacific, which includes the coastal waters of Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO_2 to 560 and 840 ppm, respectively. This projected decrease

[2] Mid-latitudes" are the areas lying between the tropics and the polar regions, or approximately 30° to 60° north or south of the equator.

in pH is equivalent to a 100-150% increase in the hydrogen ion concentration or “acidity” of the oceans. (Feely et al. 2009)

More details about these and other impacts are provided in the four “Science Summaries” prepared for each ecological system (see Appendix E), the climate impacts summary table in Appendix B, and the individual papers cited herein. Table 2.1 illustrates how projected climatic changes and associated impacts may produce ecological consequences that impact ecosystem services in Washington.

Climate change is not the only issues facing ecosystems, habitats, and species, however. Existing problems with pollution, habitat fragmentation, reduced genetic and species diversity, and competition from invasive and exotic species can reduce the adaptive capacity of ecosystems, habitats, and species. Human responses to climatic change and associated impacts may also affect ecosystems, habitats, and species in negative ways. For example, increased groundwater pumping in response to warmer temperatures and growing water demands could reduce groundwater contributions to summer streamflow, increasing the potential for warmer summer stream temperatures and increased thermal stress for coldwater adapted species. Water levels in wetland systems could also be impacted. Levees installed for flood protection may restrict channel migration, limiting the diversity of riparian habitat. Consequently, it is critical to consider how Washington’s ecosystems, habitats, and species can adapt to both the direct and indirect (e.g., human) impacts of climate change in the context of existing stressors.

TABLE 2.1: Projected Climate Change Impacts, Ecological Consequences, and Impacts on Ecosystem Services[3]

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Marine & Coastal	1. **Sea level rise.** Projected increase in Puget Sound of +6" (range: 3-22") by 2050 and +13" (range: 6-50") by 2100. 2. **Ocean acidification.** Ocean pH is projected to decrease in the North Pacific and Puget Sound due to increased concentrations of CO_2 in the atmosphere. 3. **Increasing sea surface temperature.** Sea surface temperature is projected to increase +2.2°F for the 2040s. 4. **Increasing coastal storm intensity** projected (i.e., more intense precipitation and winds). 5. **Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Flood risk increases in some basins, particularly west-side transient (rain/snow mix) basins. These changes will affect freshwater inflow to	• **Reduced and/or lost coastal habitats** (1-4) • **Changes in the distribution of coastal habitats** (1-5) • **Loss of spawning grounds, rearing grounds, and key foraging and resting sites** (1-5) • **Reduced and/or lost habitat connectivity** (1-4) • **Increased coastal erosion** (1,4) • **Increased coastal hypoxia** (3,5) • **Shifts in species migration and distribution,** e.g., salmon migration ranges may shift due to sea surface temperature changes (1-5) • **Changes in food webs,** e.g., shifts in phytoplankton diversity (1-5) • **Impacts to marine and coastal water quality** (2,3,5) • **Impacts on range and competitive ability of exotic and invasive species** (1-5)	• **Impacts on food production** due, for example, to losses in spawning and rearing grounds for fish, losses in aquaculture beds, and changes in marine food webs affecting species distribution • **Reduced flood, storm surge, and erosion protection,** particularly in areas where sea level rise reduces coastal habitats that typically provide buffering capacity • **Reduced water quality,** e.g., water temperature, sedimentation, dissolved oxygen • **Impacts on biodiversity,** including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species. • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to coastal

[3] The four "Science Summaries" for each ecological system (see Appendix E) and the climate impacts summarized in Appendix B provided the references for this table.

[4] "Primary impact drivers" refers to any combination of projected climate impacts identified in the first column. Primary impact drivers are impacts that play a significant role in a specific ecological consequence but should not be interpreted as the *only* cause (or causes) of the identified ecological consequence. Also note that human responses to climate change impacts will have a role in determining the extent to which ecological consequences are realized. Human impacts are not included in this table.

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Marine & Coastal	coastal waters.		sites that are significant to tribes; loss of community identities (and economies) tied to aquaculture or fishing • **Impacts on recreation** and related economic activities**,** e.g. shifts in/lost opportunities for fishing, wildlife viewing, or harvesting (e.g., shellfish) due to loss/shifts in coastal habitat, changes in species distribution.
Forests	**1. Increased air temperature.** Warming is projected by all models for all seasons through the 21st century, with the largest warming in the summer months. **2. Changes in precipitation**. Average annual precipitation is projected to increase slightly with an enhanced seasonal cycle (drier summers and wetter falls and winters) likely. **3. Reduced snowpack**. Projected decline in April 1 snowpack in the range of -37% or -44% by the 2040s (depending on the greenhouse gas emissions scenario) and -53% or -65% by the 2080s. **4. Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Flood risk increases	• **Changes in forest productivity**. Enhanced productivity at upper elevations as snowpack declines; decreasing productivity at lower elevations where decreasing water availability is a limiting factor (1,2,3,5,6) • **Impacts on species composition, distribution, and abundance,** particularly for species less able to move in response to habitat changes ; includes changes in elevational boundaries (1-6) • **Changes in the distribution of forest habitats**, e.g., projected declines in climatically suitable habitat for Douglas fir and pine species; exacerbated for alpine habitats, which have limited ability to move upslope in response to warming (1-6) • **Reduced and/or lost habitat connectivity** (1,2,3,4) • **Changes in phenology** (the timing of ecological	• **Impacts on fiber, timber, and fuel production** due, for example, to shifts in commercial timber species, losses from increased disturbances (e.g., insect outbreaks, forest fires), or drought • **Impacts on biodiversity**, including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species • **Reduced water quality,** e.g., sediment loads • **Impacts on water supply benefits**, particularly surface and groundwater regulation and flow • **Impacts on climate regulation**, e.g., temperature regulation, carbon storage,

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Forests	in some basins, particularly west-side transient (rain/snow mix) basins, and decreases in other basins, including east-side snowmelt dominant watersheds. **5. Declining soil moisture**. Modest decreases in July 1 soil moisture are projected overall with the largest declines projected for the Cascades and Olympic Mountains. **6. Altered groundwater.** Changes in groundwater possible although highly uncertain and with great spatial variation. Shallow aquifers are more likely to be affected than deep aquifers.	events) (1-4) • **Increased susceptibility to pests and diseases** (1-6) • **Impacts on the range of exotic and invasive species** (1-4) • **Changes in tree moisture** (1-5) • **Increased frequency and duration of fires and increase in area burned** (up to double or triple likelihood of severe fire by 2080s) (1-6) • **Increased risk of drought** (1-6)	carbon sequestration • **Impacts on nutrient cycling and soil health** necessary to support healthy forest ecosystems • **Reduced erosion and flood protection,** particularly in unstable areas after disturbance (e.g., forest fires, landslides) • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to sites that are significant to tribes, or loss of community identities (and economies) tied to forest-related activities • **Impacts on recreation** and related economic activities, e.g. hunting, fishing, hiking, wildlife viewing
Freshwater/ Aquatic	**1. Increased air temperature.** Warming is projected by all models for all seasons through the 21^{st} century, with the largest warming in the summer months. **2. Changes in precipitation**. Average annual precipitation is projected to increase slightly with an enhanced seasonal cycle (drier summers and wetter falls and winters) likely. **3. Reduced snowpack.** Projected decline in April 1 snowpack in the range of -37% or -	• **Shifts in aquatic community composition, distribution, and abundance** (1-9) • **Changes in phenology** (the timing of ecological events) (1-9) • **Reduced and/or lost freshwater/aquatic habitat, wetlands, and floodplain connectivity** (1-9) • **Impacts on the range of exotic and invasive species** (aquatic vertebrates, invertebrates, fishes) (1-4,6,8,9)	• **Impacts on biodiversity**, including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species • **Impacts on commercial, sport, and subsistence fisheries, shellfisheries, and harvesting** of other natural resources derived from freshwaters • **Reduced flood control and drainage**

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Freshwater/ Aquatic	44% by the 2040s (depending on the greenhouse gas emissions scenario) and -53% or -65% by the 2080s. **4. Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Flood risk increases in some basins, particularly west-side transient (rain/snow mix) basins, and decreases in other basins, including east-side snowmelt dominant watersheds. **5. Declining soil moisture**. Modest decreases in July 1 soil moisture projected overall with largest declines projected for the Cascades and Olympic Mountains. **6. Reduced glacial size and abundance.** Could lead to short-term increases in summer streamflow but will ultimately exacerbate decreasing summer streamflow conditions. **7. Altered groundwater.** Changes in groundwater possible although highly uncertain and with great spatial variation. Shallow aquifers more likely to be affected than deep aquifers. **8. Increased summer stream temperatures** and longer periods of warmer stream temperatures, although with significant	• **Increased mortality and displacement** of redds and juvenile fish associated with flooding and streambed changes (2-5) • **Impacts on stream and river channel dynamics**, including migration, incision, aggradation, bed texture, and mass wasting; includes upland channels and river mouths (2-4,6,9) • **Increasing sediment loads** (2,4,6) • **Increased salt water intrusion** into coastal rivers and streams, freshwater wetlands (4,9) • **Increasing thermal stress** during summer months for coldwater adapted fish species like salmon (1-8) • **Increased nutrient loading** (e.g. eutrophication) (1,2,4)	provided by flood plains, wetlands • **Impacts on water quality,** e.g., water temperature, sediment loads, dissolved oxygen, pollutant loading • **Impacts on water supply and filtration benefits** associated with wetlands, bogs, fens, etc., including groundwater recharge and reduced groundwater contributions to summer streamflow in rivers and streams near impacted wetlands. • **Reduced or loss of cold water refugia** for coldwater adapted fish species such as salmon • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to sites that are significant to tribes, or loss of community identities (and economies) tied to forest-related activities • **Impacts on recreation** and related economic activities, e.g. hunting, fishing, wildlife viewing, rafting

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
	spatial variation around the state. 9. **Sea level rise.** Projected increase in Puget Sound of +6" (range: 3-22") by 2050 and +13" (range: 6-50") by 2100.		
Aridlands	1. **Increased air temperature.** Warming is projected by all models for all seasons through the 21st century, with the largest warming in the summer months. Increased length of the frost-free period expected although impact on growing season length in eastern Washington will be limited by water availability. 2. **Changes in precipitation**. Average annual precipitation is projected to increase slightly with an enhanced seasonal cycle (drier summers and wetter falls and winters) likely. 3. **Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Spring flood risk projected to decrease in east-side snowmelt dominant watersheds. 4. **Changes in soil moisture.** Projected changes in July 1 soil moisture in arid lands vary. Most areas in eastern Washington show modest decreases in July 1 soil moisture	• **Changes in arid lands productivity**, including reduced carbon sequestration, due to (for example) changes in soil carbon and nitrogen cycling, microbial biomass concentrations (1,2) • **Increased risk of drought** (1-5) • **Reduced and/or lost arid lands habitats** (1-5) • **Changes in the distribution of arid lands habitats** (1-5) • **Impacts on species composition, distribution, and abundance**, particularly in areas affected by disturbance (e.g., fire, overgrazing, erosion, insect or disease infestation) and for species less able to move in response to habitat changes ; includes changes in elevational boundaries (1-5) • **Changes in phenology** (the timing of ecological events) (1,2,3) • **Impacts on the range of exotic and invasive species**, e.g., cheatgrass, sagebrush moth, particularly in areas affected by disturbance (1-5) • **Increased risk of fire** (1-4) • **Increased erosion**, particularly in areas affected	• **Impacts on biodiversity**, including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species • **Impacts on water quality,** e.g., water temperature, sediment loads • **Impacts on water supply benefits** associated with riparian areas, wetlands, springs, intermittent water courses, vernal pools. May include reduced water supply for livestock and wildlife, reduced groundwater recharge, reduced groundwater contributions to summer streamflow in rivers and streams near impacted areas. • **Impacts on nutrient cycling and soil health** necessary to support healthy arid land ecosystems • **Reduced erosion protection,** particularly in unstable areas after disturbance (e.g., fire, overgrazing, erosion, insect or disease

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Aridlands	while some areas in south central Washington may see slight increases as a result of increasing winter and spring precipitation in some climate scenarios. 5. **Altered groundwater.** Changes in groundwater possible although highly uncertain and with great spatial variation. Shallow aquifers more likely to be affected than deep aquifers. 6. **Increased summer stream temperatures** and longer periods of warmer stream temperatures, particularly in eastern Washington (1-5)	by disturbance (2,3) • **Increasing thermal stress** during summer months for coldwater adapted fish species using riparian habitat in arid lands (1-5)	infestation) • **Reduction or loss of cold water refugia** for coldwater adapted fish species such as salmon using riparian habitat in arid lands. • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to sites that are significant to tribes, or loss of community identities (and economies) tied to activities connected to arid lands ecosystems • **Impacts on recreation** and related economic activities, e.g. hunting, fishing, hiking, wildlife viewing

III PRIORITY STRATEGIES AND ACTIONS

This chapter introduces a set of priority strategies and examples of recommended near-term actions to advance them. The strategies and actions were developed with the intent to sustain natural systems and the critical ecological services they provide for human health and well being.

STRATGIES IDENTIFIED FOR ECOLOGICAL SYSTEMS

TAG3 members reviewed climate change risks and evaluated possible actions separately for four major ecological systems: coastal and marine, freshwater, forests and prairies, and aridlands. Appendix A includes the full complement of the strategies and actions identified for each system, as well as considerations for implementation, including existing programs, new programs or policies needed, and institutional barriers. The goal was not a comprehensive review of all changes, vulnerabilities, and adaptation options within each system; rather, it was to ensure that our assessment considered at some level the full range of systems and species that are likely to be impacted in different ways. Once these strategies and actions were identified for each of the four major ecological systems, the TAG reviewed the collective list and looked for common themes and strategy recommendations that were important and applicable for all habitat types.

OVERARCHING GOALS AND NEAR TERM ACTIONS

TAG3 developed ten broad goals which apply programmatically across the state and cross all ecological systems. Drawing from the recommendations for each ecological system (Appendix A), we identified high priority strategies and near-term actions for each goal. Near-term is defined as 1-5 years. The criteria for determining a priority strategy or near-term action were qualitatively applied, and included consideration of the certainty and severity of the impact (urgency), the opportunity cost of delayed action, and whether or not other actions depended on its completion. For a more substantive discussion on criteria for determining priorities, please see Appendix C.

We tried to capture as many priority strategies as possible from each ecological system in the overarching goals, strategies and actions presented in this chapter. However, some strategies and actions that are unique to a particular habitat type may not be fully reflected. Please see the tables found in Appendix A for all of the strategies and actions developed for each of the four habitat areas considered.

Note that the goals, strategies and actions are numbered only to facilitate discussion and do not indicate relative priority. When possible, we have also provided a reference to the corresponding recommendation within a particular ecological system; more information on a given strategy can be found in the appropriate table in Appendix A.

The goals and strategies to achieve them are roughly divided into two sections. The first set focuses on actions to facilitate the ability of natural systems to provide ecological functions and services in the face of climate change. The second set is oriented towards building the necessary scientific and institutional readiness to support effective adaptation.

Facilitate the Resistance, Resilience and Response of Natural Systems

1. Provide for habitat connectivity across a range of environmental gradients
2. For each habitat type, protect and restore areas most likely to be resistant to climate change.
3. Increase ecosystem resilience to large-scale disturbances, including disease, invasive species, catastrophic fire, flooding, and drought.
4. Address stressors contributing to increased vulnerability to climate change.
5. Incorporate climate change projections into plans for protecting sensitive and vulnerable species.

Build Scientific and Institutional Readiness to Support Effective Adaptation

6. Fill critical information gaps and focus monitoring on climate change.
7. Build climate change into land use planning.
8. Develop applied tools to assist land managers.
9. Strengthen collaboration and partnerships.
10. Conduct outreach on the values provided by natural systems at risk from climate change.

DESCRIPTION OF PRIORITY STRATEGIES AND NEAR-TERM ACTIONS FOR EACH GOAL

The following actions are designed to facilitate the ability of natural systems to continue to provide ecological functions and services in the face of climate change, and build scientific and institutional readiness to support effective adaptation

GOAL #1: Provide for habitat connectivity across a range of environmental gradients

Habitat connectivity is expected to allow species and ecosystems to better withstand climate change by allowing them to follow changes in climate across the landscape and maintain critical ecological processes such as dispersal and gene flow. For example, sea level rise will directly displace coastal species; therefore, their persistence will require the ability to move inland to new habitats. In general, it is much costlier and more difficult to restore connectivity than to maintain existing connectivity, yet ongoing development rapidly removes this opportunity. Planning for habitat connectivity in the near term will be far more economical the sooner it is implemented.

Key Concept	Identifying important areas for habitat connectivity is expected to enhance species and ecosystem capacity to adapt by facilitating changes in range. Connectivity should be considered along gradients in elevation, latitude and temperature.
Priority Strategies	1. Identify and designate areas most suitable for core habitat and connectivity in light of a changing climate. 2. Protect and restore areas most suitable for current core habitat, likely future core habitat, and connections between them. 3. Protect and re-establish connectivity of rivers and their floodplains. 4. Adjust the size and boundaries of conservation areas (parks and natural areas) to accommodate anticipated shifts in habitat and species' ranges. 5. Adjust land use designations in important connectivity areas (for example, allowable density). 6. Facilitate inland migration of coastal habitats.
Near Term Actions	1. Secure adequately detailed elevation maps necessary to determine areas most sensitive to sea level rise and determine areas suitable for maintaining costal-inland connectivity. (Marine/Coastal 1.1.1) 2. Complete the habitat connectivity analyses under development by the Washington Habitat Connectivity Group, and work to integrate findings into land use planning activities (Forests 1.1.1) 3. Use regulatory and non-regulatory means to secure or limit inappropriate activity in high priority buffer areas and habitat connectivity corridors for both coastal and terrestrial systems (Marine/Coastal 1.1.1)

	4. Update flood maps in floodplain and riparian areas to account for potential climate change impacts. (Freshwater 1.3.1) 5. Protect and restore current sediment sources and transport processes throughout the littoral system (Marine/Coastal 1.1.2)

GOAL #2: Protect and restore areas most likely to be resistant to climate change, aiming for a full representation of habitat types.

Broadly speaking, climate refugia are areas where climatic change is likely to occur more slowly or to a lesser extent than other areas. The concept of refugia can be considered on different scales; for example, the moist temperate climate of the west side of the Cascades and the high mountains of the state will likely serve as refugia for some species at very broad spatial scales. However, in this instance we are using the concept on a more localized scale, for example, some refugia are created by physical landscape features, such as north-facing slopes, valleys or other low areas that serve as sinks for cold air, or streams fed by deep coldwater springs. Other refugia are supported by biological features, such as the ability of forests to maintain cooler, moister conditions. Once identified and protected, refugia can help facilitate the long-term survival of species or at least buy time for species to adapt to changing conditions. Restoration can also target the creation of refugia, for example by reforestation or the reintroduction of beavers.

The concept of climate refugia can be expanded to apply to sea level rise as well. The rate of sea level change within Washington State is highly variable—sea level is currently dropping around Neah Bay but rising faster than the global average in the South Sound—so areas with slower rates of sea level rise could be considered refugia. The rate of effective sea level rise can in some circumstances be slowed by restoring natural or enhanced rates of sediment input and accretion (e.g. through removing dams or restoring certain types of coastal marshes), and by limiting groundwater withdrawals.

Current thinking suggests that high quality habitats may help to provide refugia for species under stress from climate change. In this case, the concept of refuge is not specific to climatic change; rather it refers to places where stressors related to habitat loss or degradation are reduced and which ostensibly increase the ability of species to withstand or recover from stresses linked to climate change.

Key Concept	Where possible, restoration and protection programs should be carried out in ways that help to slow the rate of climatic change locally or regionally, and used to provide refugia for species likely to be under stress from climate change

Priority Strategies	1. Identify and protect high quality habitats that are minimally affected by (or resistant to) climate change and most likely to act as climate refugia, including maintaining and improving ecological function and integrity.
Near Term Actions	1. Develop criteria to identify areas most resistant to and resilient to climate change in different ecological systems. 2. Inventory and map important thermal refugia and snowmelt systems in priority freshwater systems (sub-basins within WRIAs) and prioritize for protection. (Freshwater 1.1.1) 3. Evaluate size and location of existing reserves and protected areas to address opportunities to protect important climate resilient habitats. (Forests 1.2.1; Aridlands 1.3.2)

GOAL #3: Increase ecosystem resilience to large scale disturbances, including disease, invasive species, catastrophic fire, flooding and drought

Climate change will likely affect species and ecosystems both through gradual, directional changes in climate conditions and through increased frequency and intensity of major disturbances such as wildfire, extreme weather events such as droughts or flood, species invasion, disease and parasite outbreaks. While reducing vulnerability to gradual changes typically relies more on supporting resistance to change or facilitating longer-term responses to change that maintain desired characteristics or functions, reducing vulnerability to large-scale disturbances more often focuses on supporting resilience, that is, the ability of a system to return to its former state after a disturbance.

Key Concept	Larger, well-functioning ecosystems better withstand large-scale disturbance than smaller ecosystems because of their greater likelihood of containing remaining resources such as remnant seed and vegetation sources or pockets of undisturbed animal populations. Diverse, functioning ecosystems allow easier dispersal of system elements to help recover impacted areas or colonize new areas, and in this way contribute to ecosystem resilience.
Priority Strategies	1. Promote structural and landscape diversity to minimize the impacts from catastrophic disturbances. 2. Redefine priorities for fire management in areas important to biodiversity; priorities should shift emphasis from fire prevention/suppression to proactive management designed to increase resilience to fire and decrease likelihood of severe fire. 3. Protect and restore habitat to support adequate water supply,

	moderate temperature, and mitigate flooding impacts, through reintroduction of beaver, wetland creation and other off-channel water storage basins, and by protecting cold-water springs.
Near Term Actions	1. Target habitat restoration programs towards increasing species and structural diversity and disturbance-resistant species. 2. Modify existing land management plans to promote (seral stage) diversity such as using prescribed fire and thinning in forest systems to promote structural complexity. (Forests 2.1.4) 3. Identify priority systems (sub-basins within WRIAs) for basin-wide climate adaptation planning; including habitat restoration, promoting conjunctive use of groundwater and surface water, and integrating riparian and floodplain management.

GOAL #4 Address stressors contributing to increased vulnerability to climate change

Reducing non-climate stressors such as unsustainable harvest, pollution or habitat fragmentation can help to increase overall ecosystem resistance and resilience to climate change. Human responses to climate change or other existing stressors may further interact to increase or decrease overall vulnerability. Possible interactions of non-climate stressors and increased vulnerability to climate change include the following:

- Overharvest: reduced population sizes from over-harvesting can limit the ability of a population to adapt evolutionarily to changing condition because of the reduction in genetic diversity. Smaller populations are also more at risk to local extinctions from catastrophic events such as floods or droughts.
- Habitat fragmentation: fragmentation reduces connectivity and thereby the ability of individuals and species to move across the landscape in response to changing conditions.
- Pollutants: the toxicity and bioavailability of many pollutants is affected by soil, air, or water temperature and chemistry, all of which are changing as a result of climate change. Also, some pollutants increase species' sensitivity to high temperature or other climate-related stressors.
- Invasive species: some invasive species directly increase the climate vulnerability of the ecosystems they invade (e.g. nutria have destroyed or degraded coastal wetlands in the areas of the U.S. where they have become established, and this degradation increases the vulnerability of the coastline to flooding, erosion, and the impacts of sea level rise). Climate change in some cases will increase the success of invaders, and in other cases potentially decrease their success and make eradication more feasible.

- Habitat loss: in addition to direct habitat loss as a result of climate change (e.g. coastal habitat lost to rising seas, freshwater habitat lost to increasing drought), restoration projects may become less successful if restoration practitioners fail to incorporate changing climatic conditions in their plans.

It should be noted that simply addressing existing stressors will not always be an effective adaptation strategy. In some cases this approach will work, but in others it will not (e.g. reducing harvest levels won't be the most effective strategy if the habitat is vulnerable to degradation) or increasing the size of a protected area may not be the most effective strategy if the land is highly vulnerable to sea level rise).

Key Concepts	• Reducing non-climate stressors such as unsustainable harvest, pollution or habitat fragmentation can help to increase overall ecosystem resilience to climate change. • Human responses to climate change or other existing stressors may further interact to increase or decrease overall vulnerability
Priority Strategies	1. Evaluate and prioritize efforts to address human activities that can exacerbate climate change impacts in vulnerable systems (for example, stormwater pollution which impairs water quality; habitat fragmentation from development pressure, fuel buildup from wildfire suppression). 2. Integrate climate change into invasive species management. This may include use of climate models to highlight areas where invasion by particular species may become more problematic or where eradication may be possible, as well as using existing tools and best practices.
Near Term Actions	1. Reduce non-climate stressors (such as stormwater and septic issues, non-point and point source pollution) that contribute to hypoxic conditions and exacerbate marine acidification. (Marine/Coastal 1.4.1) 2. Conduct vulnerability assessments to determine specific areas and/or species most vulnerable to climate change impacts and under threat from existing stressors. 3. Manage stormwater to protect and restore flow characteristics in light of expected climate change impacts. (Freshwater 2.2.2) 4. Manage water withdrawals to ensure adequate stream flows and lake levels to maintain freshwater systems. Potential tools such as acquiring water rights, using water banks, incentives, and regulatory, planning and policy tools. 5. Implement the Washington Invasive Species Strategic Plan .

GOAL #5: Incorporate climate change into plans for protecting sensitive and vulnerable species and the habitats they depend on

While protecting the most robust species and systems can be effective at retaining processes and functions of ecosystems, there are multiple reasons to focus on sensitive and vulnerable species and systems as well. These include preserving species and landscape diversity and protecting culturally or spiritually important species. Some even argue that it can be more strategic to focus on species whose survival is most dependent on human intervention, rather than those likely to survive regardless. Furthermore, some existing laws mandate the protection of sensitive and vulnerable species and systems; effectively fulfilling this mandate requires taking a climate-smart approach. For example, focusing only on current habitat is unlikely to be successful in the fact of climate change, given that core habitat for some threatened and endangered species is already shifting.

Key Concepts	Climate change will increase the stress on species that are already sensitive or vulnerable, and alter what is necessary for their recovery and protection.
Priority Strategies	1. Map, protect and restore likely future critical or important habitat for vulnerable and at risk species based on a range of climate projections. 2. Incorporate actual and anticipated climatic changes and associated impacts into species recovery and management plans.
Near Term Actions	1. Develop and maintain long-term, large-scale monitoring of early warning indicators of species responses, including range shifts, population status and changes in ecological systems functions and processes. 2. Complete the Pacific Northwest Climate Change Vulnerability assessment for species and habitats and integrate findings into species conservation plans. Identify areas within vulnerable species critical habitats that would remain relatively stable given future climate change because of their physical characteristics. 3. Modify protection and recovery plans to accommodate individual movements and migration as well as longer-term species range shifts associated with climate change and its effects. 4. Coordinate among agencies, tribes and organizations to identify and prioritize additional research needs to identify adaptation strategies for vulnerable species.

GOAL #6: Fill critical information gaps and focus monitoring programs on climate change and impacts

Although there are many uncertainties in planning for climate change, there are key knowledge gaps that we can fill that will help us to develop and implement climate-smart conservation and resource management. Means of filling data gaps include vulnerability assessments that enable prioritization of adaptation efforts, experiments, monitoring, and modeling efforts that further our understanding of how species and ecosystems respond to climate change. Sociological research could also fill information gaps related to developing adaptation options that integrate a range of community values.

Monitoring is important in several ways. First, it allows managers to track how climate change is progressing and how species and systems are responding to it. This information in turn allows us to refine and test the models we use for projecting future changes and responses. Monitoring can also be designed to test the assumptions underlying proposed management options and the effectiveness of the management actions in practice. Monitoring for climatic change and associated impacts can be carried out as a stand-alone effort or by integrating relevant variables into existing monitoring efforts. For example, California is investigating how it might incorporate climate change-relevant considerations into its statewide Marine Protected Area monitoring program.

Additional suggestions for developing appropriate monitoring programs include the following:

- Monitoring programs should be tied to specific management options, hypotheses, or questions. For example, rather than monitoring for precipitation changes using some standard or pre-existing set of precipitation-related parameters, monitor for changes in parameters that are directly linked to planning and management decisions (e.g., timing and volume of peak spring flooding for salmon biologists; size of 100-year flood and maximum rainfall in a 24-hour period for road and culvert engineers).
- Implement monitoring programs with sufficient coverage to track climate patterns and changes in those patterns on management-relevant scales, as well as track changes in related physical or chemical environmental parameters (e.g., marine pH, salinity, base stream flow, etc.).
- Implement monitoring programs that can identify changes in biota (plants and animals) and aquatic systems and relate those changes to climate conditions, weather events, and related physical or chemical parameters (e.g., ocean acidification).
- Implement monitoring programs designed specifically to test ecological assumptions underlying proposed adaptation actions (e.g., the assumption that pristine systems are more resistant or resilient to change).
- Implement monitoring programs designed specifically to test the effectiveness of adaptation actions.

Key Concepts	Monitoring programs are needed to: • Track climate patterns and changes on management-relevant scales. • Identify changes in biota (plants and animals) and aquatic systems and be able to relate those changes to climate conditions. • Test ecological assumptions underlying proposed adaptation actions. • Test the effectiveness of adaptation actions. • Inform management decisions.
Priority Strategies	1. Identify species and ecosystems within geographic areas most vulnerable to climate change 2. Identify key indicators for climate change response in species and ecosystems. 3. Design and implement monitoring programs that are sufficiently sophisticated and precise to identify species and vegetation changes and relate those changes to climate conditions. 4. Enhance existing monitoring of physical, chemical and biological properties of marine systems to identify and track climate change impacts. 5. Enhance statewide monitoring networks to document climate change impacts on freshwater systems. 6. Coordinate data collection needs, ensure data sharing and facilitate access to all relevant data among conservation partners (state and federal agencies, tribes and other organizations).
Near Term Actions	1. Update hydrologic information currently used in planning to better represent current conditions and enable adaptation to represent future scenarios for groundwater and hydrology. (Freshwater 1.2.1) 2. Develop and maintain large scale monitoring of key early warning indicators for species of interest such as timing of migration, changes of population patterns, size at first reproduction, etc. (Forests 2.8) 3. Identify map and monitor essential floodplain and riparian functions at risk from climate change, including updating flood maps, and tracking shifts in distributions of wetland and lake dependent species and vegetation. (Freshwater 1.3.1) 4. Conduct monitoring and research of marine acidification to understand local extent and impacts to food web and water quality. (Marine/Coastal 2.2) 5. Conduct a climate change vulnerability assessment for marine species. (Marine/Coastal 2.6)

GOAL #7 Incorporate climate change considerations into ocean and land use planning

The actions under this goal are designed to ensure that existing and future land and ocean use planning policies, guidance, technical assistance and incentive programs address climate change consequences and integrate adaptation strategies. This goal addresses one of the most immediate and relevant approaches for building our institutional capacity to adapt to climate change impacts on the ground.

"Land use plan" is intended here to be broadly defined and includes land management plans and policy documents such as local government comprehensive plans, conservation plans, grazing plans, Forest stewardship plans and habitat conservation plans. The concept of land use planning as used here also includes the regulatory mechanisms that drive land use planning at the local level, including the Growth Management Act, Shoreline Master Programs and rules to set in-stream flows. Ocean use planning includes establishment of marine reserves, regulation of marine harvest and recreation, and any future marine spatial planning efforts.

Key Concepts	Land and ocean use policy, planning, and implementation represent a big opportunity to institutionalize climate-smart approaches.
Priority Strategies	1. Ensure existing land and ocean management plans and regulatory processes incorporate climate change consequences and include adaptation strategies. 2. Integrate planning and decision making at watershed and statewide scales to identify, avoid, or resolve conflicts among adaptation strategies.
Near Term Actions	1. Develop mitigation requirements for habitat loss and degradation from development related to human response to climate change (e.g., additional water storage facilities). 2. Integrate findings from the Habitat Connectivity analysis and vulnerability studies into planning, policy and land management activities. (Forests 2.3.1) 3. Develop a state water plan that allows holistic planning of water resources and responses climate change. (Freshwater 2.2.1) 4. Evaluate Shoreline Master Programs to address current practices and institutional barriers that prevent inland migration of critical coastal habitats at risk from inundation. Options might include greater development setbacks, dynamic setbacks, and requiring planning that addresses future climate change impacts prior to allowing development projects to be built. (Marine/Coastal 2.1) 5. Build climate change into marine spatial planning from the start.

GOAL #8: Develop applied tools for decision makers and land managers

Climate change requires new ways of assessing information and determining the best tools or course of action for land managers and other decision makers. For instance hydrologic information based on past data may not be sufficient to determine what land restoration strategies are best for a particular location; changing soil moisture levels may need to be considered in determining what tree species are best for reforestation. Tools that effectively incorporate past and future changes in climate and associated variables into land and water management, as well as options for adapting land and water management to these changes, are critical to making good decisions affecting natural systems. Some existing land conservation and management tools can likely be adapted to incorporate climate change considerations but new ones may also be needed.

Key Concepts	Easy access to data and tools will help decision-makers adequately incorporate climate change considerations into management plans affecting natural systems.
Priority Strategies	1. Make information on climate change adaptation strategies and actions accessible and targeted towards the needs of land managers and other decision makers. 2. Develop tools and information to increase the contribution of working lands to ecological resilience. 3. Develop incentives and tools to encourage water conservation
Near Term Actions	1. Identify climate-smart management practices for cultivated and grazing lands. (Aridlands 2.4) 2. Incorporate climate change considerations into existing planning tools which evaluate the effects of alternative land-use policies (for example, INVEST, and models from the Natural Capital Project). 3. Expand landowner capacity to implement silvicultural practices that increase working forest resilience in the face of climate change impacts (for example, practices to increase forest structural diversity and species diversity such as thinning and species selection). Work with existing landowner assistance programs such as extension programs. (Forests 2.1.1) 4. Conduct pilot projects to develop decision analysis tools for land managers; for example, build on the USGS/NWS Methow Basin project for future runoff projections. 5. Develop tools (for example, transfer of development rights) to create incentives to reduce risk of conversion of working forests and to non-forest uses in areas most susceptible to climate change impacts. (Forests 2.2.1)

	6. Develop incentives for protection of essential habitats that will help mitigate losses from climate change impacts. 7. Develop incentives to allow for retreat of wetlands.

GOAL #9: Strengthen collaboration and partnerships

Climate influences human and natural systems in a multitude of ways—where and how infrastructure is developed, what industries succeed in a particular location, where and how species interact, and when different populations of plants or animals reproduce or migrate are just a few climate-sensitive elements of the world around us. Thus climatic change will bring changes in many systems and processes simultaneously. To minimize chaos and cost and to maximize the chance of success, agencies at all levels, private and public land managers, conservation organizations, tribes, and others must work collaboratively and on a landscape scale when addressing climate change. Communication and coordination can prevent time and money being invested in efforts that counteract each other (for example, restoring wetlands in an area that will be flooded by the construction of a new dam). Partnerships can also help to leverage support from federal or non-profit funders, prevent the duplication of effort when it comes to climate modeling, response modeling, or gathering and analyzing data, and facilitate development, transfer, and assimilation of effective adaptation approaches.

Key Concepts	Because changing climatic conditions will influence human and natural systems in intertwined ways across a range of scales, coordinated and collaborative adaptation efforts can increase the success and decrease the costs of such efforts. At the very least, good communication may limit adaptation efforts working at cross-purposes.
Priority Strategies	1. Coordinate at regional and statewide scales to develop, prioritize and implement specific adaptation strategies and actions, and resolve conflicts across jurisdictions and among different resource users. 2. Develop institutional mechanisms to enable and facilitate shared resources, joint projects and coordinated action between federal, state, local agencies, tribes, NGOs, tribes, private entities, universities, and landowners.
Near Term Actions	1. Develop climate change conservation partnerships for ecological systems or specific landscapes/basins to share information, leverage resources, identify shared priorities and facilitate implementation of climate change adaptation strategies.

	2. Support existing landscape scale conservation initiatives and integrate climate change consequences and responses (for example, Arid Lands Initiative, Landscape Conservation Cooperatives, Western Governors Association initiatives). 3. Develop a mechanism for shared accountability for implementing climate change adaptation.

GOAL #10: Conduct outreach and education on the values of ecosystem services at risk in the face of climate change

Education about the importance of maintaining and restoring healthy well-functioning natural systems is a critical climate adaptation strategy. Washington's diverse ecosystems, species, and habitats provide a complex range of goods and services, collectively referred to as "ecosystem services" that benefit Washington residents in numerous ways (see chapter II). Many of these services in fact become even more valuable in the face of climate change, helping to lessen associated impacts to human communities. Education targeted at all levels – K-20, policy makers, general public – is essential to ensure that the value of ecosystem services is fully recognized as we develop response strategies and take action to respond to climate change.

Key Concept	Education and outreach can help ensure that the value of ecosystems and the services they provide is considered in adapting to climate change.
Priority Strategies	1. Conduct outreach and education on the values provided by natural assets at risk from climate change. 2. Promote a climate literate citizenry. 3. Promote opportunities for citizens to engage in actions that will help minimize impacts from climate change (for example, habitat protection and restoration, citizen science programs, preventing invasive species, etc).
Near Term Actions	1. Provide case studies and real world examples of the economic and social benefits ecological systems provide; emphasizing the mitigating impacts of climate change on communities and human well being. 2. Initiate and support existing efforts to quantify value of ecological services and natural systems particularly those comparing the lifetime cost-effectiveness of nature-based versus engineered adaptation options (for example, the flood protection analysis performed by Earth Economics for the Chehalis River Basin Flood Authority).

	3. Integrate messages about the value of ecological services at risk from climate change into environmental education programs and curriculum. 4. Consider nature-based alternatives to more typically engineered adaptation options such as flood control, ensuring water quality and water quantity, erosion control, etc. 5. Facilitate development of programs to engage citizens in monitoring impacts of climate change on the landscape (for example, citizen science monitoring network and the National Phenology Network, nature center programs, etc.). 6. Make information about climate and climate change understandable and accessible to the general public.

IV OVERARCHING CONSIDERATIONS AND NEXT STEPS

In the course of its work, TAG3 raised a number of important issues and topics that it had insufficient time and opportunity to adequately develop. This section introduces or reiterates selected issues with the recommendation that they be further described, examined, and considered as the Statewide Integrated Response Strategy is developed and implemented.

1. INTEGRATE RECOMMENDATIONS INTO POLICIES AND PROCEDURES

Ultimately, implementation of any of the recommended strategies in this report depends on how approaches and strategies are "mainstreamed"; that is, integrated into existing policies, programs and guidance. Further work is needed to identify governance and policy tools that could help institutionalize adaptationmindset. In particular, effort is needed at the level of implementing agencies and bodies to ensure that climate change considerations are built into relevant processes. Examples include environmental assessment programs (for example, building climate criteria into SEPA), state funded grant programs to acquire or restore habitat or conservation land (for example, including criteria for climate resilience in acquisition proposals), and land use planning guidance and technical assistance programs (for example, providing assistance to local jurisdictions to build climatic changes and adaptation needs into critical areas ordinances).

One important next step is for the Steering Committee to include a recommendation in its final report that asks state agencies (and possibly local governments) to review and incorporate climate change considerations into existing programs, policies and funding mechanisms.

2. AVOID MALADAPTATION

As awareness about current and projected impacts from climate change grows, and as government jurisdictions begin to craft plans and approaches for responding to these impacts, the risk of unintended consequences of adaptation strategies increases. Most adaptation actions require some sort of trade-off; when the negatives of an adaptation action or strategy outweigh the benefits, it becomes a maladaptation. When an adaptation strategy becomes a maladaptation can be subjective or contextual, and what may seem successful to one group, at one time, or in one location may seem damaging to others or at other times and places. For example, subsidizing or providing extra water allocation to farmers growing water-intensive crops in areas experiencing increasingly dry summers may seem like a good adaptation strategy in the short term, but in the long term it increases their vulnerability by reducing incentives to shift to crops or agricultural strategies more suited to a dry location.

Similarly, subsidizing rebuilding costs for communities in coastal areas vulnerable to sea level rise may seem like an appropriate adaptation in the near term (it reduces the harm done by sea level rise to the community), but in the long term it encourages the community to remain in harm's way. Building seawalls or bulkheads to protect one property often increases the vulnerability of others by increasing erosion farther down the shoreline, and can even worsen erosion in front of the property it is designed to protect. Developing new water storage facilities as a response to more frequent or severe drought may increase the vulnerability of cold-water species to climate change by increasing water temperatures both up- and down-stream of the dam. The state's Climate Change Response strategy should be built on a framework that evaluates all consequences and tradeoffs before responses are selected and seek to design up front ecosystem-based approaches that benefit both natural and human systems.

3. PROMOTE ECOSYSTEM-BASED ADAPTATION

While some human responses to climate change will be detrimental to ecosystems, it is important to avoid creating a false dichotomy between adaptation actions that benefit natural systems versus actions that benefit people. For many climate impacts, it is desirable to develop "ecosystem-based adaptation" strategies that deliver benefits to people *and* natural systems. Ecosystem-based adaptation uses sustainable management, conservation, and restoration of ecosystems to provide services that help human communities adapt to the impacts of climate change.[5] Examples of ecosystem-based adaptation include: increasing the resilience of coastal communities by maintaining or restoring coastal wetlands to reduce coastal flooding and coastal erosion; and increasing the resilience of forest systems by implementing forest restoration and forest health treatments, thereby reducing the risk of catastrophic fire and damage to people and property.

By considering impacts to both human and ecological communities and concurrently considering a range of adaptation approaches for these two communities, adaptation strategies are more likely to succeed. Using ecosystem-based adaptation can also be more cost-effective than measures based on hard infrastructure and engineering, and it generates social, economic, and cultural co-benefits.[6] Many of the strategies we recommend in our report, while they will benefit ecosystems, will also benefit people. We encourage the Steering Committee to ensure that the Statewide Integrated Climate Response Strategy includes adaptation actions that are in the best interests of both human *and* natural communities.

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[5] *Connecting Biodiversity and Climate Change Mitigation and Adaptation (2008),* The Ad Hoc Technical Expert Group on Climate Change and Biodiversity (AHTEG) & Ecosystem Based Adaptation. http://www.cbd.int/doc/publications/cbd-ts-41-en.pdf

[6] Ibid

4. **INCREASE OPPORTUNITIES FOR MULTI-SECTOR, LANDSCAPE-LEVEL APPROACHES**
   Several recommendations in this report address the need and opportunity for collaboration at landscape scales and across jurisdictions. This is because actions in one location may drastically influence vulnerability to climate change in other locations. The rate of relative sea-level rise threatening a coastal community, for example, may be influenced by dams or diversions that can limit sediment influx to the coast or withdrawal of water from nearby aquifers that may cause subsidence. Thus coordination should be undertaken at a level determined by the systems and actions under consideration. This notion should be further developed and integrated into the Climate Change Response Strategy.

5. **CONSIDER IMPLEMENTATION PLANNING**
   TAG3 recommends that the Steering Committee include an implementation plan as part of the final report. The implementation plan should identify lead organizations or entities for advancing priority recommendations, and lay out specific actions and timeframes.

6. **PROVIDE ONGOING LEADERSHIP AND COMMITMENT**
   Finally, TAG3 recognizes the imperative that the state climate response strategy be a dynamic document; effective implementation will require continued leadership and commitment. The 5560 Steering Committee should evaluate mechanisms for ensuring ongoing leadership (such as a standing steering committee, a state level cabinet post on climate change, etc.) as well as providing guidance and support for active adaptive management that builds new science, tools and approaches.

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Appendix B3-A: SPECIFIC ADAPTATION STRATEGIES FOR ECOLOGICAL SYSTEMS

INTRODUCTION AND FORMAT

The following section presents specific adaptation strategies for four separate ecological systems. Each subsection begins with a narrative description of the system and projected climate impacts and follows with a table listing the major adaptation objectives, strategies and actions identified by the subgroups working on this system. The tables include early ideas and considerations related to implementation, including existing programs, new programs or policies which might be needed, and institutional barriers that may need to be addressed prior to implementation.

The narrative for each ecological system also highlights a selected number of strategies considered more or less unique to that system. While many adaptation strategies for ecosystems and species are similar across habitat types, some are more exclusive or applicable to a single habitat type. Each of the following narratives thus highlight those strategies most applicable to the specific ecological systems for which they were developed.

Marine and Coastal systems in Washington [7]

Description and Distribution

Washington's coastline stretches through 3,100 miles of diverse terrain along the shores of the Pacific Ocean and Puget Sound. This area encompasses a variety of habitats including bays and estuaries, coastal dunes and beaches, rocky shores, and the continental shelf.

Projected Climate impacts and consequences on marine and coastal ecosystems:

- Coastal estuaries, tidal flats, beaches, dunes and other coastal habitats particularly vulnerable to many of the projected impacts from climate change. For example:
- Sea surface temperatures are projected to increase 2.2 degrees by 2030-2059, affecting salmon migration ranges, introducing increased stress and diseases for shellfish, sea urchins and some mammals.
- Conservative estimates project a sea level rise of 6-22" in Puget sound by 2050, with estimates for 2100 projected at 6-50". Sea level rise at the mid range of 23" would result in significant loss or reduction of coastal habitats -- 65% loss of estuarine beaches, 61% loss of tidal swamps, 44% loss of tidal flats. These changes will reduce the availability of refuge and spawning areas for finfish, shellfish, wildlife and shorebirds.
- Coastal erosion is expected to increase due to sea level rise and intensified storm activity, resulting in lost near shore habitat and lack of sediment accretion.

[7] The primary reference document for this section was "Climate Change Effects on Marine and Coastal Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

- A lack of dissolved oxygen in coastal waters, known as costal hypoxia is also expected to increase due to more upwelling, sea surface temperature rise and changes in the delivery of nutrients to coastal zones. Hypoxic conditions can result in fatal stresses for some organisms, such as rockfish, Dungeness crab, and decreases in reproductive success and growth rates for others. Coastal hypoxia is also believed to exacerbate ocean acidification.
- Ocean acidification, a decline in ocean pH, is already observed in Washington's coastal waters. Future projections depend on the concentrations of atmospheric CO2 , but could be significantly increased. The reduced carbonate harms shell building species such as corals and shellfish, as well as some plankton. Shifts in phytoplankton diversity has potential implications for ocean food webs.
- Loss of snowpack and changes in freshwater inflow to Puget Sound and ocean systems will alter the hydrology of coastal systems; for example, increased winter flooding could bring in increased nutrients and pollutants and salinity patterns may be altered due to reductions in freshwater inflow.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Facilitate inland migration of habitats; preserve and restore corridors.			
Strategy 1.1.1: Identify, designate and protect areas most suitable for natural habitat migration zones. Actions might include: • Secure better maps and modeling; know the rate of sea level rise at specific locations. • Conducting a vulnerability assessment to determine areas most sensitive to sea level rise, • Using regulatory, non-regulatory means to designate and secure natural buffer areas. • Develop non-regulatory incentive programs to protect migration corridors. • Acquire land or development rights. • Assess costs and remove incentives of maintaining at-risk development, • Use failure as an opportunity to remove or move structures and barriers versus building them back.	Designate priority habitats for protection under GMA -- critical areas ordinances and through state agency conservation designations. Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private), Washington Wildlife Recreation Program, Salmon Recovery Funding Board grants, ESRP (state) and USFWS coastal grant (federal) . Ensure climate change and the importance of preserving habitat migration zones is integrated into the Puget Sound Near Shore Estuary Restoration Program (PSNERP)	Integrate climate change adaptation priorities into federal and state funded agricultural easement program.	Better maps and characterization of sea level rise vulnerability for WA coast. Identification of high priority areas for inland habitat migration
Strategy 1.1.2: Restore priority habitat areas most suitable for natural habitat migration zones – current and future. Actions might include: • Identify priority areas for restoration,	Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private), Washington Wildlife Recreation Program, Salmon Recovery Funding	Address potential economic impacts to agricultural community from removing dikes. Conduct cost/benefit for	Identify areas to relocate land uses that require heroic protection. Resistance from development community.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Recover essential processes (fluvial, tidal connections, material transport). • Redesign and ultimately remove existing structures and barriers to inland migration for priority areas (for example, dikes, roads, seawalls, bulkheads).	Board grants, ESRP (state) and USFWS coastal grant (federal) . Habitat restoration programs focused on dike removal (Skagit and Nisqually deltas). Coastal erosion programs.	maintaining at risk properties (those vulnerable to sea level rise and storm surges).	Possible economic impacts to agricultural community from removing dikes.
OBJECTIVE 1.2: Maintain Shoreline Sediment Transfer Processes.			
Strategy 1.2.1: Protect current sediment sources and transport processes throughout the littoral system. Actions might include: • Prohibit armoring on feeder bluffs • Prohibit barriers in sediment transport in drift cells. • Protect connectivity b/w sediment sources and deposition areas. • Protect habitat structure that influences sediment processes (i.e., submerged aquatic vegetation (eelgrass beds, seafloor morphology) • Strengthen existing setback regulation in SMA and local programs.	Puget Sound Nearshore Ecosystem Restoration project (PSNERP) Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private), Washington Wildlife Recreation Program, Salmon Recovery Funding Board grants, ESRP (state) and USFWS coastal grant (federal) . Shoreline Management Act and the HPA permits are existing regulatory tools which can possibly be used to facilitate implementation.	Ensure that data on areas important for protection is in useable formats for planners and others.	Finer scale mapping of sediment sources in coastal areas. Costs to preserve sediment transport; eliminate barriers and preserve connectivity. Resistance from communities and others on development restrictions.
Strategy 1.2.2. Restore sediment sources and transport processes that provide ecosystem services.	Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private),	Programs to mitigate the short term impact from the restoration action.	Finer scale mapping of sediment sources in coastal areas.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Actions might include: • Prioritize areas most in need or most valuable for restoration. • Explore removal of dams and other barriers where feasible. • Explore small scale projects with significant benefit (for example, Stavis NRCA estuary restoration). • Consider beach nourishment where restoration is not possible.	Washington Wildlife Recreation Program, Salmon Recovery Funding Board grants, ESRP (state) and USFWS coastal grant (federal) . PSNERP: Prioritize areas most in need or most valuable for restoration		Resistance from communities and others on development restrictions.
Objective 1.3 Protect viable populations of native species			
Strategy 1.3.1: Identify and protect high quality habitats that are resilient to climate change or important to maintaining species diversity (genetic, dispersal, recruitment). Actions might include: • an inventory of coastal lands which provide high quality habitats and which are resilient to climate change and currently have inadequate protection.	Land acquisition programs (federal, state and NGO funded). Use regulatory mechanisms to designate and protect lands (for example (GMA – critical areas ordinances, Shoreline Management Program, HPA permits). Employ existing voluntary programs, , such as tax incentives for open space.		Costs – purchase and longterm maintenance of lands. Inventory of coastal lands which provide high quality habitats and which are resilient to climate change and currently have inadequate protection
Strategy 1.3.2: Increase the resiliency of species vulnerable to climate change by reducing current and preventing future stressors. Actions might include: • Prevent fragmentation of habitats,	PSNERP addresses priorities for protection and restoration of habitat. Oil Spill Task Force. Clean Water Act		Better understanding the role and impact of non native species. What do priority species need to maintain viability?

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Improve water quality, • Address invasive species • Reduce risks from consumptive uses (including harvest pressure) • Recover processes influenced by human activities and that exacerbate climate change impacts.	Invasive Species Council and programs need to address climate change priorities.		
Objective 1.4: Preserve high water quality for humans and species.			
Strategy 1.4.1: Reduce non-climate stressors that contribute to hypoxic conditions and exacerbate marine acidification. For example, stormwater and septic issues, non-point and point source pollution.	Federal and State Water Pollution laws. Coastal Zone and Shoreline management laws. Local land use laws. Federal and state grant programs.	Enhance existing programs to address hypoxia and acidification.	
Build the Necessary Scientific and Institutional Readiness to Support Effective Adaptation			
Strategy 2.1: Address existing practices and institutional barriers that prevent inland habitat migration. Actions might include review and revision of policies, for example: • Requiring greater development set back and dynamic or adaptive setbacks such as rolling easements. • Preventing shoreline hardening through use of alternatives	Use regulatory tools to address institutional barriers to protecting priority areas for inland habitat migration -- (for example (GMA – critical areas ordinances, Shoreline Management Program, HPA permits).	Evaluate and consider implementation of tools such as rolling easements.	Address possible impacts due to increased risk of property damage from flooding? Better maps and characterization of SLR vulnerability for WA coast. Build a better science base to inform alternatives to hard armoring.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Build a better science base to inform alternatives to hard armoring. • Requiring planning that addresses future climate change impacts prior to allowing development projects to be built.			
Strategy 2.2: Conduct monitoring and research of marine acidification to understand local extent and impacts to food web and water quality	Existing marine monitoring programs should address acidification. Federal and state grants; dedicated state and federal funding	Expanded monitoring and research programs to understand extent and impacts from acidification.	Research on this subject is in the early stages – much is not known about impacts and potential adaptation. Perception that it is a federal program.
Strategy 2.3: Address the impacts of climate change related changes in freshwater inputs to marine and estuarine waters. Actions might include: • Adjust design standards for stormwater to better protect marine waters, include promoting low impact development. • Implement programs for managing instream flows to enhance resiliency of the marine and estuarine environment.	Government and academic researchers. Federal, State, and Tribal water quality and habitat programs. State and Federal grants and dedicated funding. Improvements to stormwater permits and state water management programs.		Lack of regulatory and management structure to address large-scale cumulative effects. Research, monitoring, and modeling needed to understand the effects of these changes.
Strategy 2.4: Incorporate sea level rise and increased storm events in prioritization, design and post project maintenance of toxic cleanup sites on shorelines. Actions might include: • Assess degree of threat and existing efforts.	Incorporate sea level rise into federal, State, and Tribal water quality and toxic cleanup programs.	Enhance existing programs to address climate impacts.	Lack of regulatory and management structure to address climate impacts. Research, monitoring, and modeling needed to understand these impacts.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.5: Enhance existing monitoring of physical, chemical and biological properties of the estuarine and marine water column and sediments to monitor climate change impacts. Actions might include: • Evaluate potential cumulative impacts with enhanced monitoring programs.	Existing marine monitoring and research programs could be expanded and enhanced. For example: • Support expanded monitoring for long term oceanographic data for nearshore waters in Puget Sound, Gray's Harbor and Willapa Bay. • Establish long term monitoring stations near the western extent of the Strait of Juan de Fuca to monitor characteristics of oceanic waters.		Establish a marine zooplankton monitoring program to characterize zooplankton populations and their vulnerability.
Strategy 2.6: Conduct a climate change vulnerability assessment for marine species. Actions might include: • Inventory who is doing what, conducting research to understand the productivity of food webs and species relationships among trophic levels. • Develop a management plan for maintaining most at risk species that includes actions to address climate change. •	Puget Sound Partnership Action Agenda – Science Panel.	Inventory "who is doing what". Need a partnership to implement – maybe between federal, state, tribes, academics, NGOs	Information about species distribution in marine environments. Research to understand impacts to productivity of food webs and relationships among trophic levels.

Forests and Western Prairies[8]

Description and Distribution

Forests cover close to half of Washington State. They make up the principal ecosystems and comprise the major landscapes of the Pacific Northwest. These forest systems are dominated by native conifers with interspersed areas of hardwoods where recent or frequent disturbance has allowed species such as alder, maple or cottonwood to temporarily flourish. The western and wetter eastern portions of the state have forests dominated by Douglas-fir (*Pseudotsuga menziesii)*, which is also the most commercially harvested species.

Thousands of acres of once mixed species stands also have been planted to Douglas-fir for commercial purposes. Other conifer species dominate stands with areas of western hemlock, western red cedar, Sitka spruce, or silver fir on the west side of the state and Ponderosa and lodgepole pine becoming more dominant on the east side of the state. The ecological services provided by the forested areas of the state include clean cold water, clean air, flood and temperature attenuation, and nutrient and soil development, not to mention the numerous wood and other products and resources upon which we depend.

Western Prairies

The grassland prairies of western Washington once covered tens of thousands of acres in the lowlands and islands of Puget Sound and south to the Columbia River. They developed on soils leftover from the retreating glaciers of the most recent "stade" of the past ice age which reached its peak 15,000 years ago. Today only about three percent of the original prairies remain. The prairie areas existing today are threatened by encroaching tree cover, due to the suppression of fire once used to as a management tool; continued development of residential areas and the desire to exploit the gravel deposits that underlay them. These areas provide significant ecological services for groundwater recharge due to the porosity of the soils on which they are found.

Projected Climate Impacts and Consequences

Climate change is likely to bring significant changes to Washington's forest and prairie ecosystems. Particularly, shifts in the frequency and type of precipitation, with decreased snowpack and warmer, wetter winters and summers that are longer with less rain and higher temperatures, will impact the plant associations and distribution of the forests and forest types. It is expected that an increase in the intensity and frequency of wildfires will be an outcome of

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[8] The primary reference document for this section was "Climate Change Effects on Forest, Alpine and Western Prairie Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

these shifts. Tree species also are likely to become more susceptible to pests and increased storm intensity will bring more threats from landslides and flooding.

- **Drier Summers**: For summer months, a majority of models projected decreases in precipitation, with the average declining 16% by the 2080s. Some models predicted reductions of as much as 20-40% in summer precipitation; these percentages translate to 3- 6 cm over the summer season (June/July/August).
- **Wetter winters:** In winter, a majority of models projected increases in precipitation, with an average value reaching +9% (about 3 cm) by the 2080s under the higher-emissions modeling scenario (A1B); this value is small relative to interannual variability. Although some of the models predicted modest reductions in fall or winter precipitation, others showed very large increases (up to 42%).

In general, forest species are predicted to shift their ranges northward and higher in elevation, with new vegetation communities developing over space and time. The predicted rates of climate change may push the climatic boundaries of forest types northward at a rate faster than the predicted rate of species migration, such that shifts could lag behind changes in climate. Increases in fire frequency could result in shifts in vegetation community composition toward more fire-tolerant species or otherwise alter plant communities that depend on a given fire regime to persist. In addition to altering forest structure, a change in fire frequency and duration could influence the susceptibility of forests to insect attacks (either more or less so, depending on change).

Projected changes in climate will have impacts on western Washington prairie ecosystems as well. Warmer springs and associated shifts in stream peak flows, longer and drier summers, and more intense rainfall events may affect species composition and competition between native and invasive species. While some of the impacts might be negative for vulnerable endemic species, there might also be opportunities created for oak-woodland restoration efforts as climatic conditions for oak growth and development improve. Longer summer drought may favor the continuation or expansion of prairie grasslands into areas where conifer encroachment has overtopped and changed the prairie landscape.

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Maintain connectivity between core functioning forest habitats.			
Strategy 1.1.1: Identify important connectivity areas for plants and animals that are robust to climate change (areas that provide connectivity across climatic gradients, including elevational, latitudinal, and precipitation gradients.) Actions might include: • Complete ongoing climate change connectivity analysis at ecoregional level; • Conduct periodic update analysis to incorporate changing land use patterns and climate change science.	Washington Wildlife Habitat Connectivity Working Group (WWHCWG). – statewide analysis of habitat corridors project. The PNW Climate change Vulnerability Assessment for Species and Habitats.		Species movement requirements and habitat preferences are often highly uncertain
OBJECTIVE 1.2: Maintain ecological services provided by forest landscapes.			
Strategy 1.2.1: Adjust the size, boundaries and location of large conservation areas (e.g. parks, wilderness, NRCAs) to meet needs of biodiversity under climate change impacts. Actions might include: • Conduct study to evaluate options for changing preserve boundaries, identify new areas that are needed to provide core areas or important connectivity between cores; • Identify ecological conditions that are critical for species movements or migrations.	Agency Plans for species and habitats; DNR's Natural Heritage Plan, and WDFW Lands 20/20 Regional conservation initiatives, including Western Governors Association Pilot Projects, NW Forest Plan, and the WWHCWG. Federal and State grant programs for conservation. PNW Climate Vulnerability Assessment for Species and Habitats.		Studies to evaluate options for changing preserve boundaries in light of needs of biodiversity in a changing climate. Identify new areas that are needed to provide core areas or important connectivity between cores;

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Build necessary scientific and institutional readiness to support effective adaptation			
OBJECTIVE 2.1: Increase resilience to large scale disturbances caused by fire, flooding, insects and disease.			
Strategy 2.1.1: Expand landowner capacity to implement silvicultural practices (e.g., thinning, fuel management, underplanting) that increase forest structural diversity and enhance species diversity. Actions might include: • Increase outreach and information efforts. Expand WSU and County extension capacity to deliver forestry education programs and tools. • Fund Landowner Assistance program capacity, technical assistance, incentives and grant programs. • Diversify forest regional economy	Stewardship Forestry education. Cost share programs for landowners. Workshops hosted by a variety of NGOs and Universities Modify existing programs to accommodate climate change priorities.	Increased public education on the valued of forest structural diversity Increased markets for ecosystem services and carbon storage	Timber value impacts of variable density thinning Long-term impacts on carbon storage need to be better quantified
Strategy 2.1.2: Implement silvicultural practices that increase tree vigor and resistance to insects, pathogens, and adverse weather in areas of increased risk to climate change. Actions might include: • Increase capacity to inform and assist small private forest landowners. • Increase biomass or other marketing options for wood products. • Reduce hazardous fuels in fire prone ecosystems.	WSU and County Extension programs DNR Landowner Assistance, NRCS and Conservation Districts, Washington Forest Protection Association and Washington Farm Forestry Association.	Modify existing programs to increase forest landowner access to federal grants and other funding mechanisms. Develop new ecological services markets and/or incentives.	Expand laboratory evaluations and test out planning performance of native conifer families or alternative species. Short term impacts on species at risk poorly quantified/politically difficult

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.1.3: Develop drought and disease resistance forest ecosystem non-commercially important species. Actions might include: • Expand funding for high priority noncommercial and commercial species genetic research and testing.	USFS Research programs, BC Ministry of Forests, Universities. NW Seed Orchard Managers Association		Existing knowledge limited for some species
Strategy 2.1.4: Promote structural and landscape diversity to minimize likelihood of catastrophic disturbances. Actions might include: • Modify existing land management plans to increase seral stage diversity on landscapes. • Promote certification of lands which brings the requirement to coordinate planning on a landscape level	Forest Practices Rules Landowner management plans, Habitat Conservation Plans	Landscape level landowner agreements among multiple landowners, Encourage forest certification programs. Address apprehensions from private lands owners to coordinate planning with public land that has a different management goal	
Strategy 2.1.5: Redefine priorities for fire management in areas important to biodiversity and species at risk, shifting emphasis from fire prevention/suppression to proactive management designed to increase resilience and decrease likelihood of severe fire**.** Actions might include: • Increase fuel reduction strategic plan; • Increase fuel reduction treatments. • Public outreach. • Increase expertise and capacity in prescribed fire management.	DNR Wildfire Strategic Plan Washington Statewide Assessment and Strategy USFS National Fire Plan & Cohesive Strategy	Prioritize areas for emphasis on fuel reduction and suppression.	Pattern of ownership will remain an impediment to implementation

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
OJBECTIVE 2.2: Maintain ecological services provided by forest landscapes			
Strategy 2.2.1: Identify and implement action to increase landscape resilience by reducing risk of conversion to non-forest use in areas most susceptible to climate change impacts. Actions might include: • Purchase land or development rights in high priority areas. • Provide education and incentives to increase forest stewardship over time.	NW Environmental Forum Cascade Land Conservancy and other land trusts. Forest Legacy Programs (grant funding) "Ties to the Land" Forest conservation planning program (WSU, DNR).	Provide education and incentives to increase forest stewardship over time.	
Strategy 2.2.2: Outreach and education on values of ecological services provided by forest lands Actions might include: • Landowner/Public Opinion surveys	WSU and County Extension programs DNR Landowner Assistance, NRCS and Conservation Districts, Washington Forest Protection Association and Washington Farm Forestry Association	Develop outreach and educational materials on value of ecosystem services that can be shared among organizations	Quantifying contribution of forest ecosystem services; identifying those at risk from climate change.
Strategy 2.2.3: Protect specific habitat components that are rare, are hard to replace, or provide critical spatial and temporal habitat linkages in a time of rapid environmental change. Actions might include:	WSU and County Extension programs DNR Landowner Assistance, NRCS and Conservation Districts,	Prepare extension material and case studies that describe vulnerable elements and demonstrate protection techniques.	Identify elements at risk through the PNW Climate change Vulnerability Assessment for Species and Habitats.

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Identify elements through WDFW Vulnerability Assessment. • Prepare extension material and case studies that describe vulnerable elements and demonstrate protection techniques. • Provide special outreach to conservation area managers to communicate vulnerabilities. • Create incentives to landowners to implement conservation measures	NGOs and land trusts, State and Federal Grant programs. Forest Health and Heritage Programs.	Provide special outreach to conservation area managers to communicate vulnerabilities. Create incentives to landowners to implement conservation measures	
Strategy 2.2.4: Develop Decision support systems that make climate change science and conservation needs accessible to decision makers, landowners and managers, NGO's and other interested public Actions might include: 1. Expand capacity of DSS from pilot scope to statewide/ regional scope	WDFW – Priority Habitat and Species Database; online NOAA/USGS Pilot Project in Methow to develop climate change DSS for land use managers. DataBasin	Long-term, sustainable decision support system.	
Strategy 2.2.5: Flooding Disturbance Vulnerability Assessments Actions might include: • Outreach to planning groups • Targeted coordination with fisheries and near shore interest groups • Increased coordination on forest management with impacts on infrastructure, fish, water supply, transportation	USFS Research programs, BC Ministry of Forests, Universities USDA Forest Service, Pacific Northwest Region (Region 6) Protection Program Conservation Biology Institute data basin	Modify existing programs/laws to accommodate climate change priorities and risks Increased public education on the value of forest cover and scope of riparian influence	Relations are based on episodic events with limited public memory Private resistance to increasing riparian buffer capacity and redundancy

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.2.6: Conduct vulnerability assessment for different ecological systems and key species within forest habitats and implement findings in planning, policy and management actions. Actions might include: • Coordination of data use • Cooperative data collection • Development of new analysis methods	NatureServe Climate Change Vulnerability Index (NSVI) Climate Change Sensitivity Database (CCSD), a part of the Pacific Northwest Climate Change Vulnerability Assessment (Lawler and Case 2010), USDA Forest Service, Pacific Northwest Region (Region 6) Vulnerability Assessment underway.	Modify existing programs/laws to accommodate results of vulnerability assessment in terms of protecting elements most at risk.	Species movement requirements and habitat preferences are often highly uncertain
Strategy 2.2.7:: Implement monitoring programs that are sufficiently sophisticated and precise to identify vegetation changes and relate those changes to climate conditions or weather events. Actions might include: • Coordination of existing monitoring efforts • Provide monitoring planning specifically for change species change detection • Increased data sharing extended to non federal partners	Forest Service and National Park Service Pacific Northwest Research Station's Forest Inventory and Analysis (FIA) USDA 2010. North Coast and Cascades Network (Woodward et al. 2004) USDA Forest Service, Pacific Northwest Region (Region 6) Forest Health Protection Program	May require new interpretation of HCP requirements/ other existing agreements and regulations Focus is on federal land	Funding for monitoring programs under threat Existing temporary monitoring plots networks used for most forestry inventory might be insufficient
Strategy 2.2.8: Insect/Pest/Disease Outbreak Vulnerability Assessments Actions might include:	USDA Forest Service, Pacific Northwest Region (Region 6) Forest Health Protection Program Forest Service Pacific Northwest	May require new agreements and regulations	Coordination of existing monitoring efforts and data sharing as in the date basin project to no federal partners

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Coordination of existing monitoring efforts and data sharing as in the date basin project to no federal partners • Provide monitoring planning specifically for change species change detection	Research Station's Western Wildland Environmental Threat Assessment Center based in Oregon		
Strategy 2.2.9: Large scale Fire Vulnerability Assessments Actions might include: • Coordination of existing monitoring efforts and data sharing as in the date basin project to no federal partners	USDA Forest Service, Pacific Northwest Region (Region 6) Forest Health Protection Program Interior Columbia Basin Ecosystem Management Project	May require new agreements and regulations Existing temporary plots networks used for most forestry inventory might be insufficient	
OBJECTIVE 2.3: Maintain connectivity between core functioning forest habitats.			
Strategy 2.3.1: Integrate results of statewide connectivity analyses into planning and policy and land management activities. Actions might include: • Conduct local planning efforts, • Develop management recommendations, • Protect/conserve key connectivity areas	WDFW Priority Habitats and Species Database; Growth Management Act WWHCWG report on institutional opportunities to implement habitat connectivity planning.	Add capacity to existing FIA program	Landscape-level monitoring of species frequency and range is a substantial undertaking

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
OBJECTIVE 2.4: Minimize the number of species at risk that are vulnerable to climate change impacts.			
Strategy 2.4.1: Incorporate actual and anticipated climate change impacts into species recovery or management plans Actions might include: • Determine genetic conservation needs for Species of Greatest Conservation Need. • Modify recovery plans to accommodate movements/migrations associated with changing habitats associated with climate change.	Habitat Conservation Plans; ESA recovery plans. Natural Heritage Plan	Need mechanism to encourage the retrofitting existing HCPs and landscape plans	Determine genetic conservation needs for Species of Greatest Conservation Need.

ADAPTATION STRATEGIES FOR WESTERN PRAIRIES

WESTERN PRAIRIES
Strategy 1.1 Increase resistance of prairie systems to invasion by non-native grasses Actions might include: • Invest in strategies that effectively remove invasive grasses from prairie systems • Conserve and restore habitat components (native bunchgrasses) or processes (fire, soil nutrients) that improve competitive advantage of native species • Invest in and implement multi-ownership programs for early detection and rapid response to non-native grasses
Strategy 1.2 Maintain sensitive native prairie species and promote species and landscape diversity Actions might include: • Invest in genetic research of drought and disease resistance provenances • Conserve and restore species diversity • Reduce existing stressors where applicable • Promote landscape diversity through management and restoration to provide refugia during summer drought
Strategy 1.3 Manage prairie/grassland ecosystems so that they are more resilient to fire Actions might include: • Implement multi-ownership landscape-level planning to prioritize areas for fire management. • Collaborate with other agencies and organizations to develop technology and markets that increase economic feasibility of fire treatments. • Engage in public outreach and education opportunities that increase public awareness and support for management that promotes fire management. • Promote adaptive approach to landscape scale prairie/grassland management, including robust monitoring programs to evaluate fire effects. • Restructure how state and federal fire prevention funding is managed, shifting the emphasis from fire prevention/suppression to proactive management designed to reduce fire risk • Increase the expertise, capacity, and resources of the Department of Natural Resources to increase the use prescribed fire to promote

prairie/grassland health and sustainability of fire-adapted grasslands on state and private lands • Convene a state-wide multi-stakeholder group (incl. WDOE, WDNR, USFS, USEPA, TNC, WDFW, etc.) to identify current and projected barriers to increasing the extent of prescribed burning in relation to state smoke management guidelines and national ambient air quality standards. • Conduct prescribed burning according to best management practices to achieve ecological and management goals aligned with fuel reduction and native habitat enhancement
Strategy 1.4 Maintain and restore a diversity of habitats with complex topography and functional habitat networks Actions might include: • Collect, store and propagate seed of rare and at-risk species • Identify, preserve and/or restore diversity of habitats to provide refugia for sensitive species • Identify core and connectivity areas that are resilient to climate change effects • Identify and prioritize areas for protection that provide connectivity across climatic gradients, including latitudinal and precipitation gradients • Explore mechanisms for adjusting the size, boundaries and location of protected reserves

Aridlands and Shrubstepe[9]

Description and Distribution

The aridlands of Washington primarily exist just beyond the east slopes of the Cascade Mountains. The area is described as relatively well-vegetated semi-desert scrub or shrub-steppe that occupies comparatively lower elevations in the basins, valleys, lower plateaus, foothills, and lower mountain slopes in this region. They are composed of a number of habitat types including sagebrush-steppe, grasslands and Palouse prairie that are punctuated or crisscrossed by perennial or seasonal streams, springs, vernal pools and other wetland types, and some dune fields. Aridland ecosystems in Washington receive precipitation largely during winter and spring when evaporation and transpiration are minimal; summer storms are generally high-intensity, short-lived events that contribute relatively little water to soils. Typical areas of native vegetation include landscapes dominated by sagebrush (*Artemesia spp.)*, bitterbrush (*Purshiana tridentata)* and other woody shrub species along with bunch grasses, such as Idaho fescue (*Festuca idahoensis)* or bluebunch wheatgrass (*Pseudoroegneria spicata)* and forbs adapted to dry climatic conditions.

The aridlands of Washington are dominated by large areas of land converted to a variety of agricultural uses such as wheat fields and row crops, fruit orchards, vineyards, and livestock feeds like alfalfa. Others areas are used extensively for livestock grazing. Towns and other population centers are generally small and widely dispersed. Public lands are broadly interspersed with private lands with some private land holdings including blocks of thousands of acres in a single ownership.

Projected Climate Impacts and Consequences

The effects of climate change in the Pacific Northwest are expected to include impacts to the dry-adapted ecosystems in eastern Washington. In broad terms, temperatures will increase both seasonally and year-over-year. Spring and summer seasons will likely see greater temperature increases and the annual number of frost free days will continue to increase. Projections for changes in precipitation include a small change in annual rainfall but some models predict a trend toward wetter winters and drier summers with winter precipitation increasingly coming in the form of rain instead of snow. The increasing levels of CO_2 in the atmosphere could also have effects on vegetation growth for both native plant populations and agricultural crops potentially increasing productivity.

Changes in soil, water and air temperatures coupled with changes in precipitation will undoubtedly have impacts on the native plant and animal populations that have adapted to past conditions in the state's aridlands. The consequences of climate change on aridlands species and

[9] The primary reference document for this section was "Climate Change Effects on Grassland and Aridland Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

ecosystems will likely include degradation and loss of plant and animal habitats, spatial shifts in habitats and species, increased frequency and intensity of wildfires, increased soil erosion and conditions favorable for invasive species and changes in plant and animal phenology resulting in potential disruption in life cycles. A compounding factor that also must be considered when analyzing impacts from climate change on natural systems is how humans will respond with changes to infrastructure, water use and agricultural practices. These impacts may be “indirect” but may magnify the effects of strictly climate-driven changes to the environment. To minimize the potential detrimental consequences of climate change on the native plant and animal populations of Washington’s arid land environment, a number of strategies and actions should be adopted and implemented in order to protect and maintain the state’s biodiversity.

Table 4.3

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
GOAL 1: Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Minimize and mitigate for loss of habitat due to climate change			

Strategy 1.1.1: Protect habitat/areas most resilient to climate change and that contribute to core habitat and connectivity.
 	
Actions might include:
• Prioritize and evaluate areas for protection
  ○ Develop criteria to identify areas most resilient to climate change and which contribute to core habitat and connectivity importance
  ○ Identify areas important to biodiversity and species retention
• Protect prioritized areas
  ○ Consider what tools are best – acquisition, incentives, changes in regulation
  ○ identify best entity to implement protection
	State and Federal grant programs for habitat acquisition (for example, WWRP, National Resource Conservation Service, USFWS).
	
	Regulatory Tools, such as Growth Management Act and the Priority Habitat and Species lists.
	
	Landscape level planning initiatives with potential to address climate change: Arid lands initiative, Western Governors Association projects, Landscape Conservation Cooperative, and the Washington Habitat Connectivity Working Group.
	
	Agency strategic plans for land and species protection, including the Natural Heritage Plan, The Comprehensive Wildlife Conservation Strategy, WDFW lands 20/20 and the Habitat and Recreation Lands Coordinating Group.
		Modify existing grant program criteria to incorporate climate change.	More complete ecosystem/habitat inventory information, where resilient habitats exist, criteria for prioritizing areas for protection
			
			In general there is a lack of understanding of the value of aridlands and a lack of incentives for protecting lands.
			
			Bias toward individual wildlife species rather than plants and ecosystems.
			
			Lack of criteria for habitat protection within GMA

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
OBJECTIVE 1.2: **Maintain or increase the resilience of aridland ecosystems to climate change at both local and landscape levels**.			
Strategy 1.2.1: Maintain or improve ecological function/integrity of those high priority areas (see objective 1.1) Actions might include: • Evaluate the current ecological condition of important areas • Develop restoration goals based on changing conditions • Provide incentives for restoration on private lands ○ Retool CRMP to address ecological concerns	Federal and state grant programs for land management and restoration (USFWS, NRCS, WWRP) Ecological Integrity Assessments, currently underway through the Natural Heritage Program, WDFW and State Parks. Existing range condition methodologies	Broader adoption and implementation of Environmental Impact Assessments (or something similar) Need for common language and metrics for assessing ecological function /integrity/condition.	Research on the trajectory of change for ecosystems under climate change. What new aggregations of species can we expect?
Strategy 1.2.2: Increase the ability of plants and animals to move across the landscape. Actions might include: • Protect critical spatial and temporal linkages that accommodate climate-influenced patterns of change • Assess current connectivity and prioritize important linkage areas for conservation (may be accomplished through the Columbia Plateau project of the WHCWG). • Adopt policies to avoid development (energy, residential) in those areas. • Incorporate connectivity concerns into proposals for new transmission lines (direct impact, plus enabler for wind and solar development)	WHCWG statewide and Columbia Plateau analyses; Western Governors Association Pilot Projects; Arid Lands Initiative. Farm Bill programs (NRCS,FSA) Local jurisdiction comprehensive plans	Arid lands wide mitigation program (funds from development, conversion due to new or enhanced water storage projects; alternative energy development, transmission lines, etc.). Incentives targeting connectivity conservation as a climate change adaptation strategy	Need agreed-upon priorities for connectivity conservation for all species, ecosystems and habitats

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps

Strategy 1.2.3: Decrease threat from invasive species *and other non-climate stressors*
 	
Actions might include:
• Improve invasive species management
  ○ Establish early detection protocols
  ○ Develop invasive species tracking tools and alerts for landowners
  ○ Encourage coordinated and strategic control – Weed Management Areas?
  ○ Support innovation in control methods
  ○ Increase funding for management and weed control
  ○ Improve reporting of new and known invasive species.
	State and county weed board,
	
	Washington Invasive Species Council,
	
	Farm Bill programs (NRCS, FSA)
		Develop a program to support invasive species management and monitoring costs when acquiring land
		
		Establish an early detection/rapid response program for new species
		
		Address inadequate funding for weed control and stewardship on public lands
			Develop a shared accessible database of invasive species detections and effective treatments

OBJECTIVE 1.3: Maintain biodiversity by minimizing the number of species at risk			
Strategy 1.3.1: Maintain high value and vulnerable (rare and endemic) species in the face of threats from climate change. Actions might include • Identify and prioritize places that support 'high value' and 'vulnerable' species. • Protect prioritized places (including core habitats, connectivity needs, etc.) • Evaluate full range of conservation mechanisms for each prioritized place. • Identify organization(s)/agency(ies) best-suited for each conservation mechanism and for each place. • Apply appropriate tool(s) to priority places.	State and Federal Grant programs aimed at habitat protection, including WWRP, USFWS Regulatory tools, including GMA (priority habitats and species database), hunting and fishing laws, GMA and County comprehensive plans. Agency plans for species and habitat protection, including Natural Heritage plan and Comprehensive Wildlife Conservation Strategy		Need to aggressively apply tools to increase our understanding of impacts of climate change on individual species. Need to develop better trend data for at-risk and endemic species.

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
	Climate change vulnerability assessments currently underway through UW and at NatureServe.		
Strategy 1.3.2: Explore mechanisms for adjusting the size, boundaries and location of protected reserves Actions might include: • Conduct study to evaluate options for changing preserve boundaries, identify new areas that are needed to provide core areas or important connectivity between cores; • Identify ecological conditions that are critical for species movements or migrations	Agency planning documents addressing protected areas, including: Natural Heritage Plan, WDFW Lands 20/20, Northwest Forest Plan, Regional Conservation Planning Initiatives, including Arid Lands Initiative, Western Governors Association Pilot Projects, Existing protected areas managed by agencies, including WDFW wildlife refuges, DNR natural areas and State Parks,	Modify existing programs to incorporate climate change considerations.	Create tools to make results of the UW vulnerability assessment widely accessible to planners and land use managers.
Strategy 1.3.3: Protect specific habitat components that are rare or hard to replace Actions might include: • Identify and prioritize hard to replace habitat components. • Create a spatially explicit inventory/database • Identify/evaluate protection needs	Agency planning documents addressing protected areas, including: Natural Heritage Plan, WDFW Lands 20/20, Northwest Forest Plan, Species and Ecosystem databases, including Natural Heritage Program (DNR), Priority Habitat and Species Database (WDFW)		Need a better understanding of how climate change will impact small-patch habitats and of how small-patch habitats might either migrate or be constructed if necessary.
GOAL 2: Build necessary scientific and institutional readiness to support effective adaptation			

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.1: Establish a conservation partnership, to address climate change and other stressors, for the aridlands of Washington (including agricultural lands) that includes public and private stakeholders. Actions might include: • Support existing landscape conservation initiatives efforts to address climate change consequences and responses (for example ALI, LCC, WGA, etc.) • Evaluate and fill gaps in coordination to ensure current initiatives are able to adequately address climate change issues • Develop mechanism to share information and coordinate outcomes • Coordinate implementation of strategies across the full scope of arid lands • Develop institutional mechanisms to enable and facilitate shared resources, joint projects and coordinated action between federal, state, local agencies, NGOs, tribes, private entities and landowners. • Develop mechanism for shared accountability for conservation actions and effectiveness • Provide funding to coordinated projects, and empower main conservation initiative/s through management of that funding	Aridands Initiative Regional Conservation Planning Initiatives, including: Landscape Conservation Cooperatives, Western Governors Association Projects. Tools such as the BLM rapid ecosystem assessment	Aridlands version of the Puget Sound Partnership, Create better incentives for coordinating conservation efforts Modify existing planning process, to incorporate climate change consequences	
Strategy 2.2: Ensure existing land management plans and regulatory processes address climate change consequences and include adaptation strategies. Actions might include:	Local jurisdiction comprehensive plans; DNR Strategic Plan for Agriculture.	Arid lands wide mitigation framework (funds from development, conversion due to new or enhanced water storage projects; alternative energy	Resistance to changing objectives for land use. Concern about implementing conservation strategies on priate lands

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Determine how best to incorporate climate change adaptation strategies in existing land management plans. • Evaluate existing land management plans, and work with the appropriate planners and implementers to integrate CC adaptation strategies. ○ county planning ○ private land management plans ○ state and federal land management plans • Develop mitigation requirements for habitat loss from development directly related to human response to climate change ○ Develop a mitigation framework for development ○ Create standards applicable to energy, conversion, residential development. ○ Develop replacement or enhancement acreage equivalencies	Habitat Conservation Plans.	development, transmission lines, etc. Funds to agreed-upon priority areas that increase resilience).	
Strategy 2.3: Improve and better coordinate fire management, in light of increasing risk from climate change. Actions might include: ○ Coordinate fire management across jurisdictions, and focus on agreed-upon priorities. ○ Prioritize areas for fire management and protection • Increase public awareness and decrease human ignition sources ○ Expand public awareness campaigns ○ Increase enforcement of restrictions of high risk activities during fire season. • Reduce impact of fires that occur ○ Increase ability to implement effective post-fire rehabilitation through:	Existing agency fire management programs and resources for agency managed lands -- DNR, BLM, USFWS Local funding for fire districts	Program coordinating fire management resources and use. Funding programs for climate-smart fire management and enforcement of current restrictions Develop a wildland firefighter training and recruitment program? Develop agreed-upon priorities for fire management based on ecological role of fire.	Inadequate coordination of fire management activities across the whole landscape Perception of native systems not being “valuable resources” Inadequate enforcement of restrictions of high risk activities during fire season Inadequate funding and capacity to manage fire in native systems

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
○ Creating a native-seed-buyers cooperative, to stabilize demand and encourage stable seed supply ○ Developing a revolving fund for immediate availability of funding for rehab actions in priority areas. ○ Implementing minimum impact suppression techniques.		Increase ability to implement effective post-fire rehabilitation through: Creating a native-seed-buyers cooperative, to stabilize demand and encourage stable seed supply Developing a revolving fund for immediate for rehab actions in priority areas.	Research ecological role of fire under changing climates, in a fragmented context and with invasives such as cheatgrass.
Strategy 2.4: Increase the contribution of cultivated land to ecological resilience Actions might include: • Develop incentives for climate-smart management on private grazing lands - Flexibility in grazing leases on public lands effective - Grass banking or other "storage" of forage to deal with increased inter-annual variability - Market premium for sustainable grazing, to compensate decreased size of operation due to drought, variability - Incentives for development of climate-smart management plans. (May need a research component to determine how to incorporate climate change projections and uncertainty into grazing management.) • Identify agricultural practices on cultivated and grazing lands with most value for wildlife and connectivity, and provide incentives for their implementation	Farm Bill programs (NRCS, FSA), Sustainable Agriculture certification programs (Food Alliance)	Markets for sustainable and/or climate-smart agricultural practices Incentives focused on practices that increase ecological resilience Incentives targeting connectivity conservation as a climate change adaptation strategy Prescriptive leases	Synthesis and/or development of recommendations of best ag practices (cultivation and grazing) that best support connectivity conservation and mitigate climate change.

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.5: Implement a genetic conservation program			
Strategy 2.6: Incorporate actual and anticipated climate changes in species recovery or species management plans			
Strategy 2.7: Address information gaps to allow better understanding of how climate change can impact aridlands habitats and species			
Strategy 2.8: Develop and maintain a long-term, large scale monitoring plan of key early warning indicators of species responses (including range shifts, population status) and changes in ecological systems functions and processes Actions might include: • Design/develop long term monitoring protocol • Create Citizen Science Monitoring Network (includes Agency, Higher Ed, K-12, Adult volunteers)) to implement monitoring plan	Biodiversity Scorecard Agency species monitoring programs, Various citizen science efforts,	Modify scorecard/dashboards to include climate change indicators. Develop new programmatic citizen science monitoring network to provide mechanism to collect large scale long-term data sets. Will require strong formal science partnership between, professionals, NGOs, local citizen groups.	Citizen Science Network can serve all ecosystems. Once network is in place it can be used for collection of data and analysis of additional questions beyond monitoring.
Strategy 2.9: Develop mechanism for feeding that information back to decision makers at all levels (from policy to individual landowners) to inform management and policy decisions			

Freshwater and Aquatic[10]

Description and Distribution

Washington State is blessed with abundant freshwater resources. The Cascade and Olympic Mountains influence the precipitation patterns from weather moving in from the Pacific Ocean along the state's western edge and store large quantities of water in the form of ice and snow. They also create precipitation "shadows" creating areas of low rainfall and arid conditions along and beyond their eastern slopes. This is most noticeable in the dry eastern portions of the state. The result is strongly divided climate regimes with the western part of the state having an abundance of lakes, streams, ponds and wetlands and generally cool damp conditions much of the year and the eastern part of state experiencing semi-desert conditions with more ephemeral ponds and streams with large river systems, like the Columbia, Snake or Okanogan Rivers providing much of the water resources for agriculture and other human uses.

Projected Climate Impacts and Consequences

The impacts of climate change are likely to create significant changes to the patterns and processes affecting Washington's freshwater ecosystems. Washington relies on cool season precipitation (October through March) and resulting snowpack to sustain warm season streamflows (April through September). Approximately 75% of the annual precipitation in the Cascades falls during the cool season. Small changes in air temperature can strongly affect the balance of precipitation falling as rain and snow, depending on a watershed's location, elevation, and aspect. Based on information found in WACCIA (CIG 2009), PAWG (2008) and Karl (2009), the major climate driven effects on Washington's hydrology appear to be:

- Reduced snowpack and altered runoff regimes
- Reduced summer streamflows
- Increased flooding
- Increased water temperature
- Increased water pollution
- Altered soil moisture
- Altered groundwater
- Reduced glacial size and abundance

These effects are already being seen, for instance, in changes to hydrology in the Puget Sound Basin. Snover et al. (2005) report that freshwater inflow to Puget Sound has changed over the period 1948-2003 in the following ways:

- A 13% decline in total inflow due to changes in precipitation
- A 12 day shift toward earlier onset of snowmelt
- An 18% decline in the portion of annual river flow entering Puget Sound during the
- summer
- An increase in the likelihood of both low and unusually high daily flow events.

[10] The primary reference document for this section was "Climate Change Effects on Freshwater, Aquatic and Riparian Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

Freshwater systems may also be affected by human response to climate change. Changes to infrastructure to address changes in water use, to manage stormwater runoff and to support agricultural practices may create "indirect" but significant impacts and may magnify the effects of strictly climate-driven changes to the environment. Those indirect impacts are not addressed with specific strategies in this section, however, they should be considered when developing strategies to address climate change impacts to other sectors.

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Protect climate resilient and intact river, lake and wetland systems, especially from non-climate threats to maintain their resilience and biodiversity.			
Strategy 1.1.1: **Prioritize the most resilient systems (e.g., sub-basins within WRIAs) for protection** Actions might include: • Conducting a spatially explicit vulnerability assessment to identify risks to freshwater systems caused by climate change. • Inventory and map thermal refugia, snowmelt systems, connectivity and biodiversity. • Identify high priority systems based on resiliency, biodiversity and current function.	DNR uses ecological integrity assessment methodologies to identify areas of high priority for protection; DOE wetland rating system identifies priority wetlands based on function; Stream typing systems used by forest practices regulations and local jurisdiction identify riparian areas for protection based on fish habitat values	Existing protection policies focus on protecting areas most threatened or rare; focusing protection more on intact (robustness, resilience) systems would require criteria revisions of various evaluation/prioritization tools. State agencies may need a vehicle to develop and implement shared criteria. Prioritization could be funded through federal programs like EPA Puget Sound Protection/Restoration program Cross agency/program cooperation and developing shared goals/objectives for funding distribution.	. Need to develop criteria for "resilience" from climate change impacts as well non-climate threats Convincing policy makers most resilient (most intact) areas are highest priority for protections. Land acquisition and protection programs need policies that prioritize climate-resilient systems with high biodiversity value. Concern about using climate change as an "excuse" to lock up lands
Strategy 1.1.2: Protect ecological function and communities in high priority systems Actions might include: • Acquire land, water rights, and easements and easements for upper	Land acquisition by state and federal agencies, local jurisdictions, tribes, and non-governmental land trusts; Protection of areas by local jurisdictions through CAOs, Clean Water Act 404	Land acquisition and protection programs need policies that prioritize climate-resilient systems with high biodiversity value.	Salmon recovery, wetland protection, conservation of aquatic species that are among the most imperiled species

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
watershed forests and meadows that act as natural water and snow storage. • Provide incentives for property owners/managers. • Use current regulatory systems to reduce non-climate stressors and increase system resiliency**.** For example, review and amend CWA to address changing ecosystem conditions, Forest Practices, GMA, SEPA, SMA, HPA and providing support to local jurisdictions with strengthened critical areas. • Coordinate and fund planning and policies to protect high priority systems.	permitting Existing Funding Options: Clean Water State Revolving Funds (US EPA), Habitat Conservation and Restoration Grants (Recreation and Conservation Office), Cooperative Endangered Species Conservation Fund (USFWS)	Consider establishing watershed authorities to manage funds for restoration and protection. Authority could be funded by land use development fees based on percentage of area hardened.	
OBJECTIVE 1.2: Protect and restore streamflow and water levels for ecological function			
Strategy 1.2.1: Develop hydrologic information that better represents current conditions and can be adapted to represent future scenarios – for groundwater, hydroecology, hydrologic modeling. Actions might include: 1. Map groundwater recharge and discharge as critical areas. 2. Monitor water levels in shallow aquifers that support freshwater systems. 3. Determine system specific streamflow targets that support ecological function. 4. Develop statewide network of flow	GMA Critical Aquifer Recharge Areas (CARAs) or instream flows for water rights. Groundwater Assessment Program (GAP) maintains data on locations and data for groundwater withdrawals in the state and assesses each for vulnerability to degradation. Ecology TMDL studies often assess groundwater discharge into surface waters Ecology's River and Stream Water Quality Monitoring Program collects data on 62 long-term stations and 20 basin (rotating) stations.	Expand groundwater inventory of recharge and discharge areas as critical areas through Ecology GAP, TMDL, watershed plans, and local jurisdiction GMA and SMP. Increase River and Stream Water Quality Monitoring sites and IMWs to address basins most at risk from climate change. Explore options with watershed leads to set streamflow targets for ecological functions.	Address lack of site-specific knowledge about the timing, location, and degree of exchange between groundwater and surface water systems (dry-season seepage evaluation and instream piezometer surveys). Current CAOs address CARAs for drinking water protection; "base flows" in streams are considered but not adequately for include ecosystem services and ecological functions. There is currently no state-level

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
monitoring stations to research impacts of climate change on stream hydrology. 5. Develop synthetic rainfall, temperature time series to represent future conditions. 6. Apply hydrologic models to basin-scale analysis of stormwater retrofits in priority basins. 7. Ensure sufficient data is collected on water supply, use and discharge to allow comprehensive water budgets at the watershed scale.	**<u>3. Hydrologic modeling</u>** a. Hydrologic Analysis and Flow Control Design/BMPs; Stormwater hydrology models rely on hourly precipitation data for sizing stormwater control facilities. Low Impact Develop (LID) approaches are given credit	Assess WRIA documents to verify that climate change projections, ground-surface water, ecological instream flows are addressed. Revise regulatory statistical flows (such as critical low flows, design storms and flood frequencies) to account for climate change Increasing demand for additional groundwater from aquifers requires long-term monitoring of recharge areas and ground-surface water interaction at representative sites in selected basins. Explore options for funding WRIA grants after 2013 for salmon habitat restoration activities that also incorporate development of ground-surface water information in critical watersheds.	program to monitor and assess larger-scale ambient groundwater conditions. Ensure sufficient data are collected on water supply, use, and discharge to allow for comprehensive water budgets at watershed scale including forecasting
OJBECTIVE 3: Maintain and restore riparian, floodplain, wetland and lake functions.			
Strategy 1.3.1: Identify, map, and monitor essential functions at risk from climate change Actions might include: 1. For floodplain and riparian areas, update flood maps to account for potential climate change impacts,			

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
a. map historic and future floodplains and riparian zones, b. Monitor distribution of focal animal species, changes to vegetation, nutrient levels, c. Identify floodplain areas at increased risk of inundation, d. Identify channels at increased risk of bank erosion and channel migration – reconnect historical channels to reduce damage and provide compensating refugia. e. Identify in-stream bedload transport areas that pose increased susceptibility to direct habitat loss. f. Identify potential areas for long-term habitat enhancement to offset loss. 2. For wetlands, monitor shifts in distribution of wetland-dependent animal species and changes to vegetation. 3. For lakes, monitor shifts in distribution of lake-dependent, animal species and changes to vegetation.			
Strategy 1.3.2: Re-establish connectivity of rivers and floodplains Actions might include: 1. Acquiring flood easements, 2. Restore floodplain capacity by removing artificial constrictions such as levees, tide gates, and undersized culverts. 3. Support barrier and dam removal and	1) WWRP, ALEA, and LWCF Grants for Critical Habitat, Riparian Protection and Natural Areas and Farmland Preservation (RCO) 2) Fish Passage Barrier Removal Program – dedicated I-4 funds, Highway Construction Program (WSDOT / WDFW)	Existing Programs to include criteria that give priority to riparian and floodplain connectivity. Policies to address the timing of acquisition and spatial relation of properties for optimal riverine and habitat connectivity.	

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
river restoration where appropriate. 4. Increase groundwater infiltration by reducing nearby impervious areas. 5. Update floodway regulations to reflect climate change impacts. 6. Incorporate climate change considerations into long range and emergency planning.	3) Flood Damage Protection Grants (WSECY) 4) Floodplain Development Permits – (Local governments, based on National Flood Insurance Program) 5) Washington State Land Acquisition Coordination Board (RCO)		
Strategy 1.3.3: Increase resilience of lakes and wetlands to climate change impacts by maintaining and restoring functions. Actions might include: 1. Establishing buffers, 2. Controlling invasive species 3. Addressing water quality 4. Creating new wetlands to offset anticipated loss or degradation of refugia elsewhere, 5. Managing water levels to reduce fluctuations and to maintain water temperature & chemistry (identify and reduce water diversions, and reintroduce native species such as beaver.	• State water pollution laws and regulations • State water resources laws and regulations • Lake Management Districts • Lake Management Plans • SMA • Noxious weed laws and programs • Volunteer lake monitoring • Dam licensing	• Statewide lake monitoring program • Remote sensing methodologies for lakes • Data on lakes sufficient to support adaptation is limited. •	Monitoring and modeling would be resource intensive to provide statewide coverage of major lakes.
Build necessary scientific and institutional readiness to support effective adaptation			
OBJECTIVE 2.1: Protect and restore streamflow and water levels for ecological function			
Strategy 2.2.1: Manage water uses for adequate flows that maintain freshwater systems at risk from climate change.	• Water acquisition program • Water banks and trusts • State water resources laws and regulations	• Statewide rollout of water banking, trusts, and acquisition programs • Statewide rollout and update	• Improved water monitoring and forecasting (both water users and basin hydrology)

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Actions might include: 1. Acquiring water rights to put back in streams, lakes, ponds. 2. Establish water banks and improve legal and fiscal frameworks to allow water transfers without increasing climate related stressors. 3. Consider incentives such as fee for water use, promoting conjunctive use of groundwater and surface water, encouraging water conservation, water banks. 4. Employ regulatory tools such as instream flow rules, industrial and agricultural conservation standards, and enforcement of existing regulatory programs. 5. Use planning and policy tools, such as integrating water resource management, stormwater management and land use planning.	• Federal dam licensing • Flow monitoring and modeling programs <u>FUNDING OPTIONS</u> • Water rights fee program • State general fund, grants and loans • Mitigation credit sales Watershed-based tax district	of instream flow rules • Statewide quantification and adjudication of water rights • Statewide enforcement of water resources laws • Improved regulation of groundwater withdrawals • Stricter water conservation standards • Build prioritization into state program implementation based on climate impacts • Inclusion of instream flow benefits into water infrastructure projects, such as ASR, dams, desalinization, etc.	• Integrated watershed, regional and State Water Plans that provide for holistic Integrated Water Resource Management • Insufficient data is available on water use (permitted, exempt, and illegal), stream flows, ground water use, and interactions between ground water and surface water. • Conduct studies, such as the potential for desalination as a water supply and developing integrated water supply and demand forecasting to inform targeted flow restoration efforts.
Strategy 2.2.2: Manage stormwater to protect and restore flow characteristics in light of expected climate change impacts. Actions might include: 1. Creating incentives for more efficient stormwater management, 2. Modifying stormwater regulations to adapt to uncertain future hydrologic conditions, 3. Acquiring land for priority stormwater	• State water pollution laws and regulations • State and federal NPDES stormwater permit programs • Watershed and riparian restoration programs • Stormwater Technical Resources Center (WSU/UW) • Eastern and Western WA Stormwater Manuals • Local government stormwater programs • Puget Sound Partnership LID program	• State and Federal LID performance standards and requirements • Adapt stormwater hydrologic models to changing climate conditions • Stormwater retrofit program for land, design, construction. • Incentive program for stormwater management • Improve Stormwater TMDL Clean up plans	• Understanding of relationship between surface flows, interflows, and deep groundwater. • Basin-scale stormwater hydrologic models • Climate risk analysis plans • Local hydrologic basin modeling data for retrofits •

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
retrofits.		FUNDING OPTIONS • State and Federal grant programs • Dedicated State and Federal funding (e.g. permit fees, hazardous waste fees) • Local Stormwater Utility Fees • Flood District Fees Clean Water District Fees	

Table 4.4

Appendix B3-B

Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts

Prepared by the University of Washington Climate Impacts Group

December 16, 2010

The information provided below is largely assembled from work completed for the 2009 Washington Climate Change Impacts Assessment. Other sources have been used where relevant but this summary should not be viewed as a comprehensive literature review of Pacific Northwest (PNW) climate change impacts. Confidence statements are strictly qualitative with the exception of IPCC text regarding rates of 20th century global sea level rise. Note that periods of months are abbreviated by each month's first letter, e.g., DJF = Dec, Jan, Feb.

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Temperature	Increasing temperatures expected through 21st century	Projected multi-model change in average annual temperature (with range) for specific benchmark periods: • 2020s: +2°F (1.1 to 3.4°F)** • 2040s: +3.2°F (1.6 to 5.2°F) • 2080s: +5.3°F (2.8 to 9.7°F) These changes are relative to the average annual temperature for 1970-1999. The projected *rate* of warming is an average of 0.5°F per decade (range: 0.2-1.0°F). ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1*	Projected warming by the end of this century is much larger than the regional warming observed during the 20th century (+1.5°F), even for the lowest scenarios.	Warming expected across all seasons with the largest warming in the summer months (JJA) Mean change (with range) in winter (DJF) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.1°F (0.7 to 3.6°F)** • 2040s: +3.2°F (1.0 to 5.1°F) • 2080s: +5.4°F (1.3 to 9.1°F) Mean change (with range) in summer (JJA) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.7°F (1.0 to 5.3°F)** • 2040s: +4.1°F (1.5 to 7.9°F) • 2080s: +6.8°F (2.6 to 12.5°F)	High confidence that the PNW will warm as a result of increasing greenhouse gas emissions. All models project warming in all scenarios (39 scenarios total) and the projected change in temperature is statistically significant.	Mote and Salathé 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		emissions scenario).				
Precipitation *(extreme precipitation addressed in separate field)*	A small increase in average annual precipitation is projected (based on the multimodel average, Mote and Salathé 2010), although model-to-model differences in projected precipitation are large (see "Confidence"). Potentially large seasonal changes are expected.	Projected change in average annual precipitation (with range) for specific benchmark periods: • 2020s: +1% (-9 to 12%)** • 2040s: +2% (-11 to +12%) • 2080s: +4% (-10 to +20%) These changes are relative to the average annual temperature for 1970-1999. ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected increase in average annual precipitation is small relative to the range of natural variability observed during the 20th century and the model-to-model differences in projected changes for the 21st century	*Summer:* Majority of global climate models (68-90% depending on the decade and emissions scenario) project decreases in summer (JJA) precipitation. Mean change (with range) in JJA precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: -6% (-30% to +12%) ** • 2040s: -8% (-30% to +17%) • 2080s: -13% (-38% to +14%) *Winter:* Majority of global climate models (50-80% depending on the decade and emissions scenario) increases in winter (DJF) precipitation. Mean change (with range) in DJF precipitation for specific	Low confidence. The uncertainty in future precipitation changes is large given the wide range of natural variability in the PNW and uncertainties regarding if and how dominant modes of natural variability may be affected by climate change. Additional uncertainties are derived from the challenges of modeling precipitation globally. Model to model differences are quite large, with some models projecting decreases in winter and annual total precipitation and	Mote and Salathé 2010; Salathé et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
				benchmark periods, relative to 1970-1999: • 2020s: +2% (-14% to +23%)** • 2040s: +3% (-13% to +27%) • 2080s: +8% (-11% to +42%)	others producing large increases. Expect that the region will continue to see years that are wetter than average and drier than average even as that average changes over the long term.	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Extreme precipitation	Precipitation intensity may increase but the spatial pattern of this change and changes in intensity is highly variable across the state.	State-wide *(Salathé et al. 2010)*: More intense precipitation projected by two regional climate model simulations but the distribution is highly variable; substantial changes (increases of 5-10% in precipitation intensity) are simulated over the North Cascades and northeastern Washington. Across most of the state, increases are not significant. For sub-regions *(Rosenberg et al. 2010)*: Projected increases in the magnitude (i.e., the amount of precipitation) of 24-hour storm events in the Seattle-Tacoma area over the next 50 years are 14.1%-28.7%, depending upon the data employed. Increases for Vancouver and Spokane are not statistically significant and therefore cannot be distinguished from natural variability.	Projected increases in the magnitude of 24-hour storm events for the period 2020-2050 for the Seattle-Tacoma area (14.1 to 28.7%) is comparable to the observed increases for 24-hour storms over the past 50 years (24.7%) *(Rosenberg et al. 2009).*	The ECHAM5 simulation produces significant increases in precipitation intensity during winter months (Dec-Feb), although with some spatial variability. The CCSM3 simulation also produces more intense precipitation during winter months despite reductions in total winter and spring precipitation *(Salathé et al. 2010)*	Low confidence. Anthropogenic changes in extreme precipitation difficult to detect given wide range of natural precip variability in the PNW. Computational requirements limit the analysis of sub-regional impacts within WA to two scenarios, reducing the robustness of possible results. Simulated changes are statistically significant only over northern Washington.	Salathé et al. 2010 Rosenberg et al. 2009 Rosenberg et al. 2010
Extreme heat	More extreme heat events expected	Generally projecting increases in extreme heat events for the 2040s, particularly in south central WA and the western WA lowlands *(Salathé et al. 2010).*** Changes in specific regions vary with time period (2025, 2045, and 2085), scenario (low, moderate, high), and region (Seattle, Spokane, Tri-Cities, Yakima) but all four regions and all scenarios show increases in the mean annual number of heat events, mean event duration, and maximum event duration *(Jackson et al. 2010, Table 4).* ---------------------------- *** Definitions of extreme heat varied between the two studies cited here. Salathé et al. 2010 defined a heat*	Projected increases in number and duration of events is significantly larger than the number and duration of events between 1980-2006 (specific values vary with location, warming scenario, and time period). In western Washington, the frequency of exceeding the 90th percentile daytime temperature (Tmax) increases from 30 days per year in the current climate (1970-	n/a (relevant to summer only)	Medium confidence. There is less confidence in sub-regional changes in extreme heat events due to the limited number of scenarios used to evaluate changes in extreme heat events in Jackson et al. 2010 (9 scenarios) and Salathé et al. 2010 (2 scenarios), although confidence in warmer summer temperatures overall is high (see previous entry for temperature).	Salathé et al. 2010 Jackson et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		wave as an episode of three or more days where the daily heat index (humidex) value exceeds 90°F. Jackson et al. 2010 defined heat events as one or more consecutive days where the humidex was above the 99th percentile.	1999) to 50 days per year in the 2040s (2030-2059).			
Snowpack (SWE)	Decline in spring (April 1) snowpack expected	The multi-model means for projected changes in mean April 1 SWE for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: -27% (B1), -29% (A1B) • 2040s: -37% (B1), -44% (A1B) • 2080s: -53% (B1), -65% (A1B) All changes are relative to 1916-2006. Individual model results will vary from the multi-model average.	Projected declines for the 2040s and 2080s are greater than the snowpack decline observed in the 20th century (based on a linear trend from 1916-2006).	n/a (relevant to cool season [Oct-Mar] only)	High confidence that snowpack will decline even though specific projections will change over time. Projected changes in temperature, for which there is high confidence, have the most significant influence on SWE (relative to precipitation).	Elsner et al. 2010
Streamflow	Expected seasonal changes include increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow dominant and rain/snow mix (transient) basins, and decreases in summer streamflow. Increasing risk of extreme high and low flows also expected. In all cases, results will vary by location and basin type.	The multi-model averages for projected changes in mean annual runoff for Washington state for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: +2% (B1), 0% (A1B) • 2040s: +2% (B1), +3% (A1B) • 2080s: +4% (B1), +6% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value *(Elsner et al. 2010)* The risk of lower low flows (e.g., lower 7Q10** flows) increases in all basin types to varying degrees. The decrease in 7Q10 flows is greater in rain dominant and transient basins relative to snow-dominant basins, which generally see less snowpack decline and (as a result) less of a decline in summer streamflow than	During the period from 1947-2003 runoff occurred earlier in spring throughout snowmelt influenced watersheds in the western U.S. *(Hamlet et al. 2007)*.	Projected changes in mean cool season (Oct-Mar) runoff for WA state: • 2020s: +13% (B1), +11% (A1B) • 2040s: +16% (B1), +21% (A1B) • 2080s: +26%(B1), +35% (A1B) Projected changes in mean warm season (Apr-Sept) runoff for WA state: • 2020s: -16% (B1), -19% (A1B) • 2040s: -22% (B1), -29% (A1B) • 2080s: -33%(B1), -43% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value. *(Elsner et al. 2010)*	*Regarding changes in total annual runoff:* There is high confidence in the direction of projected change in total annual runoff but low confidence in the specific amount of projected change due to the large uncertainties that exist for changes in winter (Oct-Mar) precipitation. The large uncertainties in winter precipitation are due primarily to uncertainty about the timing of, and any changes in, dominant models of natural decadal variability that influence precipitation	Elsner et al. 2010 Hamlet et al. 2007 Mantua et al. 2010 Tohver and Hamlet 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		transient basins. *(Mantua et al. 2010; Tohver and Hamlet 2010)* Changes in flood risk vary by basin type. Spatial patterns for the 20-year and 100-year flood ratio (future/historical) indicate slight or no increases in flood risk for snowmelt dominant basins due to declining spring snowpack. There is a progressively higher flood risk through the 21st century for transient basins, although changes in risk in individual transient basins will vary. Projections of flood risk for rain dominant basins do not indicate any significant change under future conditions, although increases in winter precipitation in some scenarios nominally increase the risk of flooding in winter. *(Tohver and Hamlet 2010, in draft)* ---------------------------- *** 7Q10 flows are the lowest stream flow for seven consecutive days that would be expected to occur once in ten years.*			patterns in the PNW (e.g. the Pacific Decadal Oscillation) as well as changes in precipitation caused by climate change. *Regarding streamflow timing shifts:* There is high confidence that peak streamflow will shift earlier in the season in transient and snow-dominant systems due to projected warming and loss of April 1 SWE. There is less confidence in the specific size of the shift in any specific basin given uncertainties about changes winter precipitation *(see previous comment)*. *Regarding summer streamflows:* Overall, there is high confidence that summer streamflow will decline due to projected decreases in snowpack (relevant to snow dominant and transient basins) and increasing summer temperatures (relevant to all basin types). There is medium confidence that late summer streamflow will decline given 1) the sensitivity of late	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
					summer streamflow to uncertain precipitation changes, and 2) uncertainties about if and how groundwater contributions in any given basin may affect late summer flows. For all changes in streamflow, confidence in *specific* projected values is low due to high uncertainty about changes in precipitation and decadal variability.	
Sea level rise	Varying amounts of sea level rise (or decline) projected in Washington due to regional variations in land movement and coastal winds.	Projected global change (2090-2099) according to the IPCC: 7-23", relative to 1980-99 average *(Solomon et al. 2007)*** 2050: Projected medium change in Washington sea level (with range) *(Mote et al. 2008)*: • NW Olympic Pen: 0" (-5-14") • Central & So. Coast: 5" (1-18") • Puget Sound: 6" (3-22") 2100: Projected medium change in WA sea level (with range) *(Mote et al. 2008)*: • NW Olympic Peninsula: 2" (-9-35") • Central & So. Coast: 11" (2-43") • Puget Sound: 13" (6-50") ---------------------------- ** *Since 2008, numerous peer-reviewed studies have offered alternate estimates of global sea level rise. The basis for these updates are*	Relative change in Washington varies by location. Globally, the average rate of sea level rise during the 21st century very likely[‡] (>90%) exceeds the 1961-2003 average rate (0.07 ± 0.02 in/year) *(Solomon et al. 2007)* ---------------------------- [‡] *= as defined by the IPCC's treatment of uncertainties (Solomon et al. 2007, Box TS1)*	Wind-driven enhancement of PNW sea level is common during winter months (even more so during El Niño events). On the whole, analysis of more than 30 scenarios found minimal changes in average wintertime northward winds in the PNW. However, several models produced strong increases. These potential increases contribute to the upper estimates for WA sea level rise. *(Mote et al. 2008)*	High confidence that sea level will rise globally. Confidence in the amount of change at any specific location in Washington varies depending on the amount of uncertainty associated with the global and local/regional factors affecting rates of sea level rise. Regionally, there is high confidence that the NW Olympic Peninsula is experiencing uplift at >2 mm/yr. There is less confidence about rates of uplift along the central and southern WA coast due to	Mote et al. 2008 Solomon et al. 2007

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		known deficiencies in the IPCC's 2007 approach to calculating of global sea level rise, including assumptions of a near-zero net contribution from the Greenland and Antarctic ice sheets to 21st century sea level rise. A comparison of several studies in Rahmstorf 2010 (Figure 1) shows projections in the range of 1.5ft to over 6ft. Overall, recent studies appear to be converging on projected increases in the range of 2-4ft (e.g., Vermeer and Rahmstorf (2009), Pfeffer et al. 2008, Grinsted et al. 2009, Jevrejeva et al. 2010).			sparse data, but available data generally indicate uplift in range of 0-2mm/yr. There is high uncertainty about subsidence, and rates of subsidence where it exists, in the Puget Sound region. Although annual rates of current and future uplift and subsidence (a.k.a. "VLM") are well-established at large geographic scales, determining rates at specific locations requires additional analysis and/or monitoring. Uncertainties around future rates are unknown and would be affected by the occurrence of a subduction zone earthquake.	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Wave Heights	Increase in "significant wave height" ** expected in the near term (through 2020s) based on research showing that a future warmer climate may contain fewer overall extra-tropical cyclones but an increased frequency of very intense extra-tropical cyclones (which may affect the extreme wave climate). ------------------ *** "Significant wave height" is defined as the average of the highest 1/3 of the measured wave heights within a (typically) 20 minute period*	Based on extrapolation of historical data‡ and assumptions that the historical trends continue into the future, the 25, 50, and 100 year significant wave height events are projected to increase approximately 0.07m/yr (2.8 in/yr) through 2020s. ---------------------------- *‡ the five highest significant wave heights measured at Washington NDBC Buoy #46005 (at the WA/OR border)*	Projected changes through 2020 are comparable to the observed increase in the average of the five highest significant wave heights for the mid 1970s-2007 (0.07m/yr, or 2.6 in/yr). *More on past changes:* Over the last 30 years, the rate of increase for more extreme wave heights has been greater than the rate of increase in average winter wave height. For the WA/OR outer coast (mid 1970s-2007): • The average of all winter significant wave heights increased at a rate of 0.023m/yr (0.9 in/yr) • Annual maximum significant wave height increased 0.095m/yr (3.7 in/yr).	These findings relate to the winter season (Oct-March), which is the dominant season of strong storms	*Regarding general trend:* There is low confidence that significant wave height will increase given the dependence of this increase on a limited number of studies showing potential increases in the intensity of the extra-tropical cyclones that can affect the extreme wave climate. *Regarding specific projected increases in wave height:* There is low confidence in the calculated trend for 25, 50, and 100 year significant wave height events given that this calculation is based on extrapolation of historic data and assumptions of continued historical trends rather than physical modeling.	Ruggiero et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Sea surface temperature (SST)	Warmer SST expected	Increase of +2.2°F projected for the 2040s (2030-59) for coastal ocean between 46°N and 49°N. Changes are relative to 1970-99 average.	Projected change is substantially outside the range of 20th century variability.	*No information currently available*	Medium to low confidence in the degree of warming expected for the summertime upwelling season. Global climate models do not resolve the coastal zone and coastal upwelling process very well, and uncertainty associated with summertime upwelling winds also brings uncertainty to coastal SSTs in summer.	Mote and Salathé 2010
Coastal upwelling	Little change in coastal upwelling expected	The multimodel average mean change in winds that drive coastal upwelling is minimal	Comparable to what has been observed in the 20th century	Little change in seasonal patterns.	Low confidence given the fact that this hasn't been evaluated with dynamical downscaling of many climate model scenarios at this point.	Mote and Salathé 2010
Ocean acidification	Continuing acidification expected in coastal Washington and Puget Sound waters	The global surface ocean is projected to see a 0.2 - 0.3 drop in pH by the end of the 21st century (in addition to observed decline of 0.1 units since 1750) (Feely et al. 2010). pH in the North Pacific, which includes the coastal waters of Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO2 to 560 and 840 ppm, respectively (Feely et al. 2009). pH in Puget Sound is projected to decrease, with ocean acidification accounting for an increasingly large part of that decline. Feely et al. 2010 estimated that ocean acidification accounts for 24-49% of the pH	Projected global changes are larger than the decrease of 0.1 units since 1750, and greater than the trend in last 20 years (0.02 units/decade). The observed decrease of 0.1 units since 1750 is equivalent to an overall increase in the hydrogen ion concentration or "acidity" of about 26%.	The contribution of ocean acidification to Dissolved Inorganic Carbon (DIC) concentrations within the Puget Sound basin can vary seasonally. Ocean acidification has a smaller contribution to the subsurface increase in DIC concentrations in the summer (e.g., 24%) compared to winter (e.g., 49%) relative to other processes (Feely et al. 2010).	For global changes, confidence that oceans will become more acidic is high. Results from large-scale ocean CO_2 surveys and time-series studies over the past two decades show that ocean acidification is a predictable consequence of rising atmospheric CO_2 that is independent of the uncertainties and outcomes of climate change (Feely et al. 2009).	Feely et al. 2009 Feely et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		decrease in the deep waters of the Hood Canal sub-basin of Puget Sound relative to estimated pre-industrial values. Over time, ocean acidification from a doubling of atmospheric CO2 could account for 49-82% of the pH decrease in Puget Sound subsurface waters.			For Puget Sound, estimates of the contribution of ocean acidification to future pH decreases in Puget Sound have very high uncertainty since other changes that may occur over the intervening time were not taken into account when calculating that estimate (a percentage) (Feely et al. 2010).	

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Appendix B3-C: Criteria for Prioritizing Adaptation Actions

Note: Thanks to Lara Whitely-Binder and Dan Siemann for guiding the TAG in developing this criteria.

The following criteria were developed by TAG 3 for selecting and, where relevant, prioritizing adaptation objectives, strategies, and actions. The TAG used these criteria as general guidelines rather than in any kind of strict or quantitative fashion. TAG3 recommends that as implementation is advanced for natural resource climate adaptation strategies, these guidelines continue to be refined.

These criteria were selected because they were helpful in assessing:

- The degree to which a climate change impact needs to be addressed in the state's current adaptation planning effort (*Urgency*);
- If the objective, strategy, or action reflects key characteristics associated with increased climate resiliency, e.g., objectives, strategies, or actions that help reduce vulnerability to climate change while being able to adapt to the changing nature of projected climate change (*Robustness, Flexibility/Reversibility*);
- If, where, and how the benefits of the objective, strategy, or action are likely to be realized (*Risk of Unintended Consequences, Geographic Distribution of Benefits, Secondary Benefits, No/Low Regrets*);
- Considerations for implementing the objective, strategy, or action (*Time Frame for Implementation, Capacity, Window of Opportunity, Geographic Distribution of Benefits, Secondary Benefits, No/Low Regrets);* and, ultimately,
- Whether the objectives, strategies, and actions meet the goals and guiding principles of the TAG (*all of the criteria*).

The criteria are divided into two categories: 1) criteria that broadly evaluate the adaptive nature and relevance of an objective, strategy, or action ("general criteria"); and 2) criteria that relate more specifically to implementation considerations ("implementation criteria"). More information on each of the criteria is provided below and summarized in Tables 1 and 2.

General Criteria (Table 1)

1. ***Urgency*** – The urgency metric asks whether it is important to implement the objective, strategy, or action now as opposed to waiting. The need for urgency may be due to the fact that:
   - the impact (e.g., habitat loss) is occurring now, regardless of whether the presumed cause is climate change or some other driver (e.g., development or growing dominance of an invasive species);
   - it may take time to get all the necessary pieces in place to implement an action (e.g., legislative authorities, funding, and relevant technical data);
   - a specific action is necessary to accomplish other priority objectives, strategies, or actions; and/or

- the opportunity cost of not acting in the near-term is high (e.g., opportunities to preserve critical habitat may be lost while waiting to for sea level to rise a certain amount before taking action)

2. ***Robustness*** – asks whether the objective, strategy, or action is likely to be effective for a broad range of plausible future climate change projections rather than a single or narrow range of projections. Note that a limited range of robustness does not necessarily eliminate a specific objective, strategy, or action; a limited range of robustness may acceptable if, for example, the objective, strategy, or action is flexible and/or easily reversible or the projected impact being addressed by the objective, strategy, or action has potentially significant consequences (i.e., the urgency is high).

3. ***Flexibility/Reversibility*** – asks whether the objective, strategy, or action can be easily adjusted or reversed if future research or other factors indicate that climate impacts are likely to occur in ways not previously anticipated.

4. ***Risk of Unintended Consequences*** – asks whether the objective, strategy, or action could lead to unintended consequences. The potential for unintended consequences may be acceptable if the objective, strategy, or action is flexible or reversible. Risk tolerance will also be a factor in deciding whether the potential for unintended consequences is significant enough to warrant a different choice.

Implementation Criteria (Table 2)

5. ***Time Frame for Implementation*** – this metric is specific to actions and refers to the point in time that the action is considered "up-and-running". Work on securing the things required to implement an action (e.g., changes in law, funding, staffing, partnership building etc) could be happening in the interim period.

6. ***Capacity*** – asks whether current capacity for implementing an objective, strategy, or action is sufficient. Capacity may be determined by many factors, including the availability of funding, staff, and relevant information; access to necessary technical resources; and existing program requirements or limitations.

7. ***Window of Opportunity*** – refers to a unique (and presumably limited) opportunity for implementing an objective, strategy, or action. The window may include an upcoming revision of a strategic plan, law, or policy; allocation of a new funding source; enhancement of on-going initiatives, or other unique opportunities for integrating a recommended objective, strategy, or action into programs or other planning frameworks.

8. ***Geographic Distribution of Benefits*** - asks whether the objective, strategy, or action benefits to a small or large range and/or number of critical ecological functions11 or uniquely valuable species. Having a limited range of benefits does not necessarily reduce the value of that objective, strategy, or action since a place-specific ecological function or uniquely valuable species is important in its own right. The metric is simply a reflection of how broadly the objective, strategy, or action applies.

9. ***Secondary Benefits -*** asks whether the objective, strategy, or action provides benefits to other program or community goals beyond the primary goal of helping critical ecological functions or uniquely valuable species adapt to climate change. For example, "Re-establish connectivity of rivers and floodplains" (Freshwater/Aquatic Strategy) has the primary goal of improving habitat for aquatic and terrestrial species but also provides secondary benefits that include reducing flood risk and improving water quality. The absence of secondary benefits does not negate the value of the objective, strategy, or action, but could be a factor when prioritizing for implementation.

10. ***No/Low Regrets*** – asks whether an objective, strategy, or action is likely to provide adaptation or other benefits if climate change impacts occur in ways not previously anticipated. Although similar to "Secondary Benefits", this metric recognizes that both no/low regrets and high regrets objectives, strategies, and actions can provide secondary benefits. Consequently, "No/Low Regrets" is listed as a separate criterion that may be particularly useful when deciding which subset of objectives, strategies, and actions will be implemented in the near term.

Table 1: General Criteria

Note: "Action" should be interpreted as "objective, strategy, or action" depending on what is being evaluated.

CRITERIA	Low	Medium	High
Urgency	Low	Medium	High
Robustness	The action is effective for a narrow range of plausible future climate scenarios	(this cell left intentionally blank)	The action is effective for a wide range of future climate scenarios
Flexibility/ Reversibility	The action cannot be easily adjusted and/or reversed	The action is somewhat adjustable and/or reversible	The action can be easily adjusted and/or reversed
Risk of Unintended Consequences	The action has a high known risk of causing negative unintended consequences	The action has some known risk of causing negative unintended consequences	The action has little to no known risk of causing negative unintended consequences

Table 2: Implementation Criteria

Table note: "Action" should be interpreted as "objective, strategy, or action" with the exception of "Time Frame for Implementation", which applies specifically to actions.

CRITERIA	Low	Medium	High
Time Frame for Implementation	The action is not likely to be implemented for 5 or more years	The action is likely to be implemented in 3-5 years	The action can be implemented in 1-3 years
Capacity	Current capacity insufficient and gaps cannot be easily addressed.	Gaps exist in one or more areas but can be addressed.	Current capacity is largely sufficient.
Window of Opportunity	There is currently no window of opportunity for implementing the action	A window of opportunity can be created for implementing the action	A window of opportunity exists for implementing the action
Geographic Distribution of Benefits	The action benefits a very small geographic range and/or number of species (e.g. site specific)	The action benefits a sizeable geographic range and/or number of species (e.g., regional)	The action benefits a very wide geographic range and/or number of species (e.g., statewide)
Secondary Benefits	The action has no additional benefit(s) beyond the initial goal of helping critical ecological functions or uniquely valuable species adapt to climate change.	(this cell left intentionally blank)	The action provides additional benefit(s) beyond the initial goal of helping critical ecological functions or uniquely valuable species adapt to climate change.
No/Low Regrets	The action has no adaptation benefit(s) if climate change impacts occur in ways not previously anticipated	(this cell left intentionally blank)	The action provides adaptation benefit(s) even if climate change impacts occur in ways not previously anticipated

Note that some metrics presented here are binary in nature and therefore do not have a "medium" description. For example, it is easier (absent the use of models for testing) to qualitatively assess if an objective, strategy, or action is robust for a small vs. large range of future climate scenarios than to try to determine robustness for a small, medium, and large range of scenarios. Similarly, trying to distinguish between a medium versus high level of benefit would be hard to do in a meaningful way. Consequently, the Secondary Benefits and No/Low Regrets criteria simply ask if benefits are, or are not, expected.

Appendix B3-D: GLOSSARY OF CLIMATE CHANGE ADAPTATION CONCEPTS AND TERMS[12]

Note that this glossary defines these terms specifically in the context of climate change and that many have different or broader meanings in other contexts.

Adaptation – Adjustment in natural or human systems in response to actual or expected climatic changes and associated effects that minimizes harm or takes advantage of beneficial opportunities.

Adaptive Capacity – The ability of a system to adjust to climatic changes and associated effects (including social, economic, and ecological), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.[i]

Climate Change – Any long-term change in average climate conditions in a place or region, whether due to natural causes or as a result of human activity.

(Climate) Impacts Assessment – The practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems.

Climate Variability – Variations in the mean state of the climate and other statistics (such as standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales beyond that of individual weather events, such as the occurrence of a particularly wet or dry year.

Co-benefits – Benefits that go beyond the primary intended benefits of a particular policy, or benefits of policies designed to address multiple concerns simultaneously. For example, restoring wetlands to minimize flood risk has the co-benefit of increasing waterfowl habitat. Reducing greenhouse gas emissions from driving has the co-benefit of improving air quality.

Impact (of climate change)– Any consequence of climate change on a system, species, etc., including effects on structure, composition, or function.

Maladaptation - An action or strategy that increases rather than decreases vulnerability to climate change or its effects.

Mitigation – In the climate change community, a human intervention to reduce the sources or improve the uptake (sinks) of greenhouse gases. In the disaster community, human intervention to minimize harm.

No-regrets policy – A policy that would generate net social benefits regardless of climate change or the effectiveness of the policy in achieving its primary goal.

Refugium (pl. refugia) - An area where climatic change is relatively less rapid or extreme (e.g., due to physical landscape features, such as north-facing slopes, valleys or other low areas that

[12] Definitions adapted from the California Climate Adaptation Strategy, 2009, and also provided by TAG3 members.

serve as sinks for cold air, or streams fed by deep coldwater springs). Refugia can serve as strongholds for species that can no longer survive elsewhere.

Resilience – The ability of a population or system to bounce back to something like its previous state following disturbance or change. Resilience can also applied to managing ecosystems and species to make them more able to recover from disturbance.

Resistance – The ability of a population or system to remain relatively unaffected by climatic change and associated effects. Resistance can also be applied to managing ecosystems and species to make them more able to resist the effects of global climate change.

Response – In the context of adaptation, the longer-term shifts in ecosystems or species as a result of climate change or its effects, for example changes in a species' geographic range or in the species and systems that make up an ecosystem. Response can also be applied to managing species or system responses to maintain desired resources or ecosystem services over time. The philosophy is essentially one of facilitating natural responses to change rather than trying to maintain the status quo.

Risk (climate-related) – The possibility of interaction of physically defined hazards with the exposed systems; the combination of the likelihood of an event and its consequences – i.e., the probability of climate hazard occurring multiplied the consequences a given system may experience.

System – A human community or an ecosystem; a social, economic, cultural, or natural complex; a group of interacting natural resources, species, infrastructure, or other assets.

Vulnerability – In the most general sense, susceptibility to harm or change. More specifically, the degree to which a system is exposed to, sensitive to, and unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity.

Vulnerability Assessment – A practice that identifies who and what is sensitive to change, how much change they are exposed to, and how able a given system is to respond to the changes that occur (including variability and extremes). A vulnerability assessment considers the intrinsic and extrinsic factors that govern the exposure and sensitivity of species, communities, or ecosystems to change, and the ability of the species or system to successfully adapt (evolutionarily, behaviorally, physiologically, socially, economically, and so on).

Appendix B3-E: Science Summaries for four ecological systems

(NOT INCLUDED IN THIS DOCUMENT)

Appendix B4

Washington State Climate Change Response Strategy

Interim Recommendations of the Natural Resources: Working Lands and Waters Topic Advisory Group

February 2011

Natural Resources: Working Lands and Waters Topic Advisory Group Members

Co-Chairs:
- Rachael Jamison, Department of Natural Resources
- Kirk Cook, Department of Agriculture
- Derek Sandison, Department of Ecology

Staff:
- None provided.

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Introduction

Climate change may have significant implications for Washington's working lands and waters. Our ability to adapt to the expected changes will have significant impacts on the viability of the economies that rely on our states robust natural resource base.

Natural Resources: Working Lands and Waters Topic Advisory Group (TAG)

The work of the Natural Resources (working lands and waters) TAG sought to address the challenges brought about by climate change in a manner that ensured the protection of Washington's natural resources, fostered rural economic development, positioned the state to take action that minimizes the negative impacts from climate change and, where possible, maximize those changes. The work was done using the best available data while addressing the specific concerns of Washington residents as they relate to the state's working lands.

The TAG brought together representatives of Washington's forest, agriculture, environmental and policy communities to develop a cohesive strategy that has practical applications and addresses the environmental, social, and economic needs of the state as they relate to adapting to climate change on our working lands and waters. The group intended to develop a plan that outlined actions to address climate change impacts anticipated on Washington's working lands.

Early in the process, the TAG determined that it would be beneficial to break into four smaller sub-groups to explore more deeply the four topic areas that emerged as priorities:

- **Fire Management.** Changes in summer precipitation and temperature could significantly increase the risk of wildfire on both forest and rangelands in many areas of the state. This impact will likely not only be confined to Washington but the Western United States as well, impacting our current suppression capabilities.

- **Pests and Disease**s. Forests stressed by climate change will be more vulnerable to mountain pink beetle outbreaks and will result in increased tree mortality. Climate changes will likely favor the life cycle of both insects and weeds thereby increasing the potential for damage to Washington's agricultural and forest industry. Changes in marine water chemistries and a raise in water temperatures, put Washington's shellfish and aquaculture industry at risk

- **Water Availability.** It is predicted that areas of water limited forests will increase by a minimum of 32% by the 2020s and an additional 12% in both the 2040s and 2080s. This will have a significant impact in the productivity of forested areas and will require changes in forest management. The decrease in predicted snow pack will have profound effects in some agricultural areas in the state. Those areas that rely on irrigation from melting snow pack during the growing season will likely experience shortages without modifications to current water management systems and improvements in water supply and infrastructure. Additionally, as population increases and water availability is reduced, competition for diminished resources between municipal, industrial, and agricultural interests will become acute.

- **Genetic Preservation and Development**. It is important that efforts be made to mitigate the impacts of climate change on ecosystem functions to the greatest extent possible. Activities that seek to ensure the perpetuation of genetic resources in the state will need to be explored. As the affects of climate change are experienced, it may no longer be economically rational to raise traditional agricultural and forest commodities. Various valuable tree species, too, may not be viable in a climate challenged environment. Additionally impacts to both livestock and shellfish production could be affected.

The groups were authorized to invite topical experts to assist in the identification of key risks and the development of adaptation strategies. All of the groups did this in an effort to ensure that recommendations were based on sound science, were consistent with other compatible efforts, and provided opportunities for topical experts to weigh in.

In addition to the four major topic areas, the TAG determined that several factors should be considered by all four sub-groups in their work to develop recommendations:

- **Avoided land conversion.**
  Recommended actions needed to support existing efforts to preserve and protect Washington's existing working forests and agriculture lands.

- **Land-use management.**
  Recommended actions needed to address, where appropriate, how land-use management decisions could help or hinder adaptation strategies.

- **Inter-agency collaboration (federal, state, local).**
  To eliminate redundancy in efforts, recommended actions needed to identify opportunities for agencies to collaborate and build on one another's efforts.

- **East/West Cascades differences.**
  Differences in culture, economics and politics between communities in Eastern and Western Washington needed to, the greatest extent possible, be considered and integrated into recommendations.

- **Major catastrophic events.**
  In addition to long-term planning, strategies for dealing with catastrophic events needed to be included in the recommendations.

- **Global and local economic factors.**
  Global and local economic issues play a significant role in the activities that occur on Washington's working lands. It was important to take this into account when developing strategies for adapting to climate change.

TAG 4 met approximately eight times between March 2010 and January 2011. In addition to whole tag meetings, sub-groups met intensively during this time (some as often as every week for periods of active strategy development). The success of this effort rests on the willingness of both the TAG members and the other professionals that offered their time and expertise to this process.

Key Vulnerabilities and Risks

Fire Management

Washington has over 22 million acres of forested land, more than half of the total land area (DNR 2007). Approximately 44% of forest land is in Federal ownership, while 13% is in State and local ownership, and 43% in private (Campbell *et al.* 2010). Fire plays a critical ecological role in many of Washington's forest types, particularly in the fire-adapted dry forests east of the Cascades. However, over a century of fire suppression, extensive logging, and overgrazing have resulted in forest conditions in many areas that are currently at an increased risk of unnaturally severe and extensive disturbance from fire, insects, and disease (Hessburg and Agee 2003; Hessburg *et al.* 2005; Franklin *et al.* 2008). When such disturbances do occur, they can result in significant ecological, social, and economic impacts. For example, on average, $28 million is spent annually suppressing wildfires on state and private forestland in Washington (Cline 2010 *cited in* DNR 2010). However, the true costs of such wildfires in the western U.S. may be from 2 to 30 times greater than such estimates based solely on suppression costs (WFLV 2010), while it is impossible to accurately quantify the myriad adverse environmental and social impacts.

Anticipated Impacts

Excerpted from the WACCIA Executive Summary

Forest fires, insect outbreaks, tree species ranges and forest productivity are closely tied to climate. Profound changes in forest ecosystems are possible given the magnitude of projected climate changes. The combined climate change impacts on tree growth, regeneration, fire, and insects will fundamentally change the nature of forests, particularly in ecosystems where water deficits are greatest. Many impacts will likely occur first in forests east of the Cascade crest, but forests west of the Cascades will likely experience significant changes in disturbance regime and species distribution before the end of the 21st century.

- Due to increases in temperature and decreases in summer precipitation, the area burned by fire regionally (in the U.S. Columbia Basin) is projected to double or triple (medium scenario, (A1B)), from about 425,000 acres annually (1916-2006) to 0.8 million acres in the 2020s, 1.1 million acres in the 2040s, and 2.0 million acres in the 2080s. The probability that more than two million acres will burn in a given year is projected to increase from 5% (1916-2006) to 33% by the 2080s. Fire regimes in different ecosystems in the Pacific Northwest have different sensitivities to climate, but most ecosystems will likely experience an increase in area burned by the 2040s. Year-to-year variation will likely increase in some ecosystems.
- Due to climate related stress in host trees (e.g., lodgepole pine, ponderosa pine, western white pine, whitebark pine) mountain pine beetle outbreaks are projected to increase in frequency and cause increased tree mortality. Mountain pine beetles will reach higher elevations due to increasing elevation of favorable temperature conditions as the region warms. Conversely, the mountain pine beetle will possibly become less of a threat at middle and lower elevations because temperatures will be unfavorable for outbreaks. Compared to historical conditions, other species of insects (such as spruce beetle, Douglas-fir bark beetle, fir engraver beetle, and western spruce budworm) may be more successful depending on favorable climatic conditions and host-tree stress.
- The amount of habitat with suitable climate for pine species susceptible to mountain pine beetle will likely decline substantially by mid 21st century. Much of the currently climatically suitable habitat is in places likely to be less suitable for pine species establishment and regeneration, and established trees will be under substantial climatic stress. The regeneration of pine species after disturbance will likely be slowed, and may be infrequent in some locations.

- The area of severely water-limited forests is projected to increase by at least 32% in the 2020's, and an additional 12% in both the 2040s and 2080s. Douglas-fir productivity varies with climate across the region and will potentially increase in wetter parts of the state during the first half of the 21st century but decrease in the driest parts of its range. Geographic patterns of productivity will likely change; statewide productivity will possibly initially increase due to warmer temperatures but will then decrease due to increased drought stress. It is important to note that changes in species mortality or regeneration failures will possibly occur before the point of severe water limitation (annual precipitation is exceeded by summer potential evapotranspiration.

Significant uncertainty remains surrounding additional forest-related climate change impacts and the recommendations section of this document identifies specific areas of future research.

Existing Recommendations and Concurrent Efforts

On average, $28 million dollars is spent annually in the state to suppress wildfires on state and private lands (Cline, 2010). As mentioned earlier, as the region begins to see the impacts of climate change, the risk for more severe and more frequent forest fires is expected to increase. Managing wildfires must play a central role in Washington's climate adaptation strategy, as millions of acres and human property are at risk and will be at greater risk of being negatively impacted if it's not.

The impacts of climate change on Washington's forests have been recognized as a priority in other planning efforts in the state. It is the intent this group to build on existing work and, to the greatest extent possible, harmonizes recommendations with existing literature and concurrent efforts. This will help to ensure consistency and to provide policy makers with clear and concise paths forward. The following will provide brief summaries of existing work and efforts that are currently underway in Washington that have influence on the recommendations set forth in this chapter.

2008 Preparation and Adaptation Workgroups: "Leading the Way: Preparing for the Impacts of Climate Change in Washington"

Washington State has recognized the need to strategically plan for the impacts of climate change for some time. In 2008, multiple stakeholder groups were convened, led by the Washington State Department of Ecology, to develop a plan to prepare for the impacts of climate change. The final report, "Leading the Way: Preparing for the Impacts of Climate Change in Washington," in its chapter on forestry, provided a list of action items that the group identified as being effective first steps in preparing for the changes expected in Washington's environment.

The following, excerpted from the final report, provides a summary of the recommendations related to wildfire in Washington's forests:

> "The increased temperature and dryness, combined with widespread areas of dead or damaged trees due to insect infestations, and again combined with uniform and overcrowded forest conditions; make these forests vulnerable to the spread of large and/or severe forest fires. The high density of trees, especially dead or dying trees, contributes forest fuels that allow fires to burn hotter and spread farther more quickly. Recent large fires in Eastern Washington may be evidence of this trend, although large fires also burned in prior decades. Larger and more severe wildfires also emit more carbon dioxide into the atmosphere, which further worsens climate change. Carbon dioxide emissions from wildfires in Washington have been found to be significant compared to total emissions from fossil fuel burning in the state. Forest fires could also contribute to human health problems, primarily smoke inhalation, and to damage to houses and public facilities.
>
> 1. Forest health and fire strategy recommendations

- 1.1 Provide comprehensive data and information to landowners, policy makers, and the public about existing and developing forest health and fire hazard conditions.
- 1.2 Use new state authority to create forest health scientific advisory committees to assist decision-makers in responding to extreme forest health and fire hazard problems.
- 1.3 Fully fund and implement on-the-ground pilot programs.
- 1.4 Provide public financial and technical assistance to owners of small forestland parcels.
- 1.5 Implement an active communication and education strategy.
- 1.6 Foster a collaborative atmosphere across multiple jurisdictions, landowners, and stakeholders to promote agreement on forest health and fire hazard response approaches.
- 1.7 Improve coordination of regulatory requirements to remove unnecessary barriers while ensuring program objectives are being met.
- 1.8 Engage the private sector as a partner through market and investment opportunities."[1]

DNR's Strategic Plan 2010-2014: The Goldmark Agenda

The Department of Natural Resources launched its 2010-2014 Strategic Plan in April 2010. In the plan, climate change is identified as a major area of focus for the agency's work over the next number of years. A major goal of the plan (Goal V) is to "develop renewable energy resources on state lands, address climate change, and create renewable energy jobs." In the first year of the plan, the agency is tasked with developing a climate change adaptation strategy. As part of this effort, the plan identifies that the following outcomes be achieved:

1. Develop staff education efforts regarding scientifically sound adaptation information and priorities in partnership with university and other scientists.
2. Participate in an integrated monitoring program with other entities and identify the most vulnerable situations and trigger points for change in management actions.
3. Incorporate climate change adaptation considerations in all relevant agency programs, including attention to ecological interactions, species genetics and adaptiveness, migration pathways, response to major disturbance events, and management of human infrastructure.
4. Coordinate with other state and federal agencies, tribal governments, and private organizations to develop a statewide and/or broader climate adaptation strategy.
5. Link climate adaptation strategies in eastern Washington with the renewable biomass initiative.

These goals are an overlay to the existing fire and emergency response obligations. The department manages the largest on-call Fire Department in Washington and implements an active Forest Health program to respond to forest health crises (with a focus on Eastern Washington).

Statewide Forest Resource Assessment and Strategy for Washington State

The 2008 Farm Bill required state forestry agencies, if they are to continue to receive certain assistance funding for forest landowners, to conduct a Statewide Assessment and Forest Resource Strategy. The strategy, per direction in the Farm Bill, was to be comprised of three components: Statewide Assessment of Forest Resources, Statewide Forest Resource Strategy, and an Annual Report on Use of Funds. The Department of Natural Resources completed their assessment and strategy in June 2010.

[1] "Leading the Way: Preparing for the Impacts of Climate Change in Washington." Preparation and Adaptation Workgroup, 2008.

The assessment and strategy identify six major issues for forestry in Washington State, and cite climate change as a significant threat to all of them. Wildfire hazard reduction and forest health restoration are central among the assessment and strategy issues. Three categories of forests have the greatest risk of wildfire: eastern Washington dry forests; mountain gap wind zones; and the San Juan Islands. As policies and programs are developed to address the wildfire impacts a changing climate is certain to have, it will be important to focus those efforts on the region's most vulnerable to the impacts. For example, from among the nearly 9 million acres of forested land in eastern Washington, 6.2 million are at moderate or high departure Fire Regime Condition Class. When these areas experience wildfire in the future, fires have a greater potential to be large and severe – so much so that key ecosystem components may be lost altogether.

The assessment provides a number of "opportunities" for work to address the challenges posed by wildfires, challenges that will only increase as climate change impacts continue to be seen across the state. The opportunities outlined in the assessment include:

- Improve fire prevention and suppression.
- Protect, assist and educate populations in the wildland-urban interface.
- Reduce fuel loads in Eastern Washington forests.
- Restore ecological integrity, appropriate density, structure and species composition to overstocked Eastern Washington forests.
- Integrate fuel reduction activities with forest health improvement actions.
- Partner with multiple landowners and managers to achieve landscape-scale forest health and restoration objectives.
- Use prescribed fire to restore and maintain fire-resistant stand conditions.
- Maintain and develop forest markets and infrastructure.

Over a five-year time horizon, the strategy focuses core funding for wildfire hazard reduction projects in the Spokane-area, Upper Yakima, Wenatchee, Entiat, Chelan and Okanogan watershed resource inventory areas (WRIAs). Forest health restoration work will be focused in the Colville, Lower Spokane, Middle Lake Roosevelt, and Kettle WRIAs.

The strategy also cites opportunities to expand the application of forest restoration concepts and piloting forest treatment prescriptions aimed at climate adaptation. Revisiting and adapting treatment design on an ongoing basis to insure that the desired outcomes are still being achieved is another strategic provision.

A critical data gap identified throughout the assessment and strategy's discussion of climate change threats is the need for broad-scale vulnerability analyses that can guide managers toward forests that are likely to experience the most dramatic changes.

USFS Climate Change Activities

The Washington Office of the US Forest Service recently sent out for review a draft Strategy for responding to climate change. The vision of this strategy looks a future in which:

- ➢ Forests Grasslands and human communities that depend on them successfully adapt (within their capabilities) to the changing climate.
- ➢ Through management and collaborative efforts with partners, forests and grasslands help to mitigate global climate change.
- ➢ New scientific findings, tools and technology increase our understanding of climate change impacts, adaptation and mitigation options and the risk of uncertainties that accompany our choices.

- New and stronger partnerships are forged that address climate change issues related to forests and grasslands.
- Citizens are knowledgeable about climate change and its impacts on ecosystems and landscapes important to them. They are prepared to participate in decisions and actions affecting landscapes that include their regions and grasslands.

In order to achieve this vision the agency is looking at specific objectives in three specific focus areas:

1. Assess current risks, vulnerabilities and gaps in knowledge and policies.
2. Engage internal and external partners to seek solutions.
3. Manage for resilient ecosystems, including associated human communities, through adaptation and mitigation strategies.

Region 6 of the Forest Service, which includes both Oregon and Washington, is working together with the Oregon and Washington BLM to develop:

1. A business needs assessment to determine gaps in knowledge related to climate change issues.
2. Prioritized actions needed for the respective agencies to address climate change. These actions include research priorities that develop tools for projecting changed fire regimes for ecosystems that occur across Oregon and Washington.

Information for this section comes from US Forest Service Draft Paper "US Forest Service Strategy for responding to climate change" dated April 22, 2010 and from an internal draft Climate Change Business needs assessment dated April 15, 2010.

Firewise (NWCG)

Firewise is a program sponsored by the National Wildfire Coordinating Group (NWCG).[2] Members of the NWCG are responsible for wildland fire management in the United States. They represent the USDA-Forest Service, the Department of Interior, the National Association of State Foresters, the U.S. Fire Administration and the National Fire Protection Association. The NWCG's Wildland/Urban Interface Working Team directs the Firewise program. In Washington State, the program is administered through DNR. Several local conservation districts implement Firewise activities with landowners in their district area.[3]

The national Firewise Communities program is a multi-agency effort designed to reach beyond the fire service by involving homeowners, community leaders, planners, developers, and others in the effort to protect people, property, and natural resources from the risk of wildland fire - before a fire starts. The Firewise Communities approach emphasizes community responsibility for planning in the design of a safe community as well as effective emergency response, and individual responsibility for safer home construction and design, landscaping, and maintenance. Currently, there are 44 recognized Firewise Communities in Washington State and many others across the state working toward the same goal.

National Fire Plan Cohesive Wildfire Management Strategy

In 2010, the U.S. Congress required the U.S. Forest Service and Department of Interior to submit a report that contains a cohesive wildfire management strategy. The strategy is being updated from prior versions in an effort led by the Wildland Fire Leadership Council, an intergovernmental committee of Federal, state, tribal, county, and municipal government officials convened by the Secretaries of the Interior, Agriculture, and Homeland Security dedicated to consistent implementation of wildland fire

[2] For more information, visit http://www.firewise.org/ Site last visited July 13, 2010.
[3] For one example, see http://www.skagitcd.org/firewise Site last visited July 13, 2010.

policies, goals, and management activities across jurisdictions. The strategy will provide oversight to ensure policy coordination, accountability, and effective implementation of Federal Wildland Fire Management Policy and related long-term strategies to address wildfire preparedness and suppression, hazardous fuels reduction, landscape restoration and rehabilitation of the Nation's wildlands, and assistance to communities.

The law requires that the strategy address:

- Reducing wildfire costs, losses, and damages.
- Reinvesting in non-fire federal programs.
- Assessing risk to communities.
- Appropriate wildfire responses, such as decisions about when and whether to take full suppression actions as opposed to letting fires burn for resource benefit.
- Prioritizing wildfire fuels reduction product funding.
- Assessing impacts of climate change.
- Study effects of invasive species.

Genetic Preservation and Development Background

Excerpted from the WACCIA Executive Summary

2.2. Climate and Changes in Species Biogeography

We assessed the potential for climate to alter important PNW tree species distributions by using spatially explicit projections from recently published analyses of climate and species responses for western North America (Rehfeldt et al., 2006). Specifically, we were most concerned with the potential for climatic stress on regeneration or mortality in Douglas-fir forests and the potential for stress in three species susceptible to the mountain pine beetle (lodgepole pine, *Pinus contorta*; ponderosa pine, *Pinus ponderosa*; and whitebark pine, *Pinus albicaulis*) in the PNW. Other species range changes are also important, but a full assessment is beyond the scope of this project. We focused on Douglas-fir because it is widespread and economically important and on the pine species because of their potential for interaction with the mountain pine beetle, particularly in forests east of the Cascades. For each species, we used Rehfeldt et al. (2006) grid maps of potential future habitat based on climate and combined these to develop summary maps of areas where climate is likely to exceed Rehfeldt et al.'s (2006) estimates of the tolerances of Douglas-fir. We used a similar approach to assess areas of change in pine species richness for the end of the 2040s-2060s (Rehfeldt's analyses are for the 2030s and 2060s). After Rehfeldt et al. (2006), we assumed that areas with $\geq$ 75% agreement among statistical climate/species models represented climatic conditions where the species was likely to occur. We assumed that areas with < 75% but $\geq$ 50% agreement were potential areas of future occurrence but where climatic variability might put the species at some risk, and we assumed that areas with <50% agreement were unlikely to have sustained climatic conditions appropriate for species persistence and regeneration after disturbance.

3.2. Climate and Changes in Species Biogeography

By the end of the 2060s, independent species range modeling based on IPCC scenarios (a medium emissions scenario for both HadCM3 and CGCM2, Rehfeldt et al. 2006) suggests that climate will be sufficiently different from the late 20th century to constrain Douglas-fir distribution (Figure 5). This is probably due to increases in temperature and decreases in growing season water availability in more arid environments (e.g., in the Columbia Basin) but could be due to other variables in less arid parts of the species' range. About 32% of the area currently classified as appropriate climate for Douglas-fir would be outside the identified climatic envelope by the 2060s, and about 55% would be in the 50%-75% range of marginal climatic agreement among models. Only about 13% of the current area would be climatically suitable for Douglas-fir in >75% of the statistical species models. The decline in climatically suitable habitat for Douglas-fir is most wide-spread at lower elevations and particularly in the Okanogan Highlands and the south Puget Sound / southern Olympics.

Climate is likely to be a significant stressor in pine forests in the Columbia Basin and eastern Cascades as early as the 2040s, particularly in parts of the Colville National Forest, Colville Reservation, and central Cascades (Figure 6). Of the area that is climatically suitable for at least one pine species, only 15% will experience climate consistent with no net loss of species; 85% will be outside the climatically suitable range for one or more current pine species (74% loss of one species, 11% loss of two species, <1% loss of three species).

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The following, excerpted from the final report, provides a summary of the recommendations related to "genetic preservation and development" in Washington's forests:

> "Projected 21st century changes in temperature and precipitation will affect forests differently depending on their elevation and proximity to the coast. The main impacts will be changes in tree growth, changes in establishment and regeneration, changes in disturbance regimes, and eventually, changes in species composition and range. Some of these impacts have already been observed and are consistent with observed increases in temperature.
>
> Increased summer temperature may lead to non-linear increases in evapotranspiration from vegetation and land surfaces. This effect would be worsened by possible decreases in growing season rainfall. Lower water availability, in turn, would decrease the growth, vigor, and fuel moisture of lower elevation forests (e.g., ponderosa pine, Douglas-fir and western hemlock) while increasing growth and regeneration in high elevation forests (e.g., subalpine fir, Pacific silver fir, and mountain hemlock).
>
> Higher temperatures would also affect the range and speed up the reproductive cycle of climatically limited forest insects such as the mountain pine beetle. Other insects and pathogens, whose northern or elevation ranges were previously limited by temperature, can be expected to expand northward and upslope. Lower water availability also increases the vulnerability of individual trees to insect attack. Higher temperatures or lower summer rainfall would likely increase the area burned by fire and fire frequency in both eastern and western Washington. Mountain Pine Beetle outbreaks in British Columbia and Idaho have resulted in large and possibly unprecedented landscape-scale mortality of forests. Fire severity may also increase, depending on site-level fuel characteristics.
>
> The distribution and abundance of plant and animal species will likely change over time, given that paleoecological data show their sensitivity to climatic variability. This change may be difficult to observe at local scales or in short time frames, except in cases where large-scale disturbances such as fire, insect outbreaks, or windstorms have removed much of the overstory, thereby "clearing the slate" for a new cohort of vegetation. The regeneration phase will be the key stage at which species will compete and establish in a warmer climate, thus determining the composition of future vegetative assemblages and habitat for animals.

3. Species physiology, ecology, and distribution strategy

_ *3.1. Focus initially* on both commercial and non-commercial forest tree species.

_ *3.2. Develop a better understanding* of likely impacts of climate change on tree species and evaluate strategies to minimize or adapt to those risks.

_ *3.3. Keep forestland managers*, policy makers, and the public informed with the current state of knowledge and the range of adaptation strategies being considered.

4. Commercial timber management strategy

_ *4.2. Improve scientific research* into commercial tree species' physiological responses to climate change.

_ *4.4. Implement a genetic* conservation program.

5. Protected areas and habitat strategy

_ *5.1. Complete a vulnerability* assessment to identify species, habitats, landscapes, ecosystem functions, and cultural resources that may be most sensitive to climate change.

_ *5.4. Attempt to maintain* dominant native tree and shrub species, and promote species and stand structural and landscape diversity.

_ *5.7. Develop guidelines for experimental translocation* of individual species or genetic material in special circumstances."

Water Availability Background Information

Demand for water for municipal and industrial use, and for food production, is increasing rapidly as the world population and affluence grows, despite limited supplies of potable water. At the same time, climate change is affecting water supplies, food production and population distribution globally. Within this context, water availability in the Western United States is becoming a critical issue. Shifts in population, have created new demands for water to service municipal, industrial, agricultural, and environmental needs. The problems in fulfilling these needs are becoming more acute due to the current and potentially future effects of climate change. In Washington State it is estimated that over 5,700 Mgal/d of water is used with more than 60 percent used for irrigation purposes [1].

Surface water provides 74 percent of the irrigation water used by the state's agricultural lands, compared to 26 percent from groundwater sources [3]. This water is utilized to irrigate large tracts of agricultural lands throughout the central and eastern part of the state and is critical to the future of Washington's high value fruit and vegetable production. Likewise the slow melt of winter snows provide Washington's forest with adequate water to maintain healthy stands of economically valuable trees and supports the eco-system necessary to ward off attacks of pests species that destroy the value of the forests.

Climate change has been evident for decades and we are already adapting to its changes. Reduced snowpack, droughts and floods are becoming more frequent. This trend is predicted to continue and the impacts, environmental and economic, will be greatest on Washington's working lands, especially the agricultural lands of eastern Washington. At the same time, growing demand by other water users - municipal, industrial, recreational, and environmental – will further exacerbate water shortages. Innovative solutions to preserve adequate water supplies and adapt to reduced supply brought about by increased demand and climate change is critical and should begin immediately. The competition for water for working lands will have to be balanced with those of municipalities facing a growing population. Finally, predicted changes in climate will likely increase the risks of flooding and landslides due to higher intensity storms during winter months damaging both prime agricultural and forest lands.

Preparation and adaptation activities are generally easier to develop and implement for agricultural lands than for managed forests. Several reasons for this exist. Water delivery systems on most agricultural lands are highly managed and can be relatively easy to control. The vast majority of high value crops are grown within the confines of irrigation districts or systems which are designed to distribute water at metered amounts. Reservoirs can be lowered or raised during the year in anticipation of the upcoming seasons water needs. At least on a temporary basis alternative sources of water can be obtained (i.e. groundwater sources, leasing of water rights). Some flexibility exists to change the crop grown to accommodate anticipated water availability.

Preparation and adaptation measures for dryland agriculture and managed forests are inherently more difficult to develop and implement due to the lack of "control" that can be exercised over the available water and inability to quickly modify the species grown in working forests. The impacts from increasing temperatures and decreased water availability to forests and dryland areas have the potential for more lasting impacts [4]. Such is the case with impacts caused by spruce and pine beetle infestations in the Western United States. These infestations are likely the direct result of climate changes that result in prolonged periods of stress for the trees coupled with enhancement of conditions favorable to the life cycle of the beetle. Unlike, managed agricultural systems, the recovery period for these forests is measured in decades instead of years.

While there are inherent difficulties in exercising the degree of "control" over dryland and working forests employed in other working lands, improvements or modifications to management techniques can help to address some of the predicted challenges faced within this area. Suggestions regarding forest management and fire prevention (addressed in an accompanying white paper) can lead to a maintenance or even improvement in both water quality and quantity within the watershed and downstream users. Increased focus on forest diversity coupled with actions that modify species will also result in healthier forests and improved water quality.

Impacts of Climate Change

Washington's working lands rely heavily on natural water storage in the form of snowpack in the Cascade and Olympic Mountains and higher elevations in the north central part of the state. In years where normal snowpack is achieved, Washington's current water needs are met. Total precipitation is not expected to change significantly; however, assuming the predictions of snowpack decline are accurate we can expect snowpack reductions of to 27 – 29 percent in the 2020s to upwards of 53 -65 percent in the 2080s. Combined with predicted increases in annual runoff [2] the state may be faced with regular shortages exceeding those experienced in droughts of the 1970's and 1980's. Given these conditions Washington's working lands can expect less water in the late spring and summer for forests, farms, in-stream flows and urban uses.

Climate change predictions from the University of Washington Climate Impacts Group indicate that while Washington may expect little to no overall change in the amount of precipitation received during the 2020 – 2080 period, how that precipitation is received (rain or snow) is expected to change dramatically. This coupled with the expected demand from population growth (4 percent per year through 2030 [2], or 10 million people by 2050) stresses the need to begin planning for adequate water supplies for all sectors relying on the resource.

In previous work conducted by Washington State's Climate Action Team (2007) several assumed impacts were identified as result of changes in water supply due to climate change. They are generally the result of increases in predicted temperatures which will result in significant modifications to seasonal precipitation patterns and increased drying during the summer. Currently, predictions regarding the overall annual precipitation indicate only small changes in quantity trending towards more rainfall in the winter months and less during late spring and summer periods. These predictions are anticipated to result in:

- Less snowpack to supply water to Washington users during the growing season. An increasing large proportion of winter precipitation will fall as rain instead of as snow, leaving less water stored in snowpack for the dry months.
- More frequent, extreme and persistent drought conditions.
- Higher intensity rainfall events, especially in Western Washington resulting in an increase in the frequency of winter/fall flood events.
- River and streams experiencing extended periods of low-flow conditions resulting in higher temperatures and concentrations of contaminants making violations of water quality standards more common.
- Reduced soil moisture and increased evaporation in non-irrigated agriculture and forest areas increasing the need for water or drought tolerate crops and increasing the risks of fire.
- Increased irrigation requirements if current crop patterns are to be maintained and crop losses are to be avoided.
- Increasing conflicts between water users (agriculture, industry, municipal, domestic, and in-stream flow) are to be expected as the demand for water increases.

Given the assumption that in many parts of the state the demand for water already exceeds available supplies, it is reasonable to expect that the competition for water will continue to increase (regardless of the effects of climate change). In order to develop strategies that address the increases in demand across all sectors it will be necessary to closely examine those assumptions regarding the states available water resources.

There is general agreement as to the storage capacity currently available in Washington State impounded reservoirs (16, 25 million/acre-ft)[4]. The estimated need for additional storage can be easily determined if the available resource only existed in surface water storage. The great unknown in the water availability equation is the current and projected abundance of groundwater that can be sustainably and economically utilized. Without a technically robust statewide study to determine what is and what is not available in the state aquifers, any climate adaptation strategy will have to, by necessity, be based upon known surface water storage capacity coupled with an assumed groundwater availability factor. If it is determined that assumptions surrounding groundwater availability is unacceptable, then a major recommendation of any climate adaption strategy related to water resources should include complete cataloguing of Washington's groundwater resources.

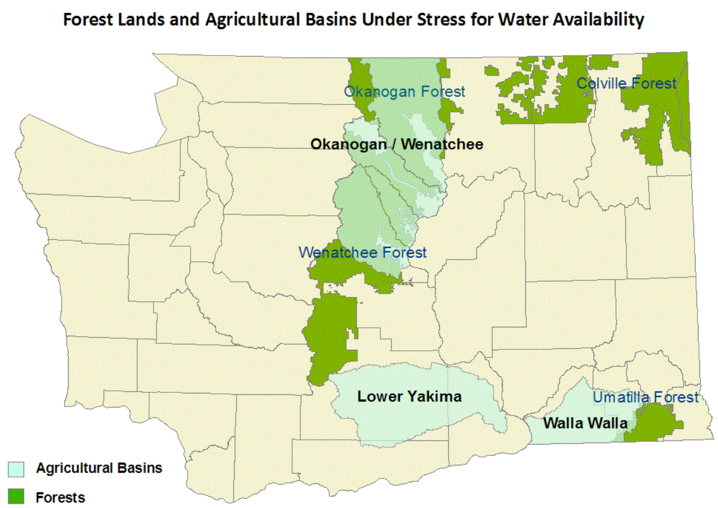
Vulnerabilities Related to Drought and Climate Change

Washington State has experienced multiple droughts since the early 1970's that have had profound effects on the state's working lands and highlighted vulnerabilities in these sectors. It is anticipated that what have been historic 50-year droughts will now occur every 10 years and what have been historic 10-year droughts will now occur about every 2 years. This being the case, it is prudent to examine how the state has addressed recent reoccurring droughts in order to begin to develop more long term actions for predicted changes in water availability as a result of climate change and the increasing demands for water.

Previously when droughts have been declared, the areas of the state most affected, from an agricultural perspective, are those snow dependant watersheds where much of the snow occurs at lower elevations. These are particularly vulnerable to warmer winter temperatures. These basins predominately are used to raise high value, water intensive crops such as tree fruit and vegetables. These areas are the Yakima Basin, and the Walla Walla and Okanogan/Wentachee River watersheds. Remedies have focused on how to maximize water availability in those areas by use of emergency permits allowing groundwater

[4] Doug Johnson, P.E., Dam Safety Supervisor, Washington State Department of Ecology

withdrawals, short term water leasing, or temporary modifications to existing water rights in order to make more water available for users for that current growing season. While these actions have addressed immediate needs, they are inadequate solutions for the more permanent changes in water availability predicted as a result of climate change.



The short and long-term effects of drought on state, federal or private forests can be forecasted by examining the results of previous droughts. Reduction in precipitation has resulted in increased vulnerability of forests to fire during the dry periods of the year. Forests in the central and eastern parts of the state are generally more vulnerable to fire than those in the western part due to lower precipitation and greater evaporation in summer which reduce soil moisture and humidity. Because of the added stress drought and reduced rainfall has on forests, populations of pests such as the Mountain Pine Beetle have begun to flourish in forests on the east side of the Cascades.

In order to begin to address longer term issues regarding water supply, it will be necessary to look beyond the effects of a year or two and factor in the increasing demands of other water users such as municipal, industrial, and environmental needs. The agricultural Preparedness and Adaptation Working Groups (PAWGs) for agricultural and forestry, in 2007 began to address some of the fundamental needs for working lands as those needs apply to water availability. The major recommendations from the Agricultural PAWG centered on the need for additional water storage facilities, improvements in water conveyance and delivery systems, and increased focus on water conservation activities.

The forestry PAWG recommendations focused on the need for additional research and information sharing related to potential changes in watershed characteristics due to climate change (increased temperature and changes in hydrologic response due to changes in precipitation patterns). In reviewing the recommendations for each PAWG it is clear that the starting line for developing recommendations for agricultural and forestry working lands is significantly different.

Discussion of Solutions to the Water Resource Dilemma

In 2007 the Preparedness and Adaptation Working Groups for agriculture, forestry and water resources developed numerous recommendations that were designed to facilitate discussions regarding overall water management in Washington given the predictions of the Climate Impacts Group. These recommendations generally fall into three categories consisting of:

- Development or modification of infrastructure
- Conservation practices and improvements in water use efficiency
- Modification of laws, regulations, and policies related to water allocation and management

In order to develop a comprehensive water management plan/strategy that addresses climate change predictions and forecasted water resource needs, elements within all three categories must be made part of the plan. Depending upon the area of the state being considered, one or more of the categories may have a greater impact than the others. For example, within the Columbia Basin there may not be as great a need for development or modification of infrastructure as there is likely to be within the Yakima Valley. Likewise, the need for conservation practices and improvements in water use efficiency may not be as critical in the Skagit Valley as is regulation or policy reform related to water resources.

Development or Modification of Infrastructure

Generally, there are four means by which to store water for use on working lands. They are large scale reservoirs, small scale reservoirs, underground in aquifers, and within the soil column. To some extent all these methods are currently in use or are being proposed in Washington State. The need for additional storage whether it is man-made or natural and the mechanisms by which to transport water from storage facilities to points of use have been a staple of water resource and climate change planning for some time. Given the volume of water storage needed to offset snowpack losses, a combination of many large, small and micro- storage structures will be needed.

<u>Water Storage and Retention Structures</u>

Development of New Structures

Traditionally water resource management discussions have centered on the development of large scale reservoirs capable of multi-year drawdown and located off-stream within semi-closed basins. These divert water from major rivers during times of high flow and release it during low flow periods. During the past several decades these types of projects have hit major stumbling blocks due to the high costs of planning, siting, development and operation. For example, the proposed 1.3 million acre-ft Black Rock Reservoir near Yakima is predicted to cost $5.6 billion (YBSA, 2007). In addition to the high costs of these projects, concerns over environmental impacts, especially to water quality and fish habitats, have stalled development of new large scale projects [6], [7].

Smaller scale projects (generally those that refill each year) are currently being investigated, such as the Wymer Reservoir. This has an estimated cost of $380 million with a storage capacity of 320,000 acre-ft. While these projects have many of the same negative issues associated with larger scale projects, the development costs (generally 25 percent of large scale projects) and overall environmental impacts are deemed to be significantly less and therefore manageable. New on-stream reservoir projects have generally fallen out of favor due to the negative impacts on fish habitats and water quality.

Modification of Current Structures

As the costs (both financially and environmentally) increase for new water storage projects, modification of currently existing facilities may be an option. Generally these modifications raise the level of currently existing retention structures to increase storage capacity. In other areas of the West, modest increases in the heights of existing dams, mostly dual purpose dams supplying both irrigation hydroelectric production, are being considered. Depending upon the reservoir size, just 5 to 10 foot increases in dam height can significantly increase storage capacity at minimal cost while limiting siting concerns and additional impacts on downstream ecology. It is unclear to what extent how many existing retention structures in Washington State would be candidates for modification; however, this may prove to be an option worthy of further investigation and study.

On-Site Storage

In addition to large storage facilities, significant amounts of water can be stored on the farm for use by the farmer. These can be filled from natural precipitation or from irrigation supplies when demand is low and then used to supplement irrigation and natural precipitation during the growing season. These usually have limited environmental impact and are subject to permits by the WDOE. Many farms have already created storage ponds, and individually they may only store a few acre-feet, widespread adoption of on-site storage could significantly add to total storage capacity.

Use of Natural Structures

Another small/micro storage alternative is the use and management of beaver ponds. Like snow, these collect water which is then slowly discharged throughout the year. These are gaining the interest of researchers and water managers as important tools in maintaining water quality and quantity in streams. They are often in the upper regions of water sheds where they hold and release water allowing intermittent and ephemeral stream to flow longer and at a more constant rate which benefits forests as well as agricultural lands. Beaver ponds have many other environmental benefits as traps for sediment which reduce pollutant loads and siltation of spawning areas and provide habitats for many animals and plants. These ponds provide known benefits to the forest sectors and currently some limited benefits to the agricultural sector such as the cranberry growing areas on Washington's coast. Natural retention structures such as beaver ponds are not a total solution to the water availability issues envisioned for the future, but they may provide to be a solution in small watershed with limited working lands [7].

Forest management can influence both water quality and quantity. Maintaining forest health and reducing fire potential allows the forests to store water, reduce sedimentation and improve oxygenation and mineral removal within to the watershed. Healthy, diverse forests also reduce runoff and improve water holding capacity of the soil to recharge shallow aquifers. This improves the ability of the soil and aquifers to act as natural "reservoirs" which allow for the measured release of water to streams and lakes over the course of the year and reduce the potential for downstream flooding.

<u>Aquifer Storage and Recovery Projects</u>

Aquifer storage and recovery (ASR) is a proven technology for water management. It allows for the same management potentials as surface water storage without many of the negative issues, such as flooding natural habitats. In an ASR project surface spreading, infiltration pits and basins, and/or injection wells are used for recharge the aquifer during periods water availability or low demand. When needed, water is pumped from wells to irrigate crops or for other uses. Water can be stored in suitable aquifers or in other suitable geologic formations to form large subsurface reservoirs. These generally have little water loss due to very low evaporation, transpiration, seepage or contamination. The potential for ASR projects in Washington State is significant. It is estimated that 60 percent of the state is underlain by aquifers capable of yielding at least 50 gallons/minute; at least 50 percent of those aquifer may be suitable for use for ASR [8]. Aquifer storage wells are regulated in Washington State under the Underground Injection Control Rules, Chapter 173-218 WAC.

Table One: Comparison of Various Storage Options

	Groundwater Storage	Small Surface Water Reservoirs	Large Dam Reservoirs
Advantages	Little evaporation loss Siting close to use Operational efficiency Available on demand Water Quality	Ease of operation Responsive to rainfall Multiple use Groundwater recharge	Large, reliable yield Carryover capacity Low cost per volume stored Flood control and hydropower Groundwater recharge
Limitations	Slow recharge rate (infiltration) Potential groundwater contamination Cost of pumping (retrieval) Recoverability < 100%	High evaporation loss fraction Relatively high cost per acre/ft Absence of over-year storage	Complexity of operations Siting issues High initial investment costs Long planning and development time Environmental impacts

Key Issues	Declining water levels Rising water levels Management of access and use Groundwater salinization Groundwater pollution	Sedimentation Dam safety Environmental impacts	Social and environmental impacts ESA issues Sedimentation Dam safety

Conservation Practices and Improvements in Water Use Efficiency

Water use conservation in the agricultural sector generally consists of one or more of the following main elements:

- Increased crop water use efficiency
- Improved irrigation application efficiency
- Decreased crop consumptive use
- Increased delivery efficiencies
- Reduced water use through adoption of conservation measures and new technologies for water management

Water conservation practices have been steadily on the increase within the agricultural sector over the last 25 years. Practices such as irrigation scheduling, tail-water return systems, and irrigation system improvements have stabilized water consumption at approximately 3.4 ft for each acre of irrigated land. Livestock consumption has stabilized at approximately 30 Mg/d [9]. The overall value of irrigated crops in Washington State was placed at $2,295.91 per acre by the USDA in 2007, with 1.67 million acres of irrigated farmland existing in the state.

Improved water use efficiency in its simplest form means reducing the water needs to achieve a unit of production in any given activity. Water use efficiency includes any measure that reduces the amount of water used per unit of any given activity, consistent with the maintenance or enhancement of water quality. The increasing cost of water recognized through either surface distribution systems or lifting via groundwater pumping are and will continue to stimulate adoption of conservation practices and improvement in use efficiency. In the area of water conservation and efficiency improvements (within the agricultural sector) two opportunities exist:

- Regional delivery systems
- On-farm irrigation methods

<u>Regional Water Delivery Systems</u>

Washington has thousands of miles of canals, pipes and ditches, some dating back to the late-1800s that distribute water from its source to individual farms and other users. These regional delivery systems have been significant sources of water loss either through unlined irrigation canals or reservoirs/canals that remain open and subject to evaporation. Water losses of 30-40 percent occur in some systems due to leakage and evaporation which can have significant impacts to overall water delivery. [10]. This represents a significant loss of water for agricultural production in Washington State.

Systems can be improved by re-routing canals, lining and covering canals and ditches, and/or replacing these with pipes. The costs associated with delivery system improvements, while substantial, can provide income recovery in excess of the initial improvements within a relatively short period of time. In most cases it is more practical to consider lining or piping of the canal system rather than covering. Reducing the leakage from unlined distribution system have can reduce loss by up to 25 percent in medium to large unlined system.

Canal rehabilitation to improve delivery efficiency can have unintended consequences. Leakage can be a primary source of recharge to the underlying aquifer, such as in the upper Tieton Basin in Yakima County and through the lower areas of the Columbia Basin Irrigation Project. Lining of the canal system, especially in the Tieton Basin, has lowered water levels in wells for irrigation and domestic water. This has resulted in a "shifting" of costs from the irrigation district to the private land owner who depended upon the canal leakage as a source of groundwater.

On-Farm Irrigation Methods

Once the water is delivered to the farm, the farmer has control over water efficiency – mostly by the selection and use of water delivery systems (i.e. sprinklers, ditch, micro-sprinkler etc.) and irrigation timing. Depending upon the method for delivering water to the crop efficiencies can improve from 60 to 95 percent, thus resulting in significant savings of water.

Table Two: Range of Application Efficiencies for Various Irrigation Systems
From Irrigation Management Series-Kansas State University MF-2243, May 1997

System Type	*Application Efficiency Range*
Surface Irrigation	
Border	60 – 95%
Furrow	60 – 90%
Surge	60 – 90%
Sprinkler Irrigation	
Handmove	65 – 80%
Traveling Gun	60 – 70%
Center Pivot & Linear	70 – 95%
Solid Set	70 – 85%
Micro-Irrigation	
Point source emitters	75 – 90%
Line source emitters	75 – 95%
Sub-Surface Drip	80 – 95%

Generally, higher efficiency systems are more expensive and may be impractical for some crops given the current cost of water and energy. As water becomes scarcer and prices escalate These systems will become more practical. Some of these more efficient systems may be in conflict with designs of current irrigation systems (those that have been designed based on old technologies such as the Columbia Basin system).

Irrigation timing based on soil moisture and crop needs is a second method that, used by itself or with improved water delivery technologies, can conserve water and improve efficiency. In Washington State a significant effort to integrate irrigation timing has been employed in the Columbia Basin Groundwater Management Area. Installation of moisture monitoring equipment has been installed on approximately 400,000 irrigated acres with a goal of eventually having 800,000 acres under irrigation water management technologies.

These methodologies can be developed to suit the specific crop and irrigation method employed and are developed and implemented in conjunction with the local conservation district assistance. To date it is estimated that irrigation use has declined 20 percent while crop yield has increased.

Again, implementation of improved on-farm irrigation methods will generally reduce infiltration to shallow aquifers. These may currently supply domestic water to the farm and neighbors who are not connected to public water supply systems. This may result in areas experiencing shallow water level declines. Additionally, reducing the water applied must be accompanied with complementary changes in nutrient application to avoid the build-up of salts within the soil and reduction of crop productivity.

Other Freshwater Alternatives

As demands for water increase, they are likely to exceed the quantities of water available for human use. As demand approaches supply, alternatives that are not currently feasible many become realistic options. For example, many of the current water conservation efforts and restrictions on water use are intended to increase stream flows and improve habitats for fish and other organisms, especially during critical periods (i.e., spawning, downstream migration, etc.). However, when the river meets the ocean these functions are complete. Theoretically, fresh water could then be removed near river mouths and pumped back upstream for irrigation and other human activities without adversely affecting fish. Similarly, desalinization of saltwater near coastal communities may provide potable water for municipal use, freeing up other water for agriculture or habitat use. Again, these types of water projects may not now be feasible or acceptable, but the increasing demand for a limited freshwater resource will force consideration of a variety of alternatives that now sound like science fiction.

Modification of Laws, Regulations, and Policies Related to Water Allocation and Management

Water availability for Washington working lands is already under pressure due to urban and commercial demands. This pressure is likely to increase as climate change puts further stress on the available water resources existing within the state. Rights originally issued to assure the development of the agricultural base in the state have gradually been shifted to satisfy the needs associated with urban and commercial development and federal laws stressing the need for improved protections for endangered species. Water law in Washington allows for some shifts in beneficial use in order to meet the demands of a changing society; however, in order to meet these demands and preserve the vitality of Washington's working lands modifications to how water is allocated and managed needs to be strongly considered.

Water law in Washington and western water law in general pose challenges for water development of measures to insure future availability. The requirement to perfect a water right and demonstrate continued beneficial use is a significant obstacle to implementing water conservation and efficiency measures in the agricultural sector. For example, programs that assist agricultural water users in implementing irrigation water conservation measures will generate water for municipalities while enabling irrigators to continue in business using less water. However, the "use it or lose it" doctrine discourages these innovations because it declares that water saved through efficiency measures is not available to the irrigator or to the provider helping to conserve. Thus, no one presently has the incentive to conserve irrigation water use. There is promise that these supply-side efficiency measures can develop water at a fraction of the cost of new, large conventional supply facilities.

In order to address this issue the Washington Department of Ecology has attempted to implement water banking programs which would allow holders of large rights (in Eastern Washington that generally means an agricultural interest) to set aside some portion of that right for temporary use by others or to enhance in-stream flows for environmental interests. While that provides a temporary solution to the water availability issue it does not address long term questions that will arise if at some time the holder of that right wishes to reclaim the portion that has been banked.

<u>Water Markets and Transfer Banks</u>

With climate change and increasing populations the main influence dictating the price of water will be scarcity. As already mentioned, new water supply projects can minimize or eliminate scarcity, but an additional method is the creation of a water market to set the price more efficiently which will improve the way water is used. Development and implementation of a water market should help to stretch the state's water resources and encourage greater sharing of currently allocated water. Creation of a water market or markets to facilitate such transfers whether permanently or for a time specific duration is essential to providing the means for such resource sharing. Washington has created the framework for a water banking system, but this system must be modified, eliminated and/or supplemented by another to obtain the level of capability needed.

There are currently a number of issues that impede the development a single water market, even at the local scale. These mostly relate to differences in groundwater and surface water access entitlements and their administration. In particular there are currently frequent incompatibilities in:

- Definition and relative securities of surface water and groundwater entitlements;
- Cost structures;
- Ownership of infrastructure;
- Physical capacity of infrastructure to deliver water to where it is to be used;
- Reporting and monitoring;
- Management plan objectives (i.e. between groundwater plans and surface water plans);
- Institutional administrative structures;
- Understanding of flow dynamics and dependent ecosystems.

Other states have developed private sector water banking networks. These range from totally private willing seller-willing buyer scenarios to state operated networks akin to the Washington system. Water markets can provide unique ways of dealing with scarcities of water, such as through dry year lease options. Used in a number of states, these leases are usually created between seasonal users (e.g. agriculture) and year round users such as municipalities. The lessee agrees to pay a sum of money to the lesser each year and in turn has the right to call in the water in times of drought. This enables agricultural users to grow crops in the years when the water is not called in by the lessee.

Water Salvaging Agreements

The concept of Water Salvaging Agreements or dry year lease options differ from water exchanges in that cooperative agreements are entered into between the holder of a water right and a party seeking to obtain water. In the case of an agricultural water user, such an agreement (contract) could be entered into with municipal water or state or local wildlife agencies such that these entities could invest in farmers' irrigation systems in exchange for some portion of the water conserved. These agreements could be permanent or temporary in nature and would not require the water right holder to give up any portion of his or her right. In order to implement this type of activity changes would have to be made to current water law in Washington State. However, the implementation of agreement such as this would serve to direct more water to growing urban needs without significantly jeopardizing future water availability for agricultural needs.

Cautionary Considerations

Implementation of water banking or other management activities must consider other impacts which fall outside issues surrounding water quantity. Among the emerging considerations is the issue of inter-basin movement of water. Movement of water from sources during periods of high flow to basins where flow is reduced or where additional storage is available may have significant consequences on habitat, endangered species and/or tribal issues. These impacts must be fully considered and addressed if a successful, comprehensive water management plan is to be accepted by all parties.

Pest and Disease Background Information

Climate change can affect play a significant role in pest and pathogens in several ways. The effect of climate change may eclipse other factors affecting the occurrence of pests and pathogens. If this is the case, the question as to how current pest and pathogen management should be modified becomes a central aspect of a climate adaption strategy for forests, agriculture and aquaculture lands.

In regards to many pest and pathogen organisms, higher temperatures may lead to accelerated disease cycles, leading to an increase in disease spread, and to increased survival due to shortened and less severe frost periods. Climate change will likely prompt changes in current farm management, which may have impacts (positive or negative) on pests and/or pathogens populations. The already existing trend to advance planting crops to bring crops early in the season to the market is done because prices are then still high, but is done also to escape plant diseases. This trend will continue when temperatures rise. The consequence will be that plant disease outbreaks will start earlier, have a longer season, resulting in more disease cycles in one vegetation season.

Currently there is a high reliance on use of chemical and biological agents to eliminate or reduce to manageable levels pest that pose a threat to commercial food and wood products. While there have been great strides in reducing the need for such agents, these still remain as the cornerstone for pest and pathogen management. Current attention as to how these tools are employed within the environment may result in limitations to their use fostering the need for new and innovative practices. This will be particularly important in dealing with unforeseen pest and pathogen outbreaks as a result of climate change.

Impacts
Washington State is predicted to experience both higher temperatures and changing precipitation patterns over the next century. These changes will likely prove increasingly favorable to new and existing forest, agriculture and aquaculture pests and diseases. Higher average winter temperatures will allow new pest species (insects, weeds, fungus, etc.) to survive the winter, while longer summers will allow these pests to complete and in some cases extend their life cycles. For example the massive population buildup of mountain pine beetle and its northward progression in the Pacific Northwest has been linked to a combination of warmer winter temperatures, reduced episodes of underbark mortality and increased drought which weakened the trees. In the last few years the potato tuber moth has become a major pest in eastern Washington.

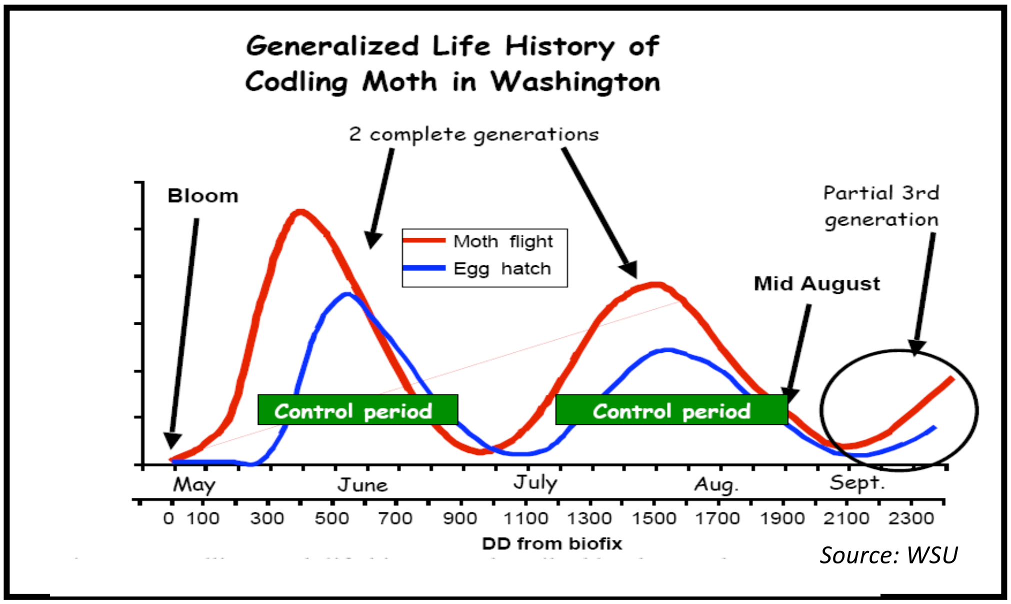
Predicted Changes in PNW Climatic Conditions

	Temperature	Precipitation
2020s		
Average	+ 2.0ºF *(1.1ºC)*	+1%
2040s		
Average	+ 3.2ºF *(1.8ºC)*	+2%
2080s		
Average	+ 5.3ºF *(3.0ºC)*	+4%

Source: Climate Impacts Group – University of Washington March 2008

The rise in occurrence is believed to be due to longer optimum conditions for breading and warmer winter temperatures that result in significantly less die-off due to freeze kill. A generalized life cycle diagram for codling moth is presented to represent the effects of longer heating days on insect populations. With respect to aquaculture, tentative links between ocean and estuarine oxygen and temperature changes have been made on disease affecting oyster production and the rapid expansion of Spartina in Willapa Bay (Field 1997).

Extension of Codling Moth Life Cycle Due to Increased Degree Days



To date pests are controlled by a variety of means including both chemical and biological. However, as changes in climate occur that represent a more favorable ecology, it can be expected that current methods will become less and less effective (insect and weed resistance, overwhelming populations). Additionally, the collateral impacts to non-target species may prove to be substantial concerns in the future.

While changing climatic conditions are expected to result in increases in pest pressures for forestry, agriculture and aquaculture the expansion of global demand for both wood and agricultural products has opened new pathways for invasive species as well as for plant and animal pathogens that are well adapted to potential climate changes and are potentially damaging to Washington forestry and agriculture. As climate conditions change worldwide requiring more trade to address food and fiber needs here and abroad, the potential for the introduction of new pest species into Washington State may significantly increase.

Key Vulnerabilities and Risks

Within the state of Washington overall farmer or farm sector vulnerability to pest and disease is currently considered to be somewhat limited. This is due in large part to implementation of innovative pest management schemes and the availability of a wide array of chemical and biological tools to address and limit outbreaks. This includes research and development of crops that are resistant to current pest and pathogen pressures and development of chemical agents with narrow targets. However, the use and effectiveness of these tools is dependent upon forward knowledge of potential new or invasive pest species that may have significant impact to the some 300+ crops grown commercially within the state.

Currently, there is a relative balance between the current deployment on management tools and changes in the pest and pathogen populations. Acceleration of pest and pathogen populations or adaptation to current tools due to rapid changes in climatic conditions presents a significant risk of tipping the current balance.

In 2007 the Prepardness and Adaptation Workgroup developed a key list of risks related to pest and disease and climate change impacts. This list remains pertainant today.

Increased temperatures and changes in precipitation patterns will result in an expansion of areas where pests are found, longer pest life cycles, and increased losses from weeds, insects and diseases. Issues for agriculture from these impacts include:

_ *Increased cost of production* from increased pest inputs.

_ *Decreased yields and crop quality*.

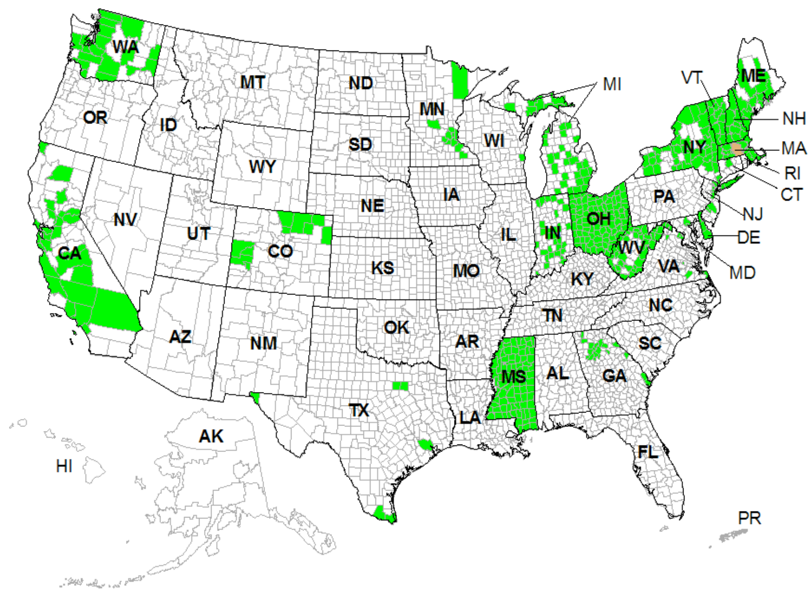
_ *Increased root-rot in perennial crops*, due to increased soil temperatures, resulting in the need to develop new "rot-resistant" varieties, or to modify current practices.

_ *Expansion of insect pests* into areas and crops in Washington not previously seen, resulting in:

- Current statewide insect monitoring program being insufficient to provide "early warning" of major pest movement
- Current integrated pest management measures potentially being insufficient for predicted expansion of new pests, and
- Increased use of pesticides to control insects and weeds

Pest populations are currently monitored on a national level by the United States Department of Agriculture through such program as the Remote Pest Identification Program, and the National Agricultural Pest Information System. While these activities aid in the tracking of pest and pest populations nationwide, they do not generally provide for timely information on a scale that is valuable to the individual grower or group of growers.

Asian Longhorned Beetle – 2009 Survey
National Agricultural Pest Information System



In 2007 the Preparedness and Adaptation Workgroup for agriculture recommended that the support be given to the Invasive Species Council to conduct an assessment of baseline conditions that would provide valuable information necessary to address questions about the extent of infestations and how they can best be managed from a statewide perspective.

The assessment would bring all the information together in one place, allowing for improved decision making by many federal, state, and local agencies. The Council would use the information to develop and implement its strategic plan, and to provide policy level planning and coordination on invasive species issues with agencies such as departments of Agriculture, Ecology and Natural Resources, Weed Boards; EPA; USDA; county governments; and Washington tribes.

The assessment, would:

_ Provide analysis of the worst invasive species in the state, the locations of the areas most affected, pathways, and resources most at risk.

_ Identify public and private efforts to prevent, control, or eradicate invasive species.

_ Bring together in one place, for the first time, the multitude of invasive species data compiled by county, state, federal, tribal, and non-governmental organizations, including GIS data created by local Weed Control Boards.

_ Identify gaps and duplication of efforts.

_ Provide critical information for the development of risk-assessment standards that will be used for meaningful priorities for preventing, controlling, and eradicating invasive species.

_ Inform public and private entities and increase their ability to coordinate efforts and resources.

Unfortunately, due to budget shortfalls a majority of this work has not been accomplished. In the absence of this action, another method that would enhance and compliment federal tracking activities is needed to provide the foundation for effective pest management planning.

The development of new and less environmentally impacting chemical control methods is the current path favored by the federal government and most state agricultural agencies. This new generation of chemical control agents is developed with targeted pests and disease in mind. This differs significantly from the historic development and application of wide spectrum pesticides that were generally more toxic to off target organisms and the environment. However, the risk of unforeseen explosions in pest and disease populations due to climate change that may not respond to current “targeted pesticides” is a factor that cannot be discounted and should be considered in the development of any adaptation strategy.

Recommended Adaptation Strategies

Fire Management Recommendations

Part A: Research and Information

Recommendation A.1: Information and Intergovernmental Collaboration

The public sector must develop adaptive capacity on two fronts: Information availability; and, the development of shared policy goals with respect to adaptation. This approach is not an end in itself, but a means of encouraging planning and action when it is justified. This recommendation recognizes the need to identify existing policies and existing science and create a mechanism for consistent communication between the two worlds. To succeed in its intent, this recommendation requires a strong focus on scientific information and data: scientifically valid information on forest health conditions (and how they vary regionally), the broader utilization of the state-and-transition model[5], identify areas where we don't have sufficient information and generate a plan to obtain the information, prioritization and vulnerability assessments, etc.

Key points of consideration:
Shared intergovernmental policy goals are important. How can new policies for resilient forests, e.g., at DNR, USFS, counties, etc. insure that all are contributing toward outcomes of shared importance? How are existing policies compatible? Adaptation will be easier if the policy playing field is clear to all observers.

Identify how the Statewide Assessment (WACCIA) plays into this process. What information are we trying to get and at what resolution? Information in the WACCIA may not fit the needs of all users, so someone needs to understand what data is in there and what could be developed from it or, especially, other sources and what that would cost.

Make sure that there are avenues of information dissemination for people that don't necessarily have good access. Attempt to ensure equal access to information, and make it understandable. Consider what information and technology transfer tools are needed to implement recommendations.

First utilize existing partnerships such as the Tapash Sustainable Forests Collaborative and the Northeast Washington Forestry Coalition that (1) have knowledge of and can relay data, information, and policy and (2) have built in mechanisms to communicate with one another: policy and information (data, science). Develop additional partnerships using demonstrated successes.

Recommendation A.2: Convene a stakeholder group that is tasked with:

1. **Facilitating the collation and dissemination of critical information to policy makers, community action groups, and landowners. This facilitation would incorporate elements of PAWG recommendations (1), (2), (4), (6) and (7) to broadly increase the availability of and access to information.**
    1. Provide comprehensive data and information to land-owners, policy makers, and the public about the existing and developing forest health and fire hazard conditions.
    2. Use new state authority to create forest health scientific advisory committees to assist decision makers in responding to extreme forest health and fire hazard problems.
    4. Provide public financial and technical assistance to owners of small forestland parcels.
    6. Implement an active communication and education strategy.

[5] Built on a forest dataset called Gradient Nearest Neighbor. It is run by the USFS PNW Research Station and can predict wildfire effects at the watershed scale under alternate future climate scenarios.

7. Improve coordination of regulatory requirements to remove unnecessary barriers while ensuring program objectives are being met.

2. **Analyzing the regulatory environment in which adaptation will occur so that (a) possible tools are maintained (e.g., prescribed fire, fuels treatment, and removing biomass and/or decreasing stand density in severely water limited forests to mitigate severe forest health problems) and (b) policies goals are shared (or at least not in conflict) among different landowners (e.g., example of wildland fire use as a permitted policy) to allow landscape level management – e.g., USFS "all lands approach".**
3. **Developing an action plan for catastrophic wildfire event.**

Recommendation A.3: Inventory existing pilot projects, identify projects that are needed, and ensure adequate funding is available for pilot projects.
Pilot projects are an essential component of forest health adaptive management and should be a method consistently implemented to test and demonstrate new authority, policy, and technology and to encourage the buy-in of stakeholders. We need to be pro-active on an on-going basis. Organizations must work together to identify pilot projects that will result in the most benefit to exploring the viability of the largest number of climate change adaptation strategies and/or that will have the most impact.

Pilot projects should be integrated into all recommendations and activities that emerge from the Fire Management group within the Natural Resources Technical Advisory Group, as a method for testing the efficacy of various strategies and to demonstrate to the public what 'successful' climate adaptation looks like.

Part 1: Identify pilot projects that are currently underway in Washington State that relate to forest health and fire management to ensure that projects are collecting relevant data and that new duplicative pilot projects are not initiated. Determine what work is already being done on a pilot scale and determine whether we are getting the data we need. If not, determine whether it is feasible for an existing project to be modified to accommodate the data needs that would be required to ensure effective testing of adaptation strategies.

Part 2: Identify the key data sets that are needed and develop a list of pilot projects based on the recommendations of the TAG's that need to be conducted prior to recommendations being implemented on a landscape level. Work with partner agencies to secure funding and, to the degree possible, apply the pilot activities across different land ownerships and forest management schemes.

Part 3: Identify and create opportunities for financial assistance to pilot programs.
Work with local, state and national partners to identify existing funding sources that are amenable to pilot scale projects related to effective fire management strategies aimed at adapting to climate change. Where there are no existing mechanisms or funding sources, work with stakeholder groups to create them.

Recommendation A.4: Engage and provide input to the Regional build-out efforts from the National Fire Plan Cohesive Wildland Fire Management Strategy.
Fire management strategies are only effective when landscape level agreement by all landholders (state, federal, SFLO, industrial land owners, others) is reached. The Cohesive strategy exists for this purpose and is linked to land management actions by major agencies, as well as agency-administered programs to assist landowners. Engagement will draw from the first iteration of the State's Comprehensive Climate Adaptation Plan.

Recommendation A.5: Develop electronic information centers across the state that summarizes regionally relevant information.
Centers will be based on feedback that is received through 'listening sessions' with residents. These sessions will ensure that information being collected is what is needed by affected communities. NOTE: This recommendation is motivated by a combination of Forestry PAWG recommendations for Forest health and fire strategy.

Recommendation A.6: Take action to (1) pre-adapt landscapes, on pilot project scales initially, to climate change and future disturbances and understand how pre-adaptation varies sub-regionally, (2) plan for responses to severe disturbance, and (3) develop information and monitoring required to incorporate this into adaptive management.
This recommendation is motivated by the understanding that disturbance area and possibly frequency and severity are likely to increase with climate change and that how we address these disturbances, both preemptively and after they happen, will determine the trajectories of our forested landscapes.

Key points of consideration:
From a scientific perspective, we know the experiments that we need to do to understand what pre-adaptation actions are effective. For example, we need to know much more than we do now about how thinning and biomass removal will affect tree vigor and response to insect (e.g., Mountain Pine Beetle) attack. This includes a need for broader understanding of how multiple insects and diseases will interact in the considerable portion of eastern Washington forests that are comprised of mixed species. Furthermore, better science is needed to understand how forests are likely to respond after inevitable severe disturbance events – which species will persist, which will regenerate, which will not. There is evidence that entirely novel, new vegetative communities could be the result (Rehfeldt et al. 2006).[6] Can a combination of thinning and prescribed fire programs make our most vulnerable forests, once they have been identified, better adapted to fire? We already know that thinning can be done in such a way that fire severity can be influenced.

Science is pointing to more active management regimes in production forests and multiple use forests to minimize the loss of canopy mortality in disturbance events. It is important to recognize that there is strong spatial variance in the degree to which this is true – the more frequent disturbance was prior to Euro-American settlement, generally, the more this management is indicated.

Pilot projects that test and demonstrate techniques for forest management and monitoring, particularly on the edges of forest types and urban/forest interface zones where they are visible and affect human values, are excellent experiments to provide data for HOW to do this and HOW to communicate it.

Pre-adaptation plans should be aimed at regeneration, tree vigor, stand density, composition and structure of forest ecosystems. Monitor closely edge or ecotones (transition zones) from wet to dry where climate effects may initially be most dramatic. These should be the focus of the initial pilot projects, designed to develop and test treatment regimes for maintaining, enhancing or restoring a resilience and healthy forest system.

It should be acknowledged that while experimental design can be deployed in the immediate-term, the results and effectiveness of the pilot projects will not be known for many years.

[6] Rehfeldt, G.E., Crookston, N.L., Warwell, M.V., and Evans, J.S. 2006. Empirical Analyses of Plant-Climate Relationships for the Western United States. International Journal of Plant Sciences. 167(6). 1123-1150.

Part B. Pilot Projects (Proof of Concepts)

Recommendation B.1: Fully Fund and Implement on the Ground Pilot Projects

Pilot projects are an essential component of forest health adaptive management and should be a method consistently implemented to test and demonstrate new authority, policy, and technology and to encourage the buy-in of stakeholders. We need to be pro-active on an on-going basis. Organizations must work together to identify pilot projects that will result in the most benefit to exploring the viability of the largest number of climate change adaptation strategies and/or that will have the most impact.

Pilot projects should be integrated into all recommendations and activities that emerge from the Fire Management group within the Natural Resources Technical Advisory Group, as a method for testing the efficacy of various strategies and to demonstrate to the public what 'successful' climate adaptation looks like. .

Part C. Increase Forest Health

Recommendation C.1: Utilize sound, science based silviculture practices to promote forests that are healthy and resilient from significant impacts of insect and disease. The objectives of these practices are they relate to climate change are:

- **Integrate wildfire management objectives with forest health restoration objectives, recognizing that often, the focus of wildfire hazard reduction actions is in close proximity to communities whereas forest health actions typically take place across broader landscapes.**
- **Manage for native species and structural diversity as current site potential and land management objectives will allow, using both historic range of variability and future climate scenarios as a guide.**
- **Where needed, utilize stand density and species management to maintain or enhance overall stand health and resiliency through increased vigor, species and structural diversity.**

Rationale: this recommendation emphasizes the need to develop resiliency and health of forests at both the stand and landscape level that will allow vegetation the ability to adapt to climate change. It recognizes that an important component of the degree to which insect and disease organisms interact with forests is closely related to overall tree vigor, species mix, and vertical and horizontal structural diversity.

Recommendation C.2: **Seek incentives to collaborate with adjacent landowners (both large and small) to affect overall landscape resiliency through the management of age class, structure, and species distribution.**

Rationale: In order to effectively adapt to changes in climate, it is important that overall forest resiliency be considered on large landscape scales. To be successful in this, collaboration across ownerships and political boundaries must be strong and should include partners from federal, state, tribal, and local governments, as well as private stakeholders.

Recommendation C.3: Adopt an "all lands" approach for allocating public funding for landowner assistance.

Washington's forest managers will play a crucial role in sustaining healthy, productive forests over time. But forest landscapes are not bounded by artificial ownership boundaries. Land ownerships of all sizes will face the same ecosystem consequences due to climate change. The difference will be in the management response by the landowners. Allocation of public funding will best be made within an "all lands" context that considers small forest landowners along with other types of forest owners, including large industrial owners, non-profits, local and state governmental agencies, DNR trust lands, tribal lands, federal lands and others. Experience suggests without this approach many small acreage landowners simply do not have the financial resources to undertake necessary silvicultural practices. Experience also shows small forest landowners to be a difficult demographic to incite toward concerted action at large scales, but direct proximity to visible, well publicized projects on federal and state lands can help. Timely deployment of recovery and adaptation actions following a severe wildfire event, when the consequences are still fresh in mind, has also proven a successful tactic.

The 2010 Washington Statewide Forest Resource Assessment and Strategy[7] can serve as a foundation for such an approach. The assessment provides an analysis of forest conditions across ownership boundaries and delineates priority landscape areas and issues. The strategies provide long-term plans for investing state, federal and private resources where doing so will be most effective. A focus on all lands and strategically assessing the forest areas that have the greatest need or highest value will get the most value from the invested effort.

Part D: Small Forest Landowners

The Forestry Resources Preparation and Adaptation Working Group recommended "providing public financial and technical assistance to owners of small forestland parcels to encourage implementation of treatments demonstrated to be successful, and tailored to diverse landowner objectives, through science-based pilot programs."[8] Washington's legislature recognizes the importance of small forest owners and the benefits their forests provide to all Washington citizens. It has stated that all citizens must recognize small forest owners' commitment to long-term forest stewardship, and support maintenance of such forests for their present and future benefit (RCW 76.13.005). Federal programs are in place, administered by the DNR Resource Protection Division, that already assist landowners with taking these actions, increasing state funding contributions to these efforts and maintaining or improving current federal funding levels should be a priority.

Recommendation D.1: Provide technical assistance to small forest landowners through a variety of existing programs and entities.

Additional assistance for small forest landowners is needed to: 1. Help the landowner understand how the anticipated forest impacts due to climate change could impact their forest management, and 2. Provide information and assistance to implement Firewise and other management strategies to reduce potential risk from forest fires as a result of changed environments.

Recommendation D.2: Use existing channels to deliver financial and technical assistance to small forest owners.

Currently there are a number of programs available at the federal, state and local levels, as well as some Tribal programs, to provide technical and financial assistance to forest land owners. The most efficient and effective assistance approach will be one relying on the existing financial and technical assistance service delivery infrastructure that is already well-suited to help accomplish this strategy. This infrastructure includes DNR, State Conservation Commission, conservation districts, WSU Extension, local governments, and NGOs such as WFFA and WFPA. DNR currently administers four programs to deliver public financial and technical assistance to small forest owners: forest stewardship; forest health; small forest landowner office; urban and community forestry. A significant challenge lies in overcoming capacity limitations that are a function of currently available funding.

Recommendation D.3: Secure expanded and sustainable funding to broaden the scope and scale of service delivery to small forest owners and secure expanded and sustainable funding to broaden services.

Currently there are a number of programs available at the federal, state and local levels, as well as some Tribal programs, to provide technical and financial assistance to forest land owners. The most efficient and effective assistance approach will be one relying on the existing financial and technical assistance

[7] Department of Natural Resources work product to be finalized in June 2010.

[8] Leading the Way: Preparing for the Impacts of Climate Change in Washington. Recommendations of the Preparation and Adaptation Working Groups. Page 145.

service delivery infrastructure that is already well-suited to help accomplish this strategy. This infrastructure includes DNR, State Conservation Commission, conservation districts, WSU Extension, local governments, and NGOs such as WFFA and WFPA. DNR currently administers six programs to deliver public financial and technical assistance to small forest owners: Forest Stewardship; Forest Health, Fire Prevention and Fuels Reduction, Small Forest Landowner Office, Urban and Community Forestry, and Forest Legacy. Additionally, the USDA Natural Resources Conservation Service administers the Environmental Quality Incentives Program (EQIP). A significant challenge lies in overcoming capacity limitations that are a function of currently available funding. The potential to secure stable funding from non-governmental sources to expand DNR's capacity to deliver financial and technical assistance should also be explored.

The legislature should increase funding to several small forest landowner assistance programs, including: the small forest landowners office at the DNR, the Washington State Conservation Commission and the local conservations districts, and WSU Extension. Managers of these programs should also seek opportunities to partner with NGOs such as WFPA, WFFA, and the Farm Bureau. The legislature should also consider compensation opportunities for ecosystem services small forest landowners provide the public. These approaches can provide small landowners with more technical assistance, land use options, and resources, which together will reduce conversion pressures.

Part E: Avoided Conversion

The working group recognizes that conversion of working forestland to other uses presents significant challenges to the application of forest management strategies for climate change adaptation. Successful working forest and natural areas conservation efforts are a key stepping stone to enabling success in the broader array of climate adaptation and integrated fire management strategies at a landscape scale. The group also recognizes working lands conservation is an essential component to success in other related efforts such as creating and retaining green jobs, restoring Puget Sound, and mitigating climate change. Finally, the group recognizes that the challenges faced by working forests – and the array of acceptable solutions – differ among western and eastern Washington landscapes. For instance, industrial landowners account for a much higher percentage of forestlands in western Washington than in eastern Washington; federal lands account for a much higher percentage of eastern Washington forests than western Washington forests. The emphasis of many avoided conversion efforts, and their underlying strategic assumptions, has been in the developing areas of western Washington. Different approaches will be required to address avoided conversion in eastern Washington from a fire management perspective.

Due to the importance of avoiding conversion of working lands, the working group recommends that the state pursue the following strategies:

Recommendation E.1: Local governments should be encouraged to protect working forest lands through existing zoning and land use designations.

Under the Washington Growth Management Act (GMA), all counties and cities are required to designate forest lands of long-term significance for the commercial productions of timber.[9] This designation is intended to protect the economic productive value of these lands. Technical assistance should be provided to local governments to assist them in evaluating their current resource lands designations in light of the anticipated ecosystem alterations due to climate change. This evaluation should consider whether the local designations should be changed to ensure sufficient forest lands are protected from conversion if there will be changes to harvest regimes due to climate change. For example, climate change may limit the amount of timber that can be harvested from these resource areas. If this is the case, will more land need to be designated to ensure sufficient available timber.

[9] RCW 36.70A.170(1)(b)

Recommendation E.2: Pass legislation to advance new market-based approaches to working lands conservation including:

- **Forest Biomass Markets. Removing biomass from forests in ecologically sustainable ways can provide income for forest landowners while improving forest health.**[10]
- **Ecosystem Services Markets. "Ecosystem services" refers to the natural resource values forests provide, such as water purification, wildlife habitat, wetland protection, and carbon sequestration. Ecosystem services markets refers to the system whereby a forested landowner can sell "credits" reflecting the value of these services in the forest, and the credits are sold to another entity who must mitigate for impacts to similar services elsewhere. Legislation would be required to facilitate this system in Washington.**[11]
- **Enable infrastructure funding for urban transfer of development rights receiving areas**
- **Provide counties with better ways to achieve conservation through cluster developments**

In 2007 and 2009, the legislature passed legislation to enable and advance transfer of development rights in Washington State and the central Puget Sound region. Transfer of development rights is a new market-based tool that allows landowners to realize development value and conserve their property while directing growth to areas designated for additional development. Numerous counties in the state have TDR programs in place, and dozens of transfers have occurred conserving tens of thousands of acres. In rural areas, counties also have various approaches to encourage cluster development to conserve open space. While these approaches do leverage market forces to achieve some conservation, counties are looking for authorization for strategies that would promote greater avoided conversion avoidance benefits in the rural development that is occurring. The 2008 Climate Action Team Forest Sector Workgroup noted the potential forest carbon benefits of better guiding growth in rural lands.

The legislature should pass legislation enabling new infrastructure financing options for cities participating in a transfer of development rights marketplace. HB 2850 proposes this linkage in King, Pierce, and Snohomish Counties. The bill was introduced in the 2010 session, and legislators are expected to reintroduce the proposal in 2011. The legislature should also look for opportunities to enable counties to achieve more permanent working lands conservation by linking TDR to fully contained communities, urban growth boundary expansions, or other forms of new rural development.

Recommendation E.3: Support state and federal working lands conservation programs.
Several existing state and federal programs provide resources and tools for avoiding conversion of forestland to other uses. Avoided conversion likely increases the capacity of forest and agricultural systems to fix CO2 and also provide more land management options in adaptation to the impacts of climate. As public conservation resources are limited, especially in the current fiscal environment, it is important to use them strategically and efficiently. Furthermore, limitation on the availability of public and philanthropic conservation dollars place additional importance on the role of innovative market-based approaches in achieving landscape-scale conservation.

There are also several federal, state and local programs to assist landowners in enhancing the economic productivity of their working forests. When forest lands is economically viable to retain as forests, the landowner has the economic incentive to continue in forestry. If the landowner can make more money through development, they will be more likely to convert the land. By providing a variety of marketing and economic options for the landowner, the likelihood of conversion for economic reasons are reduced.

[10] *Statewide Forest Resource Assessment & Strategy for Washington State*, Washington State Department of Natural Resources, June 2010, Section A, p 30.
[11] *Statewide Assessment Strategy*, Section A, p 30

Conservation programs allow the landowner to place forest lands in a more protected status but still have some harvest value.

The legislature should support and implement recommendations from the DNR 2010-2014 strategic plan Goal III: Preserve Forest Cover and Protect Working Forests and Agriculture Lands from Conversion. The legislature should also support the Washington Wildlife and Recreation Program, which provides funding for projects that reduce fragmentation and conserve farms and forests. At the federal level, Washington State should advocate for increased Land and Water Conservation Fund and Forest Legacy Program funding, which support working forest conservation easements and acquisitions. The state's federal delegation should also work to pass the Community Forestry Conservation Act, a bill that would authorize tax-exempt revenue bonds for working forest conservation. This bill (HR3302, S1501) has support from the Washington Department of Natural Resources, the Washington Forest Protection Association, and numerous local and national conservation groups.

Recommendation E.4: Provide financial and technical assistance to all landowners to assist them in the management of their lands, and in the marketing of the forest products to ensure the landowners remain economically viable in forestry.

Small forest landowners play an important role in sustaining working forests and open space in forested landscapes. Maintaining this land use preserves very low density development in these areas minimizing the fire risks and suppression cost of more dense rural residential development. However, small forest landowners face a unique set of challenges. They are not able to take advantage of the economies of scale of large timber companies and therefore incur higher operating cost. Concerns from the proximity of neighbors are amplified in small parcel landscapes. Resource protection set asides from harvest combined with property lines often creates a complex geometry which takes a larger percentage of land out of production. An economic sized forest ownerships also present the owner with difficult financial choices for subdividing into yet small parcels. Technical and financial assistance can play an important role in implementing landscape-scale conversion avoidance strategies.

The legislature should increase funding to several small forest landowner assistance programs, including: the small forest landowner office at the DNR, the Washington State Conservation Commission and the local conservation districts, and WSU Extension. Managers of these programs should also seek opportunities to partner with NGOs such as WFPA, WFFA, and the Farm Bureau. The legislature should also consider compensation opportunities for the ecosystem services small forest landowners provide the public. These approaches can provide small landowners with more technical assistance, land use options, and resources, which together will reduce conversion pressures.

Recommendation E.5: Coordinate with other groups advancing avoided conversion strategies

Other stakeholder groups in Washington State are working on strategies that involve or relate to avoiding conversion of forestland. The Puget Sound Partnership's Action Agenda Priority A1 is to protect intact ecosystems, and mentions the need to conserve working lands and implement transfer of development rights and other conservation tools. The state's Forest Carbon Offset Workgroup, convened by the Department of Ecology and the Department of Natural Resources, will discuss avoided conversion strategies that

The state should ensure coordination among these various stakeholder groups. Draft recommendations from a given group should be distributed to other groups and leaders from stakeholder various groups should meet or otherwise communicate findings, priorities, and recommendations.

Part F: Trust management

Recommendation F.1: DNR should evaluate the existing management strategies, including ecosystem and habitat plans, for state trust lands and evaluate these strategies in the context of anticipated climate change impacts.

Rationale:
Current research on climate change impacts to the forest environment indicates the potential for alteration in forest landscapes. As indicated elsewhere in this document, the combined climate change impacts on tree growth, regeneration, fire, and insects will fundamentally change the nature of forests. The existing *Policy for Sustainable Forests*, completed in December 2006, acknowledges the potential impact of climate changes and includes the policy that the department "will incorporate cost-effective forest health practices into the management of forested state trust lands to reduce or prevent significant forest resource losses from insects, disease, animals, noxious weeds and other similar threats to trust assets".[12] However, more information on the impacts to forests due to climate change may have become available since the completion of the Policy. Because of this, it is recommended the Board of Natural Resources should pursue an evaluation of the Policy to determine the potential impacts to the long-term management of state trust lands in light of the current understanding of climate change impacts. This recommendation is consistent with the Policy, which states as a policy on implementation and modification, "the department will recommend changes in policy to the Board of Natural Resources due to changes in law, scientific knowledge, new information or other circumstances".[13]

Part G: Prescribed Fire

Recommendation G.1: Increase the capacity, and resources of land managers to increase the use of both wildfire and prescribed fire to promote forest health and sustainability of fire-adapted forest types on all lands.

Recommendation G.2: Convene a multi-stakeholder group (incl. WDOE, WDNR, USFS, and USEPA etc.) to identify current and projected barriers to increasing the extent of prescribed burning in relation to state smoke management guidelines and national ambient air quality standards. Scope of discussions should also include the carbon emissions accounting of prescribed fire as opposed to alternatives such as uncontrolled wildfires.

[12] *Policy for Sustainable Forests*, Washington State Board of Natural Resources, December 2006, p.32
[13] Id, at p.50

Genetic Preservation and Development Recommendations

Part A: Continue current practices useful for adapting to change
Recommendation A.1: In reforestation activities, landowners should maintain species and genetic diversity across their ownerships. This should help buffer against changes. Some landowners may choose to plant different species or seed sources in separate planting blocks, while others may prefer to intermix them. There are tradeoffs associated with the arrangement of diversity, and the best choice will depend upon the circumstances of the landowner.

Recommendation A.2: Washington Department of Natural Resources (WDNR) and other resource agencies in Washington should cooperate with and support existing USDA Forest Service (USFS) efforts to build disease resistance in 5-needle pines and other tree species with serious disease issues. The USFS is the leader in the region for programs of selection, testing and breeding to identify and develop disease resistant trees. WDNR actively cooperates in this work by maintaining a breeding orchard, establishing field trials, and sharing data. Continued support of this work is essential to maintaining these species in our forests.

Recommendation A.3: Washington Department of Natural Resources and other natural resource organizations should continue to be active in breeding, testing & selection programs, such as those operated by the Northwest Tree Improvement Cooperative and the Inland Empire Tree Improvement Cooperative. Cooperative members should ensure that testing incorporates adaptation strategies by incorporating greater geographic diversity into tests and assessing adaptive traits such as cold-hardiness and drought tolerance. The ongoing testing of seed sources across the forest land base provides a reliable source of feedback about which sources are performing best as the climate begins to change. This allows gradual adjustments to seed orchards that should be helpful to keeping forests adapted through moderate levels of change.

Part B. Assess vulnerabilities and prioritize efforts
Recommendation B.1: Create a gene conservation plan that deals with climate change for tree species in Washington, including an inventory of significant gene conservation resources (e.g. seed collections, seed orchards, archive plantings). The gene conservation plan should consider the vulnerabilities of tree species to a wide range of risks, and address the reality that "protected areas" may not be a stable place for the trees currently growing there to exist.

Recommendation B.2: Use models of vegetation changes in Washington under various climate scenarios to help rank species or populations in terms of vulnerability to climate change. At present, there is enough uncertainty with these models that they should be used only to assess the relative vulnerability of various species. As the uncertainty is reduced over time, models must be able to reflect population differences within tree species to be truly useful for making decisions about what species and seed sources are likely to be adapted in the future.

Recommendation B.3: Use GIS map layers showing different types of risk factors in Washington (e.g. fire, insects, disease, land conversion) to help prioritize work. Although this information needs to be developed outside of the forest genetics community, it will be important for prioritizing geographic areas where genetic resources are most at risk.

Recommendation B.4: Conduct a vulnerability assessment for tree species in eastern Washington. The USDA Forest Service has assessed vulnerability of various western Washington tree species to climate change. This kind of work needs to be extended to trees east of the Cascade Mountains. Effects of climate change are expected to be more pronounced in eastern Washington, so a vulnerability assessment for tree species there is an important foundational step for further planning.

Part C. Begin active adaptation steps, including monitoring to drive decisions

Recommendation C.1: Create a cooperative tree seed bank to provide for recovery from large-scale disturbance, such as fire or insect outbreaks. This may begin with a "virtual" seed bank created with cooperative agreements among landowners who maintain seed inventories and are willing to make that seed available in the event of disturbance. It will also need to include a collection and storage program to cover seed needs not addressed by current seed inventories. The coordination of this effort should reside in a stable institution that already has the infrastructure and knowledge base to conduct this work, and can easily provide seed to landowners who need it. Washington Department of Natural Resources is a good location for this work to be centered.

Recommendation C.2: Forest landowners should implement monitoring programs to detect problems with tree growth, phenology, reproduction, or tree health. These may include monitoring already being done as part of the forest landowner's operational programs (e.g. regeneration surveys), existing inventory programs (e.g. Forest Inventory and Analysis Program in the USDA Forest Service), or could include new monitoring systems. Pilot-scale projects are encouraged to evaluate the usefulness of any new systems.

Recommendation C.3: Washington Department of Natural Resources should modify seed transfer guidelines for Washington to account for the projected effects of climate change. Geographically defined zones should be replaced with climatically defined zones. Seed transfer should be implemented using a framework that: 1) accounts for the uncertainty of climate projections and the uncertainty of resulting effects on forest trees, 2) uses a scientifically-based risk management framework that considers the risk of inaction, and 3) yields information that will allow forest geneticists to improve seed transfer guidelines over time.

Recommendation C.4: Land management agencies should incorporate into their operational planting programs a: 1) wide range of transfer distances to varying degrees, 2) robust system for tracking the seedlots used in operational plantations, and 3) monitoring system for tracking the performance of seedlots in relation to transfer distance.

Water Availability

Part A. Development of Additional Storage

Additional storage will have to be a component of any comprehensive water management strategy. However, it is not likely that "mega projects" will be viewed as favorable in the near future because of their cost and environmental impacts. Therefore, the state should accelerate its current activities devoted to evaluating sites for the development of small and medium size reservoirs that will benefit multiple water users, such as agricultural, environmental, commercial, and recreation (see Appendix One.) There is a current reluctance to commit funds for these types of projects given current budget conditions. However if an investment is not made in a relatively short time, the costs of declining water availability will significantly impact the state's ability to compete economically and will result in detrimental impacts to the environment. Recommendations related to development of additional storage are:

Recommendation A.1: Secure a reliable funding base to develop surface and groundwater storage projects;

Recommendation A.2: Continue to invest in comprehensive water resource planning efforts similar to the Yakima River Basin Enhancement Project Workgroup;

Recommendation A.3: Promote projects that focus on conjunctive use of both surface and groundwater resource storage;

Recommendation A.4: Focus on storage projects that are moderate in size and that provide both economic and environmental benefits; and

Recommendation A.5: Assess potential for modifications of current storage facilities to increase overall storage capacity and enable "capture" of runoff earlier in the season.

Part B: Promote the Enhancement of Water Distribution Systems

There is currently an effort by utilities to improve water distribution systems and reduce water loss due to leakage and/or evaporation. Given the fact that between 20 – 30 percent loss can be expected through leakage of unlined canals or compromised rural/urban deliver system, cutting that loss can contribute significantly to increasing the available water for all competing uses. The issue of cost to enact those improvements will eventually take care of itself due to the ultimate rise in the price of water, but there is merit in implementing those improvements as soon as possible through development of state or federal grants or imposing assessments on users of water from system needing improvements to reduce water loss. Recommendations to promote enhancement of water distribution systems are:

Recommendation B.1: Develop funding mechanisms to enable implementation of improvements to distribution systems, including both urban water supply and rural irrigation supply systems. These may include modifications to current rate structures or state/federal grant or loan programs;

Recommendation B.2: Focus improvements on aging systems where loss is greatest; and

Recommendation B.3: Where improvements result in declining water levels within private wells (previously supplied by system leakage) establish loan programs that allow for deepening of wells if necessary.

Part C: Promote Implementation of On-Farm Conservation and Efficiency Measures
Implementation of these types of measures has proven successful in areas of the state like the Columbia Basin Groundwater Management Area. The initial costs associated with implementation of irrigation water management and/or improved irrigation technologies have been somewhat offset by increased yields and cost share programs supported by state and federal dollars and maybe enhanced by focused tax incentives. Current programs related to climate change/water conservation within the US Department of Agriculture and or US Bureau of Reclamation should be examined as a possible source for cost share funds. Specific recommendations include:

Recommendation C.1: Improve access and delivery of water-efficiency information, voluntary water audit programs, and on-site technical assistance provided through Cooperative Extension, Natural Resources Conservation Service and other agricultural outreach efforts.

Recommendation C.2: Continue to invest in improvements and expansion of online data dissemination systems like AgWeatherNet (AWN) to provide farmers and foresters with immediate meteorological and hydrological information on climate, soil conditions, and crop water requirements. Expansion of network to cover additional forest lands will have added benefit to forest management officials.

Recommendation C.3: Provide tax exemptions or other incentives for the purchase of efficient irrigation equipment to help offset capital investments for these systems.

Part D: Modification of Laws, Regulations and Policies
Modify existing water law to allow market forces to drive the price of water and incentives to distribute and use water more effectively. However, a free market for water favors large, wealthy users, such as residential and municipal users over other, less wealthy users, such as food producers, especially as populations grow. Water markets can be an important tool, but they must be carefully crafted to achieve societal goals and not create an imbalance in the delicate economy of Eastern Washington in particular. To address this issue the concept of Water Salvaging Agreements should be investigated along with other water markets, salvaging agreements, or other "transfer" mechanism changes to current laws, regulations, and policies the following recommendations are made:

Recommendation D.1: Develop and promote healthy water markets within Washington State that provide protection of adequate supplies for agriculture and environmental needs;

Recommendation D.2: Develop new legal mechanisms by which municipal water or state or local wildlife agencies could invest in farmers' irrigation systems in exchange for some portion of the water conserved;

Recommendation D.3: Conduct a comprehensive review of Washington water law in the context of current and future growth and climate change effects and provide recommendations for action.

Part E: Cataloguing the Available Resource
There is currently insufficient data to create an accounting of water supply and demand that would allow creation of a multi-year water budget. There are measures of surface water resources including stream flows and reservoir capacity, but not of the quantity of water available from snowpack. The quantity of water available statewide from other sources, primarily groundwater, is also unknown. Without an inventory of the total water supply, including seasonal availability, it is not possible to formulate a comprehensive strategy for water use and conservation. Nor is it possible to develop strategies for conjunctive use of surface and groundwater that recognize the interconnection of each. Additionally, there is a lack of a consistent and accurate estimate of actual water use by all sectors within the state. The

lack of understanding of the current "usable reservoir" coupled with the inability to accurately account for water use will significantly hamper the ability to manage water in a sustainable manner in the future. In light of these facts it is recommended that:

Recommendation E.1: Washington state embarks on activities designed to determine the total quantity of the available resource; this includes a cataloguing of all known surface and groundwater sources;

Recommendation E.2: Washington state develops accurate methodologies using satellite imagery and other technologies to determine water use in un-metered areas;

Part F: Other Potential Solutions
Within this paper several potential proposals were touched upon that could provide various degrees of relief to the water availability dilemma posed by both population growth and predicted climate change effects. As previously noted in the paper, one potential solution for increasing water availability in forest areas and small agricultural basins is the promotion of habitat for beavers and beaver dams. While this may initially sound farfetched beaver dams are currently providing a year-around solution for forest and agricultural working lands in small portions of the state (coastal cranberry growing areas). While not discussed to a great extent, land use actions can have profound effects as far as water conservation and availability is concerned. State and local restrictions on the conversion of forest and agricultural lands can improve both water quantity and quality and improvement habitat for various species. Partnerships with research institutions, conservation organizations, and governmental agencies should be fostered to develop other unique and possibly promising solutions to the question of further water availability and climate change.

Recommendation F.1: Promote better combined land and water planning on both a state and local level;

Recommendation F.2: Encourage protection of prime agricultural and forest land from urban and suburban development through state and local land use regulations;

Recommendation F.3: Investigate and establish other mechanisms that encourage water-use efficiency to achieve broader social or environmental benefits; and

Recommendation F.4: Encourage the development of projects that merge natural ecosystem occurrences with local water storage and delivery systems

Recommendation F.5: Develop and implement improved forest management techniques that result in a reduction of fire, and an increase of forest diversity to improve water holding capacity in the upper watersheds for the benefit of downstream working lands.

Pest and Disease Recommendations

The development and implementation of a pest and disease tracking system accessible to agriculture and aquaculture is the foundation of an climate adaptation strategy. While these systems currently exist at various levels they are not generally friendly to the forester, farmer, or aquaculturalist. Additionally, there is significant need for improvement in education and information dissemination related to pest and disease occurrence and climate change.

Recommendation 1.
Improve monitoring and identification networks for invasive species entering Washington lands and waters. In 2007 the PAWG recommended supporting the actions of the Invasive Species Council to establish and baseline of invasives funding for that effort appears to be lacking. We would recommend that funding for this activity commence and consideration be given to linking Washington State University in this effort to ensure that improvements in population monitoring of existing commercially relevant species within the state occur.

Recommendation 2.
Refine and support interstate system to track and monitor pest and disease movement. It may be necessary to examine current state and federal tracking activities and evaluate where such activities can be merged or where opportunities exist to compliment activities. The results of these actions must be packaged in such a way that recommends, etc. are easily conveyed to foresters, farmers, and aquaculturalists.

Recommendation 3.
Further develop control technologies for new pests and population expansions of current pests. These activities largely fall to two entities, research institutions and pesticide registrants. It is likely that due to Washington status as a minor crop state more interest will be shown by the state and regional research institutions than private enterprise. This however, may not be the case in the areas of forestry and aquaculture were Washington is a significant market.

Recommendation 4.
Invest resources in control options for emergency situations. As noted previously, there has been a significant move to develop more protective chemical control agents than has previously been utilized. Chemical and biological agents are now developed with targeted species in mind instead of wide spectrum pesticides that potentially impact much more than the species of concern. However, in the case of population's explosions (where climate change raises the risk) there is a potential for the "new" pesticides to be less than effective in controlling an outbreak that could result in economic loss or threats to human health. A forward thinking adaptation strategy should have provisions that allow for limited production of effective yet admittedly environmentally harmful agents. These agents would only be used in the event of real economic or human health emergencies ans under strict state and federal control.

Recommendation 5.
Channel resources into tools that enhance the land owners ability to manage changing pest populations (i.e. WSU's Decision Aid System). This recommendation goes beyond those made in recommendation one in that in addition to tracking pest and disease movement, these resources can provide for tailored alternatives to manage pest populations. Coupled with this recommendation is the need to improve on site delivery of educational materials to land owners and managers related to climate change and pest impacts.

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Appendix C: Priority Response Strategies and Actions

Priority Response Strategies and Actions	
1. Protect people and communities from climate change impacts.	• *Enhance core public health capacity.* Core public health capacity will need to be enhanced to increase surveillance, early detection, and response capabilities. Public health agencies should prepare to monitor and respond to diseases and carriers typically found in warmer climates, such as Rocky Mountain spotted fever, tularemia, and Lyme disease. Vulnerable and at-risk communities should be identified, especially for infectious diseases, heat stroke, and respiratory and cardiovascular disease caused by higher temperatures, heat waves, and smoke from more frequent wildfires. Public health agencies should raise awareness of new public health risks from climate change among health providers, health organizations, and the public.
	• *Enhance emergency response capacity to address increasingly extreme floods and fires.* State and local emergency response needs are expected to increase in flood- and fire-prone areas of the state. Police, fire and rescue, and wildland firefighting will have to prepare for increased activity, more challenging conditions, and additional costs. Populations that are vulnerable to increased incidence of floods and fires should be identified and educated about the increased risks, options to reduce risks, and appropriate responses in an emergency.
2. Reduce risk of damage to buildings, transportation systems, and other infrastructure.	• *Reduce flood damage by restoring floodplains and capturing more water.* As extreme storms increase, the most effective and least costly approach to managing larger floodwaters is often to enhance floodplains' ability to accommodate flood flows and using "green infrastructure" approaches to manage stormwater. Reconnecting rivers with their floodplains and providing rivers room to flow often reduces downstream flood risks and damage. Natural approaches such as wetlands and soft armoring tend to be more environmentally beneficial than levees, dams, and other "hard" approaches to flood management.
	• *Support local efforts to prepare for coastal flooding and storm surges.* Provide information, guidelines, and technical support to coastal counties, cities, and tribes to help them evaluate the risks and vulnerability to sea level rise and coastal flooding in their communities. Roads, bridges, wastewater treatment plants, sewer and stormwater systems, gas and electric transmission systems, communication systems, and other infrastructure could be at risk. Communities should consider options to reduce vulnerabilities without harming ecosystem functions.
	• *Consider climate change impacts when siting new development and infrastructure.* Consider future flood risk when planning for new growth or permitting new structures, even if the location is not currently in the Federal Emergency Management Agency's (FEMA) regulatory floodplain or critical areas designation. Ensure the building design can accommodate projected impacts and

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	does not increase risks for neighbors.
	• *Plan for relocation if structures are damaged by floods or other impacts.* If critical structures are at risk of future flooding, communities should begin now to identify safer alternative locations for those structures. This planning will help prevent the typical response to rebuild structures in the same flood-prone location after a disaster.
3. Reduce forest and agriculture vulnerability to climate change impacts.	• *Enhance surveillance and eradication of pests and disease.* Pests and disease can cause significant damage and economic losses, and these problems are projected to increase as the climate warms. Surveillance can identify new outbreaks and promote rapid response that will reduce damage and costs. These efforts should be coordinated among federal, state, tribal, and local agencies.
	• *Promote identification of and transition to plant species that are resilient to new climate conditions.* Support research and promote genetic diversity to ensure that agricultural and forest species living in Washington are able to survive under current and future climate conditions and emerging pests and diseases.
	• *Conserve productive and adaptive farmland and forests.* Encourage local governments to adopt land use regulations and incentives to minimize conversion of farmland and forests and to support land conservation incentive programs.
	• *Reduce forest and wildland fire risk in highly vulnerable areas.* Integrate wildfire management objectives with forest, shrub-steppe and grassland restoration objectives to enhance ecosystem health and resilience from pests, diseases, and invasive species that exacerbate fire risk.
4. Improve water management to address climate-related supply reductions.	• *Promote integrated water management in vulnerable basins.* Projected changes in streamflow and runoff patterns will more likely increase the competition and conflicts among water users. Integrated water management will address existing and future water resources and ecosystem problems affecting fish habitat and agriculture, municipal, and domestic water supplies. This approach supports flexibility and adaptability under changing hydrological conditions. Models for this work include the water management efforts in the Columbia, Yakima, and Walla Walla basins.
	• *Implement enhanced water conservation and efficiency programs.* Reduce water demand, especially in water-limited basins, by monitoring water use and aggressively promoting and supporting water conservation and efficiency for agricultural, municipal, and industrial users.
	• *Ensure sufficient cold water in salmon-bearing streams during critical seasons.* Increasing stream temperatures can create barriers to migration and can kill coldwater fish such as salmon, steelhead, and bull trout. Shade, increased streamflow, and other measures can keep water temperatures cool and allow rivers to continue supporting coldwater fisheries.
	• *Incorporate climate change realities into agency decision-making.* Past hydrological data are an

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	unreliable guide to project future conditions for water management decisions. Water resources managers will need to adapt their management and planning practice to reflect changing water availability. They need to take into account the change in timing and availability of water when planning for additional supplies, deciding whether water users may use their water rights for the amount allowed, and establishing instream flows for fish habitat and ecological purposes.
5. Safeguard fish and wildlife and protect critical ecosystem services that support human and natural systems.	• *Protect and restore habitat and improve the ability of species to migrate to more suitable habitat as the climate shifts.* Identify and protect areas most suitable for current and future habitat as well as the connections between habitats. Land use planning policies, guidance, technical assistance, and incentive programs are effective ways for protecting, restoring, and acquiring habitat areas that provide refuge to species under stress from climate change.
	• *Protect sensitive and vulnerable species and their habitats.* Climate change will increase the stress on salmon and other culturally important species that are already sensitive or vulnerable. Climate risks and approaches to recover and protect vulnerable species should be incorporated into management and conservation plans and programs. This planning includes species recovery and management plans, water resources management plans, shoreline management plans, land use plans, and ocean management plans.
	• *Reduce existing stresses on fish, wildlife, plants, and ecosystems.* Fish, wildlife, plants, and ecosystems already face an array of existing stresses from human development, habitat loss and degradation, pollution, unsustainable harvest, and invasive species. Reducing existing threats is an important and effective way to help natural systems cope with the additional pressures from a changing climate. For example, reducing stormwater pollution improves water quality and aquatic habitat, increasing the resilience of aquatic species to additional stresses from climate change.
6. Reduce the vulnerability of communities, habitat, and species.	• *Protect people, property, and infrastructure from coastal hazards and avoid new development in highly vulnerable areas.* Rising sea levels, more extreme rainfall, and excessive runoff may increase risks to people, property, and infrastructure from coastal erosion and flooding. Communities should identify vulnerable areas and take steps to reduce threats, while also prioritizing actions that protect habitat and natural areas. Risks to coastal communities should be incorporated into land use and shoreline management plans, and regulatory tools, incentives, and technical assistance should be expanded or developed to incorporate climate risks.
	• *Prevent coastal habitat degradation and destruction and seek opportunities for upland habitat creation as sea levels rise.* Rising sea levels will cause a loss of valuable coastal habitats. As coastal flood risk increases, landowners should use natural approaches to reduce flood risks without harming species or habitat. Policies and incentives should be developed at the state or local level to reduce habitat degradation and destruction from hard armoring of coastlines. Incentives and regulatory tools should be modified or developed to guide development away from

	hazardous coastal areas to prevent costly flooding and to allow coastal ecosystems to be created in newly inundated areas.
	• *Reduce shellfish vulnerability to ocean acidification by reducing land-based contributions of carbon and polluted runoff to the marine environment.* Acidification is caused by both atmospheric carbon dioxide and land-based contributions of carbon from sources such as polluted runoff and leaking septic systems. While atmospheric carbon dioxide contributions can only be slowed by reducing carbon emissions, the pace of acidification in some parts of Puget Sound can be reduced by eliminating polluted runoff, leaking septic systems, and other sources of land-based carbon in the waters.
7. Support the efforts of local communities and strengthen capacity to respond and engage the public.	• *Identify existing and new funding mechanisms to support adaptation work at the local level.* In some cases, climate adaptation can be integrated into existing programs with little or no cost or additional resources. In many cases, the cost of making changes and actively managing natural and built environments to cope with the impacts of changing climate may be substantial. However, these costs are far less than costs of inaction. State agencies should leverage existing federal and state funding as well as seek new sources of funding to implement high-priority adaptation projects at the state and local levels.
	• *Develop an institutional structure to improve coordination and support an integrated approach.* Successful climate change adaptation cannot be accomplished by a single agency or organization. An effective structure is needed to support cross-agency collaboration, ensure implementation of cross-cutting strategies, and link efforts across all governmental agencies, nongovernmental organizations, and other interests. An improved coordination mechanism is needed to determine and provide state input on research needs and priorities, develop mechanisms to track and monitor progress in implementing the strategies and actions, and ensure new information on climate impacts and effective responses is integrated.
	• *Support information-gathering on climate impacts and ensure scientific information is easily accessible.* Understanding of climate impacts and responses is growing rapidly and is continually being expanded. Tracking climate-related trends such as sea level rise, severe storms, and pest and disease invasions can help the state prepare for and respond with the least cost and disruption. Tools need to be developed to make this information accessible and useful to the public and to decision makers at all levels.
	• *Engage the public in determining appropriate responses to climate change.* The state must provide leadership to ensure that communities, businesses, schools, and the public have accurate information and a forum to consider climate impacts and responses. Agencies should develop consistent messages, provide access to relevant information, and work with partners, stakeholders, and others to identify concerns and prioritize responses.

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A. Human Health

A-1. Protect the communities that are most vulnerable to impacts of climate change.	1. Identify people, communities, regions, infrastructure, and local economies that are most vulnerable to climate impacts. Provide tools that local health departments and communities can use to conduct community-wide assessments. Provide financial and technical support for local communities to develop and implement appropriate adaptation strategies to respond to current and future threats.
	2. Enhance the capacity of state and local health organizations and communities to implement preventive actions that reduce public health risks related to climate change. The focus will be on ensuring efficient organizational structure, effective policies and programs, and adequate funding.
	3. Work collaboratively with local health departments, community-based organizations, state and local planning organizations, and transportation agencies to: • Improve community planning and design, to support and promote healthy built environments and healthy living. • Expand and protect urban vegetation and open space. • Prevent construction of new critical infrastructure in vulnerable areas.
	4. Work with state and local agencies and organizations to: • Enhance efforts to develop transportation options and evacuation routes to ensure safety of vulnerable people. • Develop and publicize shelters and responses to heat and flooding extremes. • Increase access to health care for at-risk populations. • Prepare for aftermath of extreme events. • Enhance preparedness for disease prevention of vector-borne and water-borne diseases following floods and storms.
A-2. Enhance surveillance and reporting systems to monitor and support early detection of climate-related risks and swift responses to emerging health threats associated with climate change.	1. Maintain, rebuild, and increase overall efficiency of current surveillance systems—at the state level and in local health departments and health care organizations—to monitor and identify outbreaks of climate-related health diseases and illnesses.
	2. Continue development of the Department of Health's Environmental Public Health Tracking network, and focus future efforts on expanding data and health indicators linked to climate change and healthy communities.
	3. Enhance surveillance and electronic reporting from laboratories to support our ability to detect emerging health issues rapidly and implement timely and effective community responses.
	4. Develop meaningful data sets to better understand changes in zoonotic disease patterns and disease vectors, air quality conditions, and harmful algae blooms. This information will assist our future efforts in preparing for and adapting to climate change-related conditions affecting our

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	health.
	5. Develop an early warning system to identify and predict when and where a harmful algae bloom or pathogen event may occur in our marine waters. This initiative will focus on: • Characterizing environmental and biological factors that contribute to biotoxin or bacterial events. • The public health burden associated with these toxic events. • Potential policy and scientific solutions and/or information and data needs for mitigating human exposure from recreational, occupational, and seafood-related pathways during such events. • Increase collaboration between the Health and Agriculture departments on zoonotic disease surveillance improvements.
A-3. Incorporate climate adaptation strategies into the overall context of Department of Health's *Agenda for Change*, with a focus on prevention, early detection, and swift responses to protect people from diseases and other health threats caused by changing climate conditions.	1. Identify, prioritize, and incorporate into health planning and regulations climate change mitigation and adaptation strategies and actions that promote and improve healthy living and reduce greenhouse gas emissions and toxic pollutants. Collaboration with local governments can help incorporate healthy living strategies into land use planning and regulations, such as compact development that concentrates growth in compact walkable urban centers to avoid sprawl.
	2. Refine existing emergency response and public health preparedness planning to enable local health and emergency response agencies to: • Anticipate impacts of severe heat events, droughts, wildfires, and coastal flooding. • Develop early warning systems. • Quickly respond to extreme weather events. • Help local health departments assess their capacity to respond to health threats and to integrate climate preparedness into their hazard response plans and daily operations.
A-4. Engage and motivate citizens and organizations to take actions to build resilient communities.	1. Collaborate with the Northwest Center for Public Health Practice and other academic partnerships to develop a web-based resource hub to provide information and technical resources on public health and climate change preparedness. This website should provide information in several languages to help meet the needs of communities most at risk.
	2. Enhance the ability of local organizations to understand climate risks and reach vulnerable populations. Provide vulnerable populations with information on what they need to know and how to prepare for and address the risks of climate change.
	3. Pursue partnerships with non-profit organizations and businesses to develop climate change communication tools, messages, and social support networks that promote active community involvement and raise public awareness about the health problems related to changing climate.

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	4. Using the medical system, enhance awareness of the projected health problems that come from a changing climate and the services (response strategies) that are available – including the mental health system.
	5. Distribute information on how a changing climate can affect human health to doctors, nurses, and emergency response personnel that provide direct services to vulnerable citizens. Expected impacts include increased asthma, heat exhaustion, and potential new diseases transmitted from animals to humans.
	6. Pursue opportunities to engage with medical and academic institutions to raise awareness of the overarching mental health problems that come from the social and environmental disruptions related to emergencies. Potential partners include the state's mental health system, the Washington Medical Association, Washington State Department of Social and Health Services, University of Washington Medical School and School of Public Health, and the schools of social work at Washington State University, Portland State University, and Eastern Washington University.
	7. Distribute alerts to the service providers of the medical and mental health communities during extreme weather events (and in advance, when possible), so they can be best prepared to serve members of their communities that may be adversely impacted.
	8. Encourage the Washington State Public Health Association to dedicate time at the annual Joint Conference on Health to raise awareness and engage the public health and healthcare service providers about the health problems related to a changing climate. This conference also provides an opportunity to raise awareness about the tools and strategies that local communities can use to prepare for health problems associated with climate change.
	9. Use existing programs within the Department of Health's Office of Drinking Water to educate and alert public water system operators and their customers about likely impacts of climate change and the need for enhanced emergency preparedness.
A-5. Build capacity and support to safeguard human health in the face of climate change.	1. Expand training and education of health and social services providers, including mental health agencies, to build capacity to respond appropriately to human health risks of climate change.
	2. Improve our understanding of human health impacts of climate change and extreme weather through continued interdisciplinary studies at the University of Washington, Washington State University, and with agency scientists. Further work needs to focus on better understanding the risks; identifying the areas and populations at greatest risk; and exploring new methods to address the identified risks.
	3. Seek more reliable funding mechanisms that can support more localized forecasting and risk modeling to address the health implications of climate change from extreme heat events, flooding, other extreme weather events, and increased forest fires.

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	4. Pursue future funding opportunities, such as the Centers for Disease Control and Prevention (CDC) funds, to support the enhancement of critical public health infrastructure needed to promote healthy communities and to address the impacts of climate change.
B. Ecosystem, Species, and Habitats	
B-1. Conserve habitat necessary to support healthy fish, wildlife, and plant populations and ecosystem functions in a changing climate, including connectivity areas between critical habitats to allow the movement of species in response to climate change.	1. Identify opportunities and priorities for habitat connectivity, such as buffers, wildlife corridors, and a connected network of conservation areas in Washington. This action builds on the work of the Washington Wildlife Habitat Connectivity Working Group and the Western Governors' Wildlife Corridors Initiative.
	2. Increase the quantity, quality, and size of conservation areas, buffers, and connectivity corridors using the full range of conservation tools available. This action will enhance key habitat areas, facilitate migration opportunities for species vulnerable to climate change, and increase connectivity in areas at high risk from climate impacts, such as coastal habitats at risk of sea level rise.
	3. Encourage partnerships with federal, tribal, and local government, private landowners, and conservation organizations to implement landscape planning and foster adaptation strategies and actions that protect and restore habitat corridors across jurisdictional and land ownership boundaries.
	4. Identify high-quality habitats and conservation areas that are minimally affected by (or resistant to) climate change, able to sustain diverse and healthy populations, and can be used as refugia for species under stress from climate change. Prioritize these areas for protection and ecosystem management.
	5. Protect and restore high-quality freshwater habitat through the reintroduction of beavers, wetland mitigation and creation, groundwater recharge, flow augmentation, and protection of coldwater springs.
B-2. Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems be more resilient to the effects of climate change.	1. Use and improve existing regulatory and enforcement programs to build the resilience of natural systems to climate change, including such efforts as the following: • Protect and restore the connections between rivers and their floodplains. • Reduce existing pollution and contamination of freshwaters. • Manage freshwater withdrawals. • Maintain and restore streamflows and lake levels. • Reduce forest fuel buildup. • Reduce other human-induced impacts in watersheds most vulnerable to climate change.
	2. Define priorities for land management in areas important to biodiversity to emphasize resilience to fire and decrease the likelihood of severe fires.

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	3. Take early action to eliminate or control non-native invasive species that take advantage of climate changes, especially where they threaten native species or current ecosystem function.
	4. Restore riparian zones, estuaries, wetlands, and floodplains by implementing appropriate conservation, restoration, and other land stewardship actions and practices, such as mitigation banking.
	5. Collaborate with local governments to reduce and reverse habitat fragmentation and loss through comprehensive land use policies, zoning regulations, critical area ordinances, and other regulatory and non-regulatory approaches.
B-3. Manage species and habitats to protect ecosystem functions and provide sustainable cultural, recreational, and commercial use in a changing climate.	1. Incorporate climate change considerations into existing and new management plans for protecting sensitive and vulnerable species, using best available science regarding projected climate changes and trends as well as vulnerability and risk assessments. Modify protection and recovery plans to accommodate migration as well as longer-term shifts in species range associated with climate change and its effects.
	2. Conduct and refine species and habitat vulnerability assessments (such as the Pacific Northwest Climate Change Vulnerability Assessment for Habitats and Species) and other scientific studies to determine appropriate management approaches.
	3. Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species. Such efforts may include identifying areas for seed collection across different elevations and across the ranges of target species.
B-4. Integrate climate adaptation considerations for species and ecosystems into natural resource and conservation planning, land use and infrastructure planning, and resource allocation and public investment initiatives.	1. Incorporate climate change considerations for species, habitats, and ecosystem processes into planning and regulatory activities related to implementation of the Growth Management Act, Shoreline Management Act, Watershed Management Act, State Environmental Policy Act, and other state goals and policies.
	2. Ensure that land and water resources managers at the state and local levels integrate adaptation options into plans, programs, and practices. These options should address and limit the impacts of climate extremes, such as severe storms, floods, droughts, and heat waves, without causing harm to fish, wildlife, habitats, and ecosystem functions.
	3. Engage with cities and counties to support incorporation of climate change considerations into activities, guidelines, and both regulatory and non-regulatory programs that protect or conserve habitats and species. The changes should consider the impacts of climate change on habitats and species and potential for safeguarding priority habitats and species from the effects of climate change and catastrophic events.
	4. Update natural resource protection plans, land use plans, and water resources management plans to address climate change considerations for species and ecosystems and to support habitat resilience in a changing climate.

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	5. Develop criteria and guidance to consider impacts of climate change on species and ecosystems when funding new infrastructure and economic development, mitigating impacts from ongoing degradation associated with human development, and compensating private landowners for conservation practices.
B-5. Build capacity and support for the adoption of response strategies that help protect and restore ecosystem function and services at risk from climate change.	1. Establish an interagency, multidisciplinary forum (such as an interagency climate change task force) to strengthen existing partnerships and build new collaborations across jurisdictions. The forum would facilitate sharing new research and approaches to address climate impacts to ecosystems and to ensure that the needs of species, habitats, and ecosystems are considered in other areas such as agriculture, forests, infrastructure, and human health.
	2. Increase coordination and participation in existing regional and national research and policy forums—such as the National Climate Assessment, Climate Science Centers, Regional Integrated Science and Assessment partnerships, and Landscape Conservation Cooperatives—to ensure that regional efforts recognize Washington's unique and important natural resources.
	3. Develop and integrate messages about the benefits of ecological services at risk from climate change into education programs and curriculum related to natural resources management.
	4. Initiate and support efforts to quantify the benefits of ecological services and natural systems at risk from climate change. Compare lifetime cost-effectiveness of nature-based versus engineered options for climate response to help identify cost-effective adaptation options.
	5. Develop programs to engage citizens in monitoring impacts of climate change on our shorelines, forests, rivers and streams, and other natural systems and in sharing their observations, case studies, stewardship efforts, and other activities using multimedia resources.
	6. Coordinate development and maintenance of integrated long-term, large-scale monitoring of early-warning indicators of species responses, including range shifts, population status, and changes in ecological systems functions and processes. Reconsider monitoring approaches to ensure that indicators track changes associated with climate change.
	7. Develop applied tools for decision makers and land managers to maximize the adoption of climate adaptation strategies for species and ecosystems. Such efforts may include: • Guidance, tools and technical assistance to local governments to enable them to identify, designate, and protect locally important habitats, corridors, and species at risk from a changing climate. • Incentives, tools, and information to increase the contribution of working lands to ecological resilience. • Tools to promote nature-based alternatives to engineered adaptation options such as flood control, erosion control, and protection of water quality and quantity.

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C. Coasts and Oceans	
C-1. Lead by example by developing a framework to guide decision-making and protect people, assets, and natural areas from coastal hazards.	1. Evaluate and propose revisions of laws and rules that govern land use, shoreline management, and other programs to effectively address sea level rise and other climate change impacts.
	2. Develop guidance and require state agencies to integrate current and anticipated coastal climate impacts into planning, policies, programs, and investment decisions related to: • Land use. • Transportation • Shoreline management. • Economic development. • Facility siting and design. • Conservation and restoration. • Emergency preparedness.
	3. Require all projects that the state funds, permits, or approves in vulnerable coastal areas to consider the effects of sea level rise and other coastal hazards. Evaluate alternatives to reduce vulnerability and protect communities and coastal ecosystems.
	4. Identify essential public infrastructure at risk and develop a decision-making process to determine when to protect, retrofit, relocate, or manage retreat.
	5. Revise oil spill response plans to consider climate change. The plan revisions should include geographic-specific response strategies based on risk assessments and considerations of changes in infrastructure and logistical support.
	6. Recommend an institutional arrangement to align state agencies' coastal adaptation strategies and actions, help prioritize actions across state agencies, and enhance emergency preparedness and response to extreme weather events.
C-2. Avoid development in highly vulnerable areas and promote sustainable development in appropriate, less vulnerable areas.	1. Provide guidance, updated maps, tools, and information to help local jurisdictions assess risk and vulnerability and incorporate best available information on sea level rise, climate impacts, and adaptation options into their planning, regulations, project siting, and permitting.
	2. Identify incentives and regulatory tools to reduce exposure to risk and discourage new public development in coastal areas at high risk from erosion, landslides, flooding, and storm surges. The tools should include: • Acquisition/easements. • Transfer development rights. • Setbacks. • Rebuilding restrictions. • Tax incentives and fees.

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	3. Update various planning guidelines and provide incentives to local governments to consider impacts of climate change and adaptation actions when amending shoreline master programs, land use management plans, and other plans.
	4. Develop policies and information to guide insurers in dealing with properties in vulnerable areas. Inform property purchasers and investors regarding sea level risks that may affect coastal property.
	5. Assess damage costs and remove incentives that encourage rebuilding in at-risk areas.
	6. If rebuilding is the only option, construction techniques and building code amendments should be adopted to increase resilience and reduce risk to development projects.
C-3. Accelerate efforts to protect and restore nearshore habitat and natural processes.	1. Identify priority conservation and restoration areas that can increase natural resiliency and protect vulnerable communities. Identify regulatory and non-regulatory mechanisms that local jurisdictions can use to conserve and protect those areas.
	2. Develop guidelines for state agencies, local governments, watershed groups, nongovernmental organizations, and others to address sea level rise in coastal habitat restoration and protection. Direct state agencies to use the guidelines to incorporate sea level rise into state-managed and supported coastal restoration and protection projects.
	3. Identify feasible state level policy options to avoid or minimize shoreline hardening, especially in Puget Sound. Policy options should seek to streamline state and local permitting processes to provide incentives for green shoreline and soft armoring practices.
	4. Develop a program to promote green shoreline programs for Puget Sound and some urbanized coastal areas. This program can be built on the lessons learned from pilot projects currently in progress in San Juan County and Lake Washington (City of Seattle), as well as the green shores initiative in British Columbia. Develop and provide state and local jurisdictions with green shoreline design manuals for different types of shoreline along Puget Sound and the Pacific coast.
	5. Incorporate future sea level rise in the prioritization, design, and post-project maintenance of toxic clean-up sites near the shoreline.
C-4. Build local capacity to respond to coastal climate impacts by providing tools to assess vulnerability and advancing research, monitoring, and engagement efforts.	1. Complete a coast-wide (including Puget Sound) sea level rise vulnerability assessment. Update periodically as new and improved scientific information becomes available.
	2. Identify and provide local jurisdictions with information, web-based tools, training, case studies, locally effective adaptation policies and actions, and other resources needed to build resilient coastal communities. Case studies could address, for example, how communities are using the National Oceanic and Atmospheric Administration's (NOAA) Digital Coast, which provides data, tools, and training to help manage coastal resources.
	3. Assist coastal planners with activities such as: • Simulating potential impacts of long-term sea level rise on wetlands and shorelines.

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	• Analyzing risks and potential losses from floods, sea level rise and storm surges. • Mapping hazard areas. • Assessing and evaluating the risks from sea level rise and other climate change impacts within the local jurisdictions. • Enhancing sustainable development in coastal areas. • Identifying community exposure to climate change – considering land cover, land use, zoning, structures, vacant lots, parcel values, and social disruption.
	4. Identify potential funding mechanisms and help local governments seek funding to incorporate climate adaptation into plans, policies, and projects.
	5. Assist local jurisdictions in raising awareness about the impacts of sea level rise and the need for adaptation actions by providing educational materials, participating in local events, and engaging the communities in efforts such as the King Tides, Washington Beach Program, and water quality monitoring programs.
	6. Collaborate with local partners—including local governments, tribal governments, federal agencies, universities, nonprofits, NOAA Sea Grant, and National Estuarine Research Reserves—to monitor the effectiveness of climate adaptation tools and options and to identify changes that are needed.
	7. Expand essential data collection and monitoring programs to improve our understanding of climate impacts, including: • The impacts of sea level rise and storm surge on the shoreline. • Changes in erosion. • Unstable bluffs. • Saltwater intrusion and inundation of freshwater areas.
	8. Develop an inventory of dikes, levees, tide gates, clean-up sites, nearshore fuel storage facilities, and other facilities. Provide this information to local jurisdictions and others to plan for and adapt to rising sea levels and coastal hazards and to aid investment decisions in coastal areas. Ensure that the inventory products and maps are widely available to planners, agencies, tribes, and other users.
C-5. Enhance our understanding and monitoring of ocean acidification (pH) in Puget Sound and coastal waters as well as our ability to adapt to and mitigate effects of seawater acidity on shellfish, other marine organisms, and marine ecosystems.	1. Support the work of the newly created Blue-Ribbon Panel on Ocean Acidification, convened under the auspices of the Washington Shellfish Initiative. The Blue-Ribbon Panel will focus on documenting the current state of scientific knowledge and ways to advance our scientific understanding of the effects of ocean acidification. The Panel will recommend actions to respond to increasing ocean acidification, reduce harmful effects on Washington's shellfish and other marine organisms, and adapt to the impacts of acidified waters. A report will be submitted to the Governor, NOAA's administrator, regional research groups, and other policymakers in October

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	2012.
	2. Expand collaboration with NOAA Fisheries, other federal agencies, nonprofit organizations, academic groups, and the shellfish industry to enhance monitoring to track biological and chemistry changes in oceans and coastal areas of Washington, including key areas such as Hood Canal and Willapa Bay.
	3. Coordinate with state and federal agencies to improve monitoring by evaluating and adopting improved pH measurement protocols to support fine-scale data analysis and tracking of small changes in pH. Create a new baseline data set.
	4. Continue to actively address problems of pollutants in marine waters (which add to acidity problems) by studying toxics and nutrients entering Puget Sound. Develop models to determine the effects of nitrogen discharges on dissolved oxygen levels in Puget Sound. Evaluate trends in water quality over time and detect emerging issues.
	5. Continue to explore how Clean Water Act authorities can be used to prevent or reduce localized effects from ocean acidification and climate change.

D. Water Resources

D-1. Manage water resources in a changing climate by implementing Integrated Water Resources Management approaches in highly vulnerable basins.	1. Ensure that long-range plans developed for highly vulnerable basins—including the Columbia, Yakima, and Walla Walla river basins—account for climate change impacts. Consider the risks and vulnerabilities to water resources and infrastructure, agriculture, forest, and other sectors. Integrate adaptation actions into basin plans to enhance water supply reliability, improve water quality, and improve instream flows and fish passage at existing reservoirs.
	2. Promote broader recognition that an integrated approach is feasible and beneficial, by documenting lessons learned and conclusions from the implementation of integrated water resources management plans in the Columbia, Yakima, and other river basins.
	3. Expand the models of the Columbia River Program, the Yakima River Integrated Water Management Plan, and the Walla Walla flexible water management system to other basins (such as the Dungeness and Wenatchee river basins), sub-basins and/or aquifers, based on: • Existing and emerging water management issues. • Need for integrated planning. • Community and stakeholders engagement. • Legal and institutional framework. • Capacity to develop and implement an integrated plan.

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4. Develop guidance for analyzing whether and how to incorporate projected climate information and adaptation actions into planning, policies, and investment decisions. The analysis would help state, local, federal and tribal governments and water organizations understand how changes in watershed hydrology, ecosystems, water quality, and species and habitat conditions in a given watershed may affect activities such as:
    - Water allocation decisions.
    - Water delivery.
    - Water systems operations.
    - Water quality standards.
    - Stormwater and floodplain management.
    - Infrastructure safety.
    - Ecosystem restoration and species recovery.
    - Environmental preservation and restoration efforts.
5. Incorporate climate change realities—recognizing that past hydrological data are no longer a reliable guide to project future conditions—into agency decision-making to:
    - Approve new or change existing water rights.
    - Adopt instream flows for fish habitat and ecological purposes.
    - Decide whether water users are able to utilize their water rights for the amount allowed, when purchasing or banking trust water rights.
6. Use the watershed-based framework created under Watershed Planning (RCW 90.82) to establish a well-coordinated water and land use policy that takes an integrated approach to planning. Such plans should reduce risks to rural and urban communities from extreme weather events (such as intensive flooding and frequent droughts).
7. Integrate climate change adaptation into ongoing efforts that address management of stormwater, wastewater, water quality, water reuse, and potable water demand—to ensure that planning decisions and investments made now are not increasing future vulnerability and causing unintended consequences. Require consideration of the impacts of extreme weather events in planning, siting, and designing of water, wastewater, and stormwater infrastructure and related facilities.

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D-2. Improve water supply and quality in basins most likely to be affected by changing climate.	1. Strengthen and increase the capacity of natural systems to respond to droughts, streamflow changes, and flooding by encouraging local governments to adopt land use policies and best practices. Examples include practices that reduce impervious surfaces to protect surface water quality, improve infiltration, and reduce stream erosion and sedimentation. These policies and practices would: • Direct development away from vulnerable areas. • Decrease flood risk. • Expand the protection and restoration of prime agricultural and forest lands, aquifer recharge areas, wetlands, floodplains, and wildlife habitat and corridors.
	2. Encourage the state Department of Natural Resources and the U.S. Forest Service to develop and implement forest management practices that would improve water-holding capacity in watersheds and help protect water quality from increased temperature, erosion, and associated pollutants.
	3. Support new surface and aquifer storage by capturing winter and spring runoff to make up for summer low flows, where feasible and environmentally sound; and increase storage capacity in existing reservoirs. Doing so could improve water supply reliability, and enhance instream flows, if and when stored water is released during low flow conditions.
	4. Conserve water and support water reuse, retention, and infiltration by designing development sites to minimize water needs (such as drought-tolerant landscaping), retaining graywater and stormwater on site and using reclaimed water, and expanding adoption of low-impact development (LID).
	5. Foster the development of climate-ready water utility initiatives. Highlight existing utility efforts to evaluate and incorporate climate information into planning, and support the development of peer-to-peer information sharing. Assist water and wastewater utilities, along with stormwater and floodplain managers, in implementing climate change adaptation and mitigation strategies, with the goal of fostering more resilient water systems. Provide water system planners and operators with the knowledge, capacity, resources, and skills necessary to adapt to a changing climate and continue to fulfill their public health and environmental missions.
	6. Support the development and delivery to water utilities of early-warning or rapid-response information, to address challenges and disaster risk to water systems from extreme climate events, such as devastating floods, droughts, fires, and storms.
	7. Aggressively pursue reallocation and redistribution of water in critical basins, through water transfers, water transactions, water markets, and water banks with the goal of increasing streamflows for fisheries and improving habitat conditions.
	8. Work with federal and local partners to improve the performance of existing water infrastructure, such as reservoirs, to respond to extreme events that may result from climate change and to

	improve local water supplies.
D-3. Implement water conservation and efficiency programs to reduce the amount of water needed for irrigation, municipal, and industrial users and improve basin-wide water supply.	1. Adopt the most up-to-date water conservation technologies, water-efficient practices, and alternative water supplies whenever possible and where they: • Provide the most beneficial and least costly way to decrease water demand across all sectors. • Reduce stress on existing water supplies. • Increase the benefits to aquatic ecosystems. Because of the connection between water and energy use, new energy efficient technologies may provide opportunities to reduce both energy and water use, along with greenhouse gas emissions.
	2. Expand and accelerate improvements of irrigation infrastructure, starting with aging systems in basins most vulnerable to droughts and climate change. Local conservation districts and various funding agencies—such as the Natural Resources Conservation Service (NRCS), Ecology, U.S. Bureau of Reclamation (USBR), and the Bonneville Power Administration (BPA)—must continue to help irrigation organizations and landowners improve water delivery and distribution systems. These improvements can be done through projects such as: • Lining ditches. • Piping. • Re-regulating reservoirs. • On-farm conservation. • Pump exchange (replacing water from one source with water from another). • Water use management projects.
	3. Expand and accelerate implementation of water conservation and efficiency standards for industries and businesses.
	4. Expand the US Geological Survey (USGS) and the National Weather Service (NWS) Methow Basin project—"Future Runoff Scenarios for Decision Makers for the Methow River, Washington—to other watersheds to understand and quantify how hydrologic systems respond to land use, water use, and climate changes. This effort includes using the interactive web-based database being developed for the Methow. http://wa.water.usgs.gov/projects/methow/summary.htm.

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	5. Expand accelerate implementation of municipal water use efficiency improvements to reduce amount of water used per capita/household. Improvements could include: • Water rate setting. • Water smart landscape programs. • Rebate to install/upgrade landscape irrigation systems. • Water waste regulations. • Water budgets (large water users are given a water budget instead of watering days). • Development codes and policies for new development. • Rainwater harvesting from roofs. • Education and public outreach campaigns.
	6. Seek more reliable funding mechanisms to help water providers implement climate-ready plans and practices.
D-4. Build the capacity of state, tribal, and local governments; watershed and regional groups; water managers; and communities to identify and assess risks and vulnerabilities to climate change impacts on water supplies and water quality.	1. Provide local communities and watershed groups with water forecast projections using best available data, tools, and models to assess watershed vulnerability and determine priority risks that require a response. Provide examples of management strategies that will build resilient watersheds and communities.
	2. Help watershed groups and communities identify vulnerable areas and assets at risk. Develop climate-readiness plans using approaches that would most sustainably and effectively prepare for and adapt to changes in the watershed.
	3. Provide tools and incentives to watershed groups to implement watershed protection and restoration plans focusing on: • Controlling stormwater on a regional or watershed basis. • Reducing flood peaks. • Reducing sedimentation. • Increasing recharge aquifers. • Restoring instream flows.
	4. Collaborate with the scientific community and water management entities to develop and disseminate best available data, information, and tools on: • Hydrologic changes and hazards, such as extreme floods and droughts. • Projected impacts and risks of climate change on long-term water budgets and on ecological resources in a given basin. • Alternatives to effectively respond to these changes.

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	5. Expand the central clearinghouse of data and case studies to support climate change and adaptation planning. Provide information and examples of effective strategies to prepare for climate impacts, including: • Operational changes. • Engineering and design options. • Green infrastructure approaches. • New infrastructure investment. • Planning. • Land-use controls.
	6. Inform utilities about the Climate Ready Water Utility Initiative and tools such as the Climate Resilience Evaluation and Assessment Tool (CREAT). Support water utilities, working with the University of Washington's Climate Impacts Group (CIG) and the Climate Impacts Research Consortium (CIRC), to incorporate information on climate impacts into models used in water, wastewater, and stormwater systems planning and site design.
	7. Continue to invest in improvements and expansion of online data-sharing systems to provide farmers, water utilities, and other customers with timely information on weather, soil conditions, crop water requirements, as well as water efficiency and conservation practices.
	8. Improve information on water use by expanding use of meters and implementing methodologies using satellite imagery and other technologies.
	9. Improve understanding of climate change impacts on water resources by supporting expansion and refinement of regional climate impact assessment tools and models developed by CIG, CIRC, U.S. Geological Survey (USGS), and other scientific entities. These tools are intended to cover climate change impacts on surface waters, groundwater recharge and groundwater availability and the interaction between climate, hydrology, and vegetation.
	10. Explore cooperative work with regional Climate Science Centers, NRCS, USGS, CIRC, and the Climate Impacts Group. Continue and expand existing monitoring networks, such as streamflow gages.
E. Agriculture	
E-1. Maintain and enhance agriculture productivity by supporting farmers and ranchers transition towards the goal of sustainable agriculture.	1. Conserve and protect productive and adaptable farmlands by supporting county and city policies and programs that limit sprawl and conversion of agricultural lands to development and facilitate locally-grown food and community garden plots.
	2. Maintain agricultural land in production and compensate farmers for the environmental benefits of conservation projects implemented on their lands. Examples of projects include ones that: • Preserve and restore wetlands, riparian corridors, and wildlife habitat. • Improve water quality.

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	• Sequester carbon (keep carbon in the soil).
	3. Compensate farmers using mechanisms such as purchases, leases, and establishment of conservation markets. Support the agricultural community in accessing funding programs within various state, federal, and local agencies and conservation organizations.
	4. Protect the productivity of agricultural soils from water runoff, erosion, wind storms, and excessive heat through such management practices as: • Direct-seeding. • No-till farming. • Reduced-volume irrigation systems. • On-farm water conservation and storage. • Biological and organic soil amendments, such as manure and compost. • Integrated pest management practices. • Cover-crop and fall-planted crops
	5. Facilitate access by farmers and growers to technical and financial assistance to implement the practices.
	6. Help growers select more economically and ecologically resilient crops, such as: • Pest-resistant crops. • Drought-tolerant crops. • Diversified variety of crops. • Soil and water holding crops, such as alfalfa seed.
	7. Safeguard livestock against the impacts of climate change, and protect livestock by: • Modifying facilities to reduce heat stress. • Dispersing stock in pastures. • Ensuring properly managed grazing. • Improving herd performance through good genetic stock. • Adapting the reproduction season to fit the climate and sources of feed and forage.
	8. Establishing a herd health program in impacted areas.
E-2. Reduce impacts of severe droughts and extreme weather events on irrigated agriculture.	1. Increase the ability of the state, local governments, irrigation districts, and other entities to obtain the most up-to-date forecasts of droughts and extreme events. Integrate these forecasts into drought planning and decision-making by policymakers, water users, and water managers. Improve and update existing data provided through federal agencies such as the National Oceanic and Atmospheric Administration, Natural Resources Conservation Service, and National Weather Service as well as universities including the WSU AgWeatherNet Program.
	2. Prepare for and respond more effectively to droughts. This may require revising the statutory authority for drought emergency declarations by the Governor. The declaration triggers several

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	drought response activities.
	3. Identify highly drought-vulnerable basins, provide advance warning of drought and extreme events, develop drought plans, and enable decision makers to reduce risks and damages from droughts.
	4. Enhance water conservation and efficiency activities at the farm and district levels in highly drought-vulnerable basins by expanding technical and financial cost-share assistance programs. These programs help growers reduce irrigation needs and runoff, such as improving water conveyance, improving groundwater infiltration and soil retention/capture, and planting drought-tolerant crops.
	5. Improve water reliability and increase water supplies through continued support for integrated basin water management planning and by fostering voluntary transfer of water. (Changes to current statutes may be needed to provide incentives to increase participation of existing water right holders in water transfer programs.)
	6. Expand and improve the effectiveness of the state's water right transfer program by seeking statutory changes that provide flexibility and incentives to current water right holders interested in transferring their water to other users.
E-3. Prevent, eradicate, and control pests, diseases, and weeds potentially harmful to public health, the environmental, and agriculture production.	1. Implement tracking and monitoring, pest and weed control, and eradication actions. State and federal agencies, county noxious weed boards, and county pest and disease boards should conduct these efforts collaboratively.
	2. Provide information to the agricultural community to enable farmers and growers to modify agricultural practices and to adapt to new pests and diseases.
	3. Increase awareness and protect pollinator (bees) habitat by incorporating conservation of bee habitat into land management and farm practices that minimize land use impacts on pollinators—including tillage, pesticide use, burning, grazing, cover-cropping, and roadside management.
	4. Develop and enhance emergency response plans to manage significant pest outbreaks that harm human health, the environment, and the economic viability of the agriculture sector. These plans should include streamlined approval mechanisms of new biological and chemical tools as well as monitoring.
E-4. Promote opportunities to engage the agricultural sector and rural communities in developing and implementing new policies, technologies, and practices addressing the impacts of climate change.	1. Increase participation of farmers, producers, farm organizations, industry leaders, and rural communities in research, changes to public policies, and implementation of new policies and programs that promote: • Ecosystem services. • Environmental health. • Economic profitability. • Social and economic equity.

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	2. Create or enhance existing networks to facilitate rapid transfer and adoption of new knowledge and technologies to help farmers adapt to changing climate, promote sustainability, and benefit the environment, rural communities, and farmers.
	3. Engage the agricultural community in research to assess vulnerability of various annual (e.g., cereal grains) and perennial crops, and select crop varieties capable of adapting to expected climate changes.
F. Forests	
F-1. Conserve and restore healthy, resilient forests across ownership boundaries and large geographic ranges to minimize the threats from climate change and extreme weather events.	1. Develop a comprehensive approach that integrates objectives and actions for preservation of working forests, wildfire management, insects and diseases control, and forest health protection and restoration. Developing the integrated approach needs to occur in partnership with tribal, federal, state, and local resource protection agencies; public land management agencies (DNR, USFS, BLM and others); private forest landowners; nongovernmental organizations; and other stakeholders.
	2. Develop a coordinated plan for fire hazard reduction and suppression for at-risk forests to assist policymakers, communities, and jurisdictions with land-management decisions so that forest fire threats are reduced. Information on existing and projected forest health and fire hazard conditions should be widely shared with forest landowners, managers, decision makers, and the public.
	3. Reduce development pressures on forestlands by working with local governments to protect forestlands from conversion, such as through zoning and transfers of development rights. Facilitate implementation of best practices, and engage private landowners through market and investment opportunities.
	4. Secure sustainable funding and expand financial and technical assistance to forest landowners. Use an “all-lands” approach for allocating public funding to forest landowners to implement new and modified practices that reduce risks from: • Forest fires. • Pests and diseases. • Erosion and sediment loads into rivers. • Loss of habitat. • Loss of soil moisture.
	5. Advocate at the federal level for: • Increased funding for the Land and Water Conservation Fund, Forest Legacy Program, and Environmental Quality Incentives program funding, which will benefit several states including Washington. • Passage of the Community Forestry Conservation Act, a bill that will authorize tax-exempt

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	revenue bonds for working forest conservation.
F-2. Maintain and protect forest species and genetic diversity across the landscape to ensure long-term conservation of our forest genetic resources and help buffer against impacts of climate change.	1. Ensure forest landowners continue to manage for native species and structural diversity. Use current reforestation practices to maintain species and genetic diversity across their forest lands.
	2. Build disease resistance in five-needle pines and other tree species with serious disease issues, in cooperation with existing U.S. Forest Service efforts.
	3. Maintain and expand participation in tree breeding, testing, and selection programs, such as those operated by the Northwest Tree Improvement Cooperative and the Inland Empire Tree Improvement Cooperative. Ensure that testing by cooperative members incorporates greater geographic diversity and adaptive traits such as cold-hardiness and drought-tolerance.
	4. Create a gene conservation plan for tree species in Washington based on vulnerability assessments to climate change of various eastern and western Washington tree species. The U.S. Forest Service has completed a vulnerability assessment for western Washington.
	5. Create a cooperative tree seed bank within Washington State Department of Natural Resources to provide for recovery from large-scale disturbances, such as fire or insect outbreaks. This effort may begin with a "virtual" seed bank created with cooperative agreements among landowners who maintain seed inventories and are willing to make their seed available in the event of major disturbance.
	6. Build on existing monitoring and evaluation programs to detect problems with tree growth, phenology, reproduction, or tree health.
F-3. Protect, expand, and manage urban forests to help communities reduce impacts of rising temperatures and extreme precipitation runoff events.	1. Expand Urban Forests Assistance Program (authorized under the Washington State Urban and Community Forestry Act) to help mitigate the impacts of climate change, such as the following: • Airborne pollution. • Higher water temperatures in urban streams. • Urban heat island (metropolitan area that is significantly warmer than its surrounding rural areas). • Heat waves. • Severe stormwater runoff. • Flooding. • Erosion.
	2. Secure sustainable funding sources to build the Urban Forest Assistance Program's capacity to increase participation by cities, towns, and communities in planting and sustaining healthy trees and vegetation in urban areas.

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	3. Support cities and towns in developing education and community programs to enhance community awareness of the benefits that trees provide—including public health, environmental, ecological, and economic improvements. Support communities in adopting sound tree protection and management ordinances in all communities faced with threats from heat waves, flooding, and landslides.
	4. Promote urban forests by engaging cities, communities, neighborhoods, local and state park officials, and volunteers in: • Planting trees more tolerant of heat and drought conditions. • Implementing effective options for tree watering and maintenance. • Selecting pest- and disease-resistant trees. • Removing invasive species. • Monitoring the health of the trees.
F-4. Build capacity and support for maintaining, enhancing, and restoring resilient and healthy forests.	1. Build on existing or create new pilot projects, experiments, and research to better understand how forests are likely to respond after severe disturbance events. For example, would a combination of thinning and prescribed fires help vulnerable forests better adapt to fire?
	2. Strengthen existing partnerships and build new collaborations across jurisdictions to share knowledge and information on climate change impacts and adaptation across all sectors and across broad landscapes of varying ownerships and jurisdictions. This approach is referred to as an all-lands approach.
	3. Increase coordination and collaboration with federal and tribal governments, the scientific community, and private conservation groups to ensure that research and management strategies address Washington's forest needs and recognize the important social, economic, and environmental benefits of forests.
	4. Improve forest health and reduce forest hazard conditions by providing data and information to landowners, policy makers and the public about wildfires, and pests and diseases, and benefits provided by forest ecosystem services.
	5. Improve understanding and communication of impacts and adaptation responses by engaging all levels of government, stakeholders, and the public in adaptation planning and decision-making affecting forests.
	6. Integrate messages about the benefits of forest ecosystem services into education programs and curriculum related to natural resources management, environmental protection, urban planning, economics, and other programs.
	7. Coordinate development and maintenance of integrated long-term, large-scale monitoring of early-warning indicators of species responses, including range shifts, population status, and changes in ecological systems functions and processes.

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G. Infrastructure and the Built Environment

G-1. Protect vulnerable infrastructure and ensure it is safe, functional, and resilient to climate impacts.	1. Develop a common framework and methodology for transportation infrastructure risk assessment at a regional scale and for all transportation modes and operations.
	2. Encourage local, regional, tribal, and federal governments and private entities to prepare detailed inventories, and climate vulnerability assessments to identify critical and vulnerable infrastructure within their jurisdictions.
	3. Work with ports to determine short- and long-term strategies to protect port infrastructure and transportation linkages to ensure movement of commerce and international trade.
	4. Encourage owners and operators of critical energy infrastructure to evaluate vulnerability to the impacts of climate change, including risks of damage and the potential for disruptions and outages from flooding, sea level rise, extreme heat, erosion, and extreme weather events.
	5. Adopt regulatory and incentive programs to encourage state, tribal and local funded transit organizations; public works departments; utilities; and other partners to demonstrate awareness and, where possible, consistency with efforts to address vulnerable systems.
	6. Work with the insurance industry to identify and implement mechanisms to reduce risks to property owners from climate-related hazards, and to educate consumers on ways to reduce exposure to risk.
G-2. Guide future development away from areas at risk.	1. Gather and provide the best available scientific information on climate impacts and areas at high risk from flooding, seawater inundation, landslides, extreme heat, and wildfires. Provide information for a range of climate scenarios, for all regions in the state and on a basin-by-basin basis, using consistent data from the UW Climate Impacts Group and other reputable sources. Make the information available and readily accessible to citizens, businesses, local governments, tribes, and others to assist in making informed decisions to prepare for and adapt to climate impacts.
	2. Develop guidance as well as regulatory and incentive programs to encourage state and local governments to limit new development in high-risk areas and to incorporate projected climate change impacts and adaptation actions into long-term planning, policies, and investment decisions. These policies and plans include regional or countywide planning policies, comprehensive plans, shoreline master plans, development regulations, and urban growth area expansions.
	3. Determine how to consider potential climate impacts and adaptation options for non-project and project actions, as part of the State Environmental Policy Act.
	4. Encourage the federal government to accelerate modernized flood mapping and implement fundamental reforms to the National Flood Insurance Program to incorporate risks from climate

	change.
	5. Limit new development in floodplains and coastal areas vulnerable to sea level rise and return some coastal and floodplain areas to natural conditions.
	6. Encourage local jurisdictions to identify and implement ordinances and other approaches to reduce wildfire risks.
G-3. Reduce or avoid climate risks by considering climate in the planning, funding, design, and construction of infrastructure projects and by promoting improved design and construction standards in areas vulnerable to climate risks.	1. Develop a framework to guide the state's planning and investments to: • Protect, repair, elevate, or decommission vulnerable infrastructure. • Protect safety and key evacuation routes. • Protect critical transportation facilities and corridors for the movement of people and freight, both within Washington and to nearby states and Canada. • Potential financial, social, and environmental impacts. • The framework should identify a process to decide when the state will not invest in at-risk projects with a long lifespan.
	2. Require incorporation of climate impacts and response strategies in the state's long-range transportation plans; mode-specific plans for highways, rail, aviation, and ferries; and regional transportation plans.
	3. Develop transportation design and engineering guidance to minimize climate change risks. The design guidance should be used when siting and designing new transportation infrastructure and project-related infrastructure, such as stormwater treatment and flow control, wetlands protection and mitigation, and fish passages. The guidance should provide information on techniques and materials resistant to increased heat and other climate impacts.
	4. Require consideration of climate risks and response strategies in the site selection, design, and construction of state-funded infrastructure projects.
	5. Advance the adoption and enforcement of progressive building codes and design standards to reduce vulnerability of structures to climate-related hazards.
	6. Provide incentives to incorporate climate risks and response strategies in the design of commercial and residential buildings. Promote strategies and technologies, including those that: • Reduce energy and water use. • Accelerate deployment of smart-grid technologies—using electronic control, metering, and monitoring to reduce energy. • Maximize rain and snow seepage into the ground, which reduces runoff and replenishes groundwater, using green infrastructure and low-impact development approaches. • Collect rainwater onsite. • Maximize open spaces to reduce urban heat effects.
	7. Identify and provide financial incentives to property owners to reduce exposure to risk, such as low-cost

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	loans or financial incentives to rebuild—or relocate—according to improved construction standards, increased setbacks, or elevation of the structure.
G-4. Enhance the preparedness of transportation, energy, and emergency service providers to respond to more frequent and intense weather-related emergencies.	1. Incorporate information about climate impacts into state and local emergency planning efforts, including the Comprehensive Emergency Management Plan, the State Hazard Mitigation Plan, and the Hazard Identification and Vulnerability Analysis.
	2. Bolster contingency plans for key critical transportation, energy supply and distribution networks, telecommunications, and water infrastructure at risk.
	3. Identify and protect critical evacuation routes. Coordinate emergency evacuation planning among adjacent cities and counties.
	4. Improve systems to provide engineers, public works, and maintenance staff with early warning of problems, engage onsite protections in advance of an emergency, and provide early warning to the public. Revise existing systems—or develop better systems, such as using sensors and smart technologies—for monitoring: • Bridge abutments. • Land slopes. • Stormwater runoff and drainage systems. • Real-time flood levels and storm surge. • Other climate impacts on infrastructure.
	5. Adjust routine operations, maintenance and inspection, and capital budget expenses to prepare for more frequent and intense storms, floods, landslides, wildfires, and extreme heat events.
	6. Seek more reliable funding mechanisms to ensure that local governments can safeguard vulnerable populations, especially during heat waves. Provide incentives to prepare for energy supply interruptions and develop backup systems in schools, clinics, and emergency shelters.
	7. Foster interaction with communication service providers to improve reliability of emergency services during extreme weather events, encourage communication companies to identify alternative means of communication during emergencies, and seek incentives for new technology to diversify and decouple communications from electric grids or otherwise improve their resilience.
G-5. Build capacity of the energy sector to respond to climate-related disruptions and meet potential increases in energy demand and changes in supply.	1. Continue to consider climate-related changes in energy supply and demand, system reliability, and in the State Energy Strategy and the Northwest Power Plan. Encourage utilities to consider potential climate impacts in integrated resource plans.
	2. Require consideration of climate risks in relicensing existing and siting new energy projects.
	3. Aggressively increase energy efficiency and conservation efforts.
	4. Encourage additional research into the impacts of climate change on alternative energy sources. Identify how future climate impacts could affect the state's renewable energy goals , and work

	with utilities to ensure that renewable energy and energy conservation goals are met.
	5. Encourage the development of small energy sources on site (e.g., solar panels) to increase reliability by having redundant systems and to reduce risks associated with the long-distance transmission of energy.
	6. Construct stronger, more resilient transmission and distribution systems to improve system reliability and to create additional capacity and redundancy.
	7. Adjust reservoir management to account for climate impacts—either too little water or too much water—in considering multiple objectives for energy production, agriculture irrigation, flood management, fish flows, and other needs.

H. Research and Monitoring

H-1. Improve scientific knowledge and ensure that climate science is responsive and applied to the needs of policymakers, managers, planners and others.	1. Solicit input from local governments, tribes, businesses, nongovernmental organizations, and other stakeholders to identify needs for data, information, and resources that would foster their understanding of the risks and consequences of climate change at the regional, state, and local levels.
	2. Participate in current research efforts conducted by the UW Climate Impacts Group, Climate Science Centers, Regional Integrated Science and Assessment Center - Climate Impacts Research Consortium (CIRC) - the North Pacific and Great Northern Landscape Conservation Cooperatives, and others to ensure the scientific research agenda recognizes Washington's distinctive natural resources and addresses priority needs of the state.
	3. Support the periodic update of the National Climate Assessment and CIG's comprehensive regional climate scenarios for Washington State.
H-2. Partner and collaborate with state, federal, tribal, and local governments and various organizations to enhance existing monitoring systems, and develop new systems where needed to monitor the impacts of climate change and the efficacy of adaptation responses.	1. Establish an extensive network of sentinel site monitoring stations at locations that are not expected to be subject to local land use changes. The term "sentinel site" is used to describe a monitoring station for which long-term monitoring data are available.
	2. Include continuous monitors that track multiple measures, such as temperature and streamflow gages, at sentinel sites and at selected long-term ambient monitoring sites. Develop and revise field and statistical procedures.
	3. Take measurements in and around streams to: • Assess hydrologic effects to stream channels from extreme storm events, including measuring the geometry and sediment composition of stream channels. • Assess biological integrity with regard to climate change impacts, such as monitoring of sediment- tolerant/intolerant organisms (taxa) and heat-tolerant/intolerant organisms. • Assess the stresses to riparian vegetation from dropping water tables and changing temperatures.

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	4. Evaluate signals in hydrology such as those developed by The Nature Conservancy through the Indicators of Hydrologic Alteration (IHA) software.
	5. Work with the U.S. Geological Survey to implement a robust, multi-purpose groundwater monitoring program in Washington State, which will be part of the national groundwater climate response network (CRN). In Washington, a minimally functional groundwater CRN consists of at least 11 wells, of which five are currently in place.
	6. Implement monitoring programs designed specifically to test the effectiveness of adaptation actions and the assumptions underlying proposed adaptation actions. Encourage each agency or partner to monitor the implementation of its respective actions.
	7. Collaborate with various agencies to monitor the spread of pests and diseases and to increase the overall efficiency and sensitivity of current surveillance systems.
H-3. Support development and use of applied tools for decision makers and land and water managers to help them understand the risks and consequences of changing climatic conditions on communities, infrastructure, and natural systems; and select effective adaptation options to build resilience.	1. Share existing tools with local governments, state and tribal agencies, and local communities to help them understand key vulnerabilities to climate impacts and what actions can be taken. Examples include the Climate Ready Water Utilities Toolbox, Georgetown Climate Center sea level rise tool, and other tools. Incorporate climate change considerations into existing planning tools that evaluate the effects of alternative land use policies, such as ENVISION, INVEST, and models from the Natural Capital Project.
	2. Maintain the state's climate adaptation clearinghouse and link to other clearinghouses to improve the availability of information. Leverage and link existing efforts to support climate adaptation efforts at the state, tribe, and local levels.

I. Climate Communication, Public Awareness, and Engagement

I-1. Create coordinated and cohesive communication messages and tools on climate change impacts and adaptation, and ensure they are effectively distributed to a wide variety of people and professionals across all	1. Continue to leverage partnerships between state agencies and research organizations to develop clear and consistent messaging on climate change impacts and adaptation. The messages must connect to other priority issues and resonate with people's core values, such as health, safety, and the economy.
	2. Develop targeted climate change risk communication training for communications staff.
	3. Conduct targeted outreach to state and local elected officials, leaders, and staff to share

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levels of government and the public.	information and outreach materials, improve the understanding of risks, and inform decision-making.
	4. Develop communication materials focused on vulnerable communities that are at high risk and have a low capacity to respond, paying particular attention to low-income and underserved populations.
	5. Develop risk maps and decision-support tools to identify climate change risks for specific geographic areas throughout the state.
	6. Support additional research to identify how people perceive climate risks, what messages resonate with people, and how people learn and respond to information about climate change.
I-2. Leverage existing education and outreach networks and integrate communication about climate change.	1. Build on existing networks and integrate climate change into current state agency education and outreach efforts related to public health, land use, ecosystems, water resources, coastal management, agriculture, forests, and infrastructure.
	2. Use a variety of channels to communicate about climate change, such as: • Web sites, agency listservs, newsletters, and news releases. • Social media, including Facebook, Twitter, and video clips. • Climate educator network and climate communicators group. • Presentations at public events. • Publications including Frequently Asked Questions (FAQs).
	3. Promote effective integration of client change education into K-12 educational programs and school curricula.
	4. Bolster the network for climate educators, such as hosting peer-to-peer networking events and summits to share and exchange information, experiences, and best practices.
	5. Encourage universities and community colleges to integrate climate considerations into vocational and educational training programs. For example, provide training for engineering students to incorporate more frequent and severe weather, flooding, sea level rise, or other climate impacts into design.
	6. Build on the climate education website and continue to provide information on existing tools, materials, and best practices in teaching and learning about climate change.
	7. Partner with extension programs to incorporate climate information into community outreach efforts and programs. Build on successful models such as the Washington State University Extension's Carbon Masters program, the Master Gardeners program, and others.
	8. Provide peer-to-peer professional training opportunities and encourage sharing of information among levels of government, nongovernmental organizations, and professional associations.
I-3. Engage the public in climate change conversations and solutions for	1. Develop a framework for citizen engagement and action, modeled after the framework developed in 2007 as part of the Governor's climate change challenge.

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addressing impacts.	2. Develop compelling, visual stories and social media to connect climate change impacts to concerns people already have, convey the benefits of addressing climate change, and demonstrate how actions currently underway can address impacts of climate change.
	3. Partner with scientists, community leaders, and organizations credible to target audiences and those affected directly by the impacts of climate change when delivering messages on climate change to citizens.
	4. Engage the news media and provide information to help citizens make informed choices.
	5. Develop "citizen science" initiatives that engage the public in making observations and collecting and recording data on climate change and its effects on communities and the environment. Build on successful initiatives, such as the Washington King Tides Photo Initiative, Washington Sea Grant citizen science initiatives, National Phenology Network, and Audubon's Christmas Bird Count.
	6. Improve the climate change clearinghouse to make the information more accessible and easier to understand. Build off successful models in other states, such as the Cal-Adapt website and link to existing tools, case studies, projects and portals, such as the Climate Adaptation Knowledge Exchange (CAKE) and the Georgetown Climate Center's Adaptation Clearinghouse.

Appendix D

Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts

Prepared by the University of Washington Climate Impacts Group for the Washington Department of Ecology **Version date: March 21, 2012**

The information provided below is largely assembled from work completed for the 2009 Washington Climate Change Impacts Assessment. Other sources have been used where relevant but this summary should not be viewed as a comprehensive literature review of Pacific Northwest (PNW) climate change impacts. Confidence statements are strictly qualitative with the exception of IPCC text regarding rates of 20th century global sea level rise. Note that periods of months are abbreviated by each month's first letter, e.g., DJF = Dec, Jan, Feb.

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Temperature	Increasing temperatures expected through 21st century Variations in season and annual temperature associated with natural variability (e.g. El Niño and La Niña) will continue to occur even as long term average temperature increases. There is no consensus currently as to how El Niño and La Niña might be affected by climate change.	Projected multi-model change in average annual temperature (with range) for specific benchmark periods: • 2020s: +2°F (1.1 to 3.4°F)** • 2040s: +3.2°F (1.6 to 5.2°F) • 2080s: +5.3°F (2.8 to 9.7°F) These changes are relative to the average annual temperature for 1970-1999. The projected *rate* of warming is an average of 0.5°F per decade (range: 0.2-1.0°F). ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected warming by the end of this century is much larger than the regional warming observed during the 20th century (+1.5°F), even for the lowest scenarios.	Warming expected across all seasons with the largest warming in the summer months (JJA) Mean change (with range) in winter (DJF) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.1°F (0.7 to 3.6°F)** • 2040s: +3.2°F (1.0 to 5.1°F) • 2080s: +5.4°F (1.3 to 9.1°F) Mean change (with range) in summer (JJA) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.7°F (1.0 to 5.3°F)** • 2040s: +4.1°F (1.5 to 7.9°F) • 2080s: +6.8°F (2.6 to 12.5°F)	High confidence that the PNW will warm as a result of increasing greenhouse gas emissions. All models project warming in all scenarios (39 scenarios total) and the projected change in temperature is statistically significant.	Mote and Salathé 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Precipitation *(extreme precipitation addressed in separate field)*	A small increase in average annual precipitation is projected (based on the multimodel average, Mote and Salathé 2010), although model-to-model differences in projected precipitation are large (see "Confidence"). Potentially large seasonal changes are expected.	Projected change in average annual precipitation (with range) for specific benchmark periods: • 2020s: +1% (-9 to 12%)** • 2040s: +2% (-11 to +12%) • 2080s: +4% (-10 to +20%) These changes are relative to the average annual precipitation for 1970-1999. ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected increase in average annual precipitation is small relative to the range of natural variability observed during the 20th century and the model-to-model differences in projected changes for the 21st century	*Summer:* Majority of global climate models (68-90% depending on the decade and emissions scenario) project decreases in summer (JJA) precipitation. Mean change (with range) in JJA precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: -6% (-30% to +12%) ** • 2040s: -8% (-30% to +17%) • 2080s: -13% (-38% to +14%) *Winter:* Majority of global climate models (50-80% depending on the decade and emissions scenario) project increases in winter (DJF) precipitation. Mean change (with range) in DJF precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: +2% (-14% to +23%)** • 2040s: +3% (-13% to +27%) • 2080s: +8% (-11% to +42%)	Low confidence. The uncertainty in future precipitation changes is large given the wide range of natural variability in the PNW and uncertainties regarding if and how dominant modes of natural variability may be affected by climate change. Additional uncertainties are derived from the challenges of modeling precipitation globally. Model to model differences are quite large, with some models projecting decreases in winter and annual total precipitation and others producing large increases. Expect that the region will continue to see years that are wetter than average and drier than average even as that average changes over the long term.	Mote and Salathé 2010; Salathé et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Extreme precipitation	Precipitation intensity may increase but the spatial pattern of this change and changes in intensity is highly variable across the state.	State-wide *(Salathé et al. 2010)*: More intense precipitation projected by two regional climate model simulations but the distribution is highly variable; substantial changes (increases of 5-10% in precipitation intensity) are simulated over the North Cascades and northeastern Washington. Across most of the state, increases are not significant. For sub-regions *(Rosenberg et al. 2010)*: Projected increases in the magnitude (i.e., the amount of precipitation) of 24-hour storm events in the Seattle-Tacoma area over the next 50 years are 14.1%-28.7%, depending upon the data employed. Increases for Vancouver and Spokane are not statistically significant and therefore cannot be distinguished from natural variability An increase in the intensity of the winter season midlatitude storm track in the Northern Hemisphere is expected globally, however there is considerable variation in model results at the regional scale *(O'Gorman 2010, Ulbrich et al. 2008)*.	Projected increases in the magnitude of 24-hour precipitation events for the period 2020-2050 for the Seattle-Tacoma area (14.1 to 28.7%) is comparable to the observed increases for 24-hour events over the past 50 years (24.7%) *(Rosenberg et al. 2009).*	The ECHAM5 simulation produces significant increases in precipitation intensity during winter months (Dec-Feb), although with some spatial variability. The CCSM3 simulation also produces more intense precipitation during winter months despite reductions in total winter and spring precipitation *(Salathé et al. 2010)* Projections for increases in coastal precipitation intensity are for the winter season. There is little information on how summer precipitation intensity may change along the coast or in the interior PNW.	Low confidence for increases in precipitation intensity. Anthropogenic changes in extreme precipitation are difficult to detect given the wide range of natural precipitation variability in the PNW. Computational requirements limit the analysis of sub-regional impacts within Washington to two scenarios, reducing the robustness of possible results. Simulated changes from those two scenarios are statistically significant only over northern Washington. Low confidence for increasing coastal storm track intensity. While there is good agreement across models at the global scale that the intensity of mid-latitude storm tracks is likely to increase, there is considerable variation in model results (and therefore considerable uncertainty) as you move to the regional scale.	Salathé et al. 2010 Rosenberg et al. 2009 Rosenberg et al. 2010 O'Gorman 2010 Ulbrich, U. et al. 2008
Extreme heat	More extreme heat events expected	Increases in extreme heat events are projected for the 2040s, particularly in south central WA and the western WA lowlands *(Salathé et al. 2010).*** Changes in specific regions vary with time period (2025, 2045, and 2085), scenario (low, moderate, high), and region (Seattle, Spokane, Tri-Cities, Yakima) but all four regions and all scenarios show increases in the mean annual	Projected increases in number and duration of events is significantly larger than the number and duration of events between 1980-2006 (specific values vary with location, warming scenario, and time period). In western	n/a (relevant to summer only)	Medium confidence. There is less confidence in sub-regional changes in extreme heat events due to the limited number of scenarios used to evaluate changes in extreme heat events in Jackson et al. 2010 (9 scenarios) and Salathé et al. 2010 (2 scenarios), although confidence in warmer summer temperatures	Salathé et al. 2010 Jackson et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		number of heat events, mean event duration, and maximum event duration *(Jackson et al. 2010, Table 4).* ---------------------------- *** Definitions of extreme heat varied between the two studies cited here. Salathé et al. 2010 defined a heat wave as an episode of three or more days where the daily heat index (humidex) value exceeds 90°F. Jackson et al. 2010 defined heat events as one or more consecutive days where the humidex was above the 99th percentile.*	Washington, the frequency of exceeding the 90th percentile daytime temperature (Tmax) increases from 30 days per year in the current climate (1970-1999) to 50 days per year in the 2040s (2030-2059).		overall is high (see previous entry for temperature).	
Snowpack (SWE)	Decline in spring (April 1) snowpack expected	The multi-model means for projected changes in mean April 1 SWE for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: -27% (B1), -29% (A1B) • 2040s: -37% (B1), -44% (A1B) • 2080s: -53% (B1), -65% (A1B) All changes are relative to 1916-2006. Individual model results will vary from the multi-model average.	Projected declines for the 2040s and 2080s are greater than the snowpack decline observed in the 20th century (based on a linear trend from 1916-2006).	n/a (relevant to cool season [Oct-Mar] only)	High confidence that snowpack will decline even though specific projections will change over time. Projected changes in temperature, for which there is high confidence, have the most significant influence on SWE (relative to precipitation).	Elsner et al. 2010
Glaciers	Decline in glacial volume and summer runoff	Projected declines in the area-averaged volume, or cumulative net balance, of Washington's seven monitored glaciers are as follows: • 2020s: -10 meters, or -3% *(equivalent water loss: 900 billion gallons)* • 2040s: - 20 meters, or -9% *(equivalent water loss: 2 trillion gallons)* • 2060s: - 30m, or -15% *(equivalent water loss: 4 trillion gallons)* All changes are relative to the mid- to late-20th century (roughly 1950s	Projected rate of decline in cumulative net mass balance through mid-century is comparable to the rate of decline observed since the mid-1950s.	Glacial contributions to summer runoff ultimately decline with loss of glacial volume, although increases may be observed in the near-term as summer melt accelerates.	High confidence that glaciers will decline given projected increases in 21st century temperature and detailed glacier monitoring data from that past 50 years showing glacial sensitivity to warming.	Jon Riedel, National Park Service; personal communication based on data published in: - Granshaw and Fountain, 2006 - Riedel and Larrabee, 2011a - Riedel and Larrabee, 2011b

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		through 2007, depending on the glacier). These projections are considered preliminary estimates given 1) data limitations on total glacial volume, and 2) the expectation that changes in volume are nonlinear, meaning the rate of volume change per 1°F of warming is likely to become greater as temperatures increase.				
Streamflow volume	Expected seasonal changes include increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow dominant and rain/snow mix (transient) basins, and decreases in summer streamflow. Increasing risk of extreme high and low flows also expected. In all cases, results will vary by location and basin type.	The multi-model averages for projected changes in mean annual runoff for Washington state for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: +2% (B1), 0% (A1B) • 2040s: +2% (B1), +3% (A1B) • 2080s: +4% (B1), +6% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value *(Elsner et al. 2010)* The risk of lower low flows (e.g., lower 7Q10** flows) increases in all basin types to varying degrees. The decrease in 7Q10 flows is greater in rain dominant and transient basins relative to snow-dominant basins, which generally see less snowpack decline and, as a result, a smaller decline in summer streamflow than transient basins. *(Mantua et al. 2010; Tohver and Hamlet 2010)* Changes in flood risk vary by basin type. Spatial patterns for the 20-year and 100-year flood ratio (future/historical) indicate slight or no increases in flood risk for snowmelt dominant basins due to declining spring snowpack. There is a progressively higher flood risk through the 21st century for	During the period from 1947-2003, runoff occurred earlier in spring throughout snowmelt influenced watersheds in the western U.S. *(Hamlet et al. 2007)*.	Projected changes in mean cool season (Oct-Mar) runoff for WA state: • 2020s: +13% (B1), +11% (A1B) • 2040s: +16% (B1), +21% (A1B) • 2080s: +26%(B1), +35% (A1B) Projected changes in mean warm season (Apr-Sept) runoff for WA state: • 2020s: -16% (B1), -19% (A1B) • 2040s: -22% (B1), -29% (A1B) • 2080s: -33%(B1), -43% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value. *(Elsner et al. 2010)*	*Regarding changes in total annual runoff:* There is high confidence in the direction of projected change in total annual runoff but low confidence in the specific amount of projected change due to the large uncertainties that exist for changes in winter (Oct-Mar) precipitation. The large uncertainties in winter precipitation are due primarily to uncertainty about the timing of, and any changes in, dominant models of natural decadal variability that influence precipitation patterns in the PNW (e.g. the Pacific Decadal Oscillation) as well as changes in precipitation caused by climate change. *Regarding streamflow timing shifts:* There is high confidence that peak streamflow will shift earlier in the season in transient and snow-dominant systems due to projected warming and loss of April 1 SWE. There is less confidence in the specific	Elsner et al. 2010 Hamlet et al. 2007 Mantua et al. 2010 Tohver and Hamlet 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		transient basins, although changes in risk in individual transient basins will vary. Projections of flood risk for rain dominant basins do not indicate any significant change under future conditions, although increases in winter precipitation in some scenarios nominally increase the risk of flooding in winter. *(Tohver and Hamlet 2010, in draft)* ---------------------------- *** 7Q10 flows are the lowest stream flow for seven consecutive days that would be expected to occur once in ten years.*			size of the shift in any specific basin given uncertainties about changes winter precipitation *(see previous comment)*. *Regarding summer streamflows:* Overall, there is high confidence that summer streamflow will decline due to projected decreases in snowpack (relevant to snow dominant and transient basins) and increasing summer temperatures (relevant to all basin types). There is medium confidence that late summer streamflow will decline given 1) the sensitivity of late summer streamflow to uncertain precipitation changes, and 2) uncertainties about if and how groundwater contributions in any given basin may affect late summer flows. For all changes in streamflow, confidence in *specific* projected values is low due to high uncertainty about changes in precipitation and decadal variability.	
Stream temperature	Summer stream temperatures are expected to increase and to remain elevated for longer periods of the summer. Impacts on juvenile	Annual maximum temperature for the B1 and A1B scenarios is projected to increase less than 1.8°F at most stations by the 2020s. By the 2080s, many stations both east and west of the Cascades are likely to warm by 3.6°F to 9°F. Because baseline water temperatures in eastern Washington are generally	In eastern Washington, the percentage of streams analyzed by Mantua et al. 2010 with temperatures lethal to juvenile salmon (>71°F) increases from 20%	*For spring temperatures:* Warmer average temperatures in streams that currently experience cool spring temperatures *increases* juvenile growth, while warmer average temperatures in streams that already	High confidence that stream temperatures will increase, although there will be significant variation in location and magnitude of change.	Mantua et al. 2010 Beer and Anderson 2011

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
	salmon will vary depending on the species and location.	warmer than in western Washington, more streams in eastern Washington become stressful to salmon than in western Washington (Mantua et al. 2010). Periods where water temperatures exceed 69°F, a threshold where water temperatures become especially unfavorable for salmon, are projected to lengthen from 1-5 weeks historically (1980s) to 10-13 weeks by the 2080s (Mantua et al. 2010).	to 41% by the 2080s, relative to the 1980s. In western, Washington, the percentage of streams with temperatures lethal to juvenile salmon (>71°F) increases from approximately 2% to approximately 14% by the 2080s, relative to the 1980s.	experience warm spring temperatures *reduces* the duration of optimal conditions for growth (Beer and Anderson 2011). *For summer temperatures:* A loss of snow enhances growth in cool summer streams and decreases growth in warm summer streams (Beer and Anderson 2011). Increases in summer water temperature will be exacerbated by loss of glaciers as sources of particularly cold water.		
Sea level	Varying amounts of sea level rise (or decline) projected in Washington due to regional variations in land movement and coastal winds.	Projected global change (2090-2099) according to the IPCC: 7-23", relative to 1980-99 average *(Solomon et al. 2007)*** 2050: Projected medium change in Washington sea level (with low to high range) *(Mote et al. 2008)*: • NW Olympic Pen: 0" (-5-14") • Central & So. Coast: 5" (1-18") • Puget Sound: 6" (3-22") 2100: Projected medium change in WA sea level (with low to high range) *(Mote et al. 2008)*: • NW Olympic Peninsula: 2" (-9-35") • Central & So. Coast: 11" (2-43") • Puget Sound: 13" (6-50") ----------------------------- *** Since 2008, numerous peer-*	Relative change in Washington varies by location. Globally, the average rate of sea level rise during the 21st century very likely‡ (>90%) exceeds the 1961-2003 average rate (0.07 $\pm$ 0.02 in/year) *(Solomon et al. 2007)* --------------------------- *‡ = as defined by the IPCC's treatment of uncertainties (Solomon et al. 2007, Box TS1)*	Wind-driven enhancement of PNW sea level is common during winter months (even more so during El Niño events). On the whole, analysis of more than 30 scenarios found minimal changes in average wintertime northward winds in the PNW. However, several models produced strong increases. These potential increases contribute to the upper estimates for WA sea level rise. *(Mote et al. 2008)*	High confidence that sea level will rise globally. Confidence in the amount of change at any specific location in Washington varies depending on the amount of uncertainty associated with the global and local/regional factors affecting rates of sea level rise. Regionally, there is high confidence that the NW Olympic Peninsula is experiencing uplift at >2 mm/yr. There is less confidence about rates of uplift along the central and southern WA coast due to sparse data, but available data generally indicate	Mote et al. 2008 Solomon et al. 2007

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		reviewed studies have offered alternate estimates of global sea level rise. The basis for these updates are known deficiencies in the IPCC's 2007 approach to calculating of global sea level rise, including assumptions of a near-zero net contribution from the Greenland and Antarctic ice sheets to 21st century sea level rise. A comparison of several studies in Rahmstorf 2010 (Figure 1) shows projections in the range of 1.5ft to over 6ft. Overall, recent studies appear to be converging on projected increases in the range of 2-4ft (e.g., Vermeer and Rahmstorf (2009), Pfeffer et al. 2008, Grinsted et al. 2009, Jevrejeva et al. 2010).			uplift in range of 0-2mm/yr. There is high uncertainty about subsidence, and rates of subsidence where it exists, in the Puget Sound region. Although annual rates of current and future uplift and subsidence (a.k.a. "VLM") are well-established at large geographic scales, determining rates at specific locations requires additional analysis and/or monitoring. Uncertainties around future rates are unknown and would be affected by the occurrence of a subduction zone earthquake.	
Wave Heights	Increase in "significant wave height" ** and extreme significant wave heights (98^{th} or 99^{th} percentile) expected based on research showing that a future warmer climate may contain fewer overall extra-tropical cyclones but an increased frequency of very intense extra-tropical cyclones (which may affect the extreme wave climate). ------------------ *** "Significant wave height" is defined as the average of*	No quantified projected changes available at this time.	Positive long-term trends in the range of +2 to +4 cm/yr in extreme significant wave heights (98th percentile) were observed between 1985-2007 along the west coast of the U.S., particularly in California and to a lesser degree Oregon and Washington (Menendez et al. 2008). These increases are due at least in part to El Niño and the Pacific/North American pattern of climate variability. Similar results were found by Mendez et al. 2010 and Young et al. 2011 for the	Winter season (Oct-March) is the dominant season of strong storms and significant wave events.	There is low confidence that significant wave height will increase given the dependence of this increase on a limited number of studies showing potential increases in the intensity of the extra-tropical cyclones that can affect the extreme wave climate.	Menendez et al. 2008 Mendez et al. 2010 Ruggiero et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
	the highest 1/3 of the measured wave heights within a (typically) 20 minute period		same or similar time periods. Mendez et al. 2010 also found that the rate of increase in extreme wave heights was greater than the rate of increase in mean monthly wave heights, which were also found to be increasing but not in a statistically significant way.			
Sea surface temperature (SST)	Warmer SST expected	Increase of +2.2°F projected for the 2040s (2030-59) for coastal ocean between 46°N and 49°N. Changes are relative to 1970-99 average.	Projected change is substantially outside the range of 20th century variability.	*No information currently available*	Medium to low confidence in the degree of warming expected for the summertime upwelling season. Global climate models do not resolve the coastal zone and coastal upwelling process very well, and uncertainty associated with summertime upwelling winds also brings uncertainty to coastal SSTs in summer.	Mote and Salathé 2010
Coastal upwelling	Little change in coastal upwelling expected	The multimodel average mean change in winds that drive coastal upwelling is minimal	Comparable to what has been observed in the 20th century	Little change in seasonal patterns.	Low confidence given the fact that this hasn't been evaluated with dynamical downscaling of many climate model scenarios at this point.	Mote and Salathé 2010
Ocean acidification	Continuing acidification expected in coastal Washington and Puget Sound waters	The global surface ocean is projected to see a 0.2 - 0.3 drop in pH by the end of the 21st century (in addition to observed decline of 0.1 units since 1750) (Feely et al. 2010). pH in the North Pacific, which includes the coastal waters of	Projected global changes are larger than the decrease of 0.1 units since 1750, and greater than the trend in last 20 years (0.02 units/decade).	The contribution of ocean acidification to Dissolved Inorganic Carbon (DIC) concentrations within the Puget Sound basin can vary seasonally. Ocean acidification has a	For global changes, confidence that oceans will become more acidic is high. Results from large-scale ocean CO_2 surveys and time-series studies over	Feely et al. 2009 Feely et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO2 to 560 and 840 ppm, respectively (Feely et al. 2009). This decrease in pH is equivalent to a 100-150% increase in the acidity of the oceans. pH in Puget Sound is projected to decrease, with ocean acidification accounting for an increasingly large part of that decline. Feely et al. 2010 estimated that ocean acidification accounts for 24-49% of the pH decrease in the deep waters of the Hood Canal sub-basin of Puget Sound relative to estimated pre-industrial values. Over time, ocean acidification from a doubling of atmospheric CO2 could account for 49-82% of the pH decrease in Puget Sound subsurface waters.	The observed decrease of 0.1 units since 1750 is equivalent to a 26% increase in the hydrogen ion concentration or "acidity".	smaller contribution to the subsurface increase in DIC concentrations in the summer (e.g., 24%) compared to winter (e.g., 49%) relative to other processes (Feely et al. 2010).	the past two decades show that ocean acidification is a predictable consequence of rising atmospheric CO_2 that is independent of the uncertainties and outcomes of climate change (Feely et al. 2009). For Puget Sound, estimates of the contribution of ocean acidification to future pH decreases in Puget Sound have very high uncertainty since other changes that may occur over the intervening time were not taken into account when calculating that estimate (a percentage) (Feely et al. 2010).	

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