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Lara Whitely Binder

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The U.S. Pacific Northwest (PNW, comprised of the states of Washington, Oregon, and Idaho) is a region of diverse landscapes and equally diverse climate change challenges. The Climate Impacts Group (CIG) at the University of Washington was established in 1995 to research the impacts of natural climate variability and anthropogenic climate change on the PNW. The goal of this research is to help the region become more resilient to climate impacts by providing information that is useful to, and used by, decision makers. The team's research over the last decade has contributed to a substantive understanding of how climate affects the PNW environment and its communities, and the importance of preparing for climate impacts at the state and local level, particularly with respect to climate change.

Projected 21st Century PNW Climate Change Impacts

CIG analysis of twenty global climate models, run with two global greenhouse gas emissions scenarios (B1 and A1B) finds that average annual temperature in the PNW is projected to increase appreciably through the twenty-first century, while changes in average annual precipitation are likely to be modest.[1] (Table 1.) The projected *rate* of warming is 0.5 degree Fahrenheit per decade (range: 0.2 to 1.0 degree Fahrenheit) through the first half of the 21st century, with the rate of warming in the second half of the century largely depending on the choice of emissions scenarios. For comparison, the observed rate of warming for the 20th century was approximately 0.2 degree Fahrenheit per decade. Warming is expected in all seasons, with the greatest warming occurring during the summer months.

* Outreach Specialist at the University of Washington's Climate Impacts Group.

1. JOSEPH H. CASOLA ET AL., CLIMATE IMPACTS GROUP, CLIMATE IMPACTS ON WASHINGTON'S HYDROPOWER, WATER SUPPLY, FORESTS, FISH, AND AGRICULTURE 10-12 (2005), *available at* www.cses.washington.edu/db/pdf/kc05whitepaper459. pdf.

Changes in Annual Mean		
	Temperature	Precipitation
2020s		
Low	+1.1°F *(0.6°C)*	-9%
Average	+2.2°F *(1.2°C)*	+1%
High	+3.4°F *(1.9°C)*	+12%
2040s		
Low	+1.6°F *(0.9°C)*	-11%
Average	+3.5°F *(2.0°C)*	+2%
High	+5.2°F *(2.9°C)*	+12%
2080s		
Low	+2.8°F *(1.6°C)*	-10%
Average	+5.9°F *(3.3°C)*	+4%
High	+9.7°F *(5.4°C)*	+20%

Table 1. Average changes in PNW climate from twenty climate models and two greenhouse gas emissions scenarios (B1 and A1B) for the 2020s, 2040s, and 2080s. All changes are benchmarked to average temperature and precipitation for 1970-1999

Changes in precipitation are less certain than changes in temperature, given the difficulties of modeling precipitation at both the global and regional scale. Average annual precipitation is projected to increase only 1 percent to 2 percent by mid-century relative to average annual precipitation for 1970-1999. Most models project increases in winter precipitation and decreases in summer precipitation. Changes in the frequency, duration, and/or intensity of extreme precipitation events are even less certain, although preliminary research by the CIG suggests an increased risk for more frequent extreme precipitation events in the PNW by the second half of the 21st century.[2]

The temperature and precipitation changes projected for the PNW are expected to have wide ranging impacts in the region, including the following (CIG 2007):

- ***Declining winter snowpack.*** The PNW is highly dependent on temperature-sensitive winter snowpack to meet growing, and often competing, water demands for municipal and industrial uses, agricultural irrigation, hydropower production, navigation, recreation, and instream flow management for threatened and endangered species.

2. Eric P. Salathé, *Influences of a Shift in North Pacific Storm Tracks on Western North American Precipitation under Global Warming*, 33 GEOPHYSICAL RESEARCH LETTERS 1, 3 (2006).

Consequently, a major concern is the impact of climate change on PNW winter snowpack. Warmer winter temperatures lead to more winter precipitation falling as rain rather than snow, particularly in mid-elevation basins where a few degrees of warming pushes average winter temperatures above freezing for longer periods of the winter season. Warmer spring temperatures also contribute to earlier spring snowmelt. April 1 snowpack is projected to decline as much as 41 percent in the Washington Cascades by the 2040s as a result of lower winter snowpack and earlier spring snowmelt.[3]

- ***Shifts in streamflow timing.*** Changes in the timing and volume of snowpack-dependent streamflows have important implications for water supply management, hydropower production, flood risk, and instream flow management for salmon. Projections for more winter rain mean increased winter streamflows. Warmer spring temperatures shift peak spring runoff earlier into the spring, increasing early spring streamflows while decreasing late spring streamflows. Lower winter snowpack and earlier spring snowmelt also contribute to lower summer streamflows. Mid-elevation basins are likely to see the greatest shifts in streamflow due to their sensitivity to small changes in temperature.[4]

3. CLIMATE IMPACTS GROUP, *supra* note 1, at 14-16.
4. *Id.* at 17.

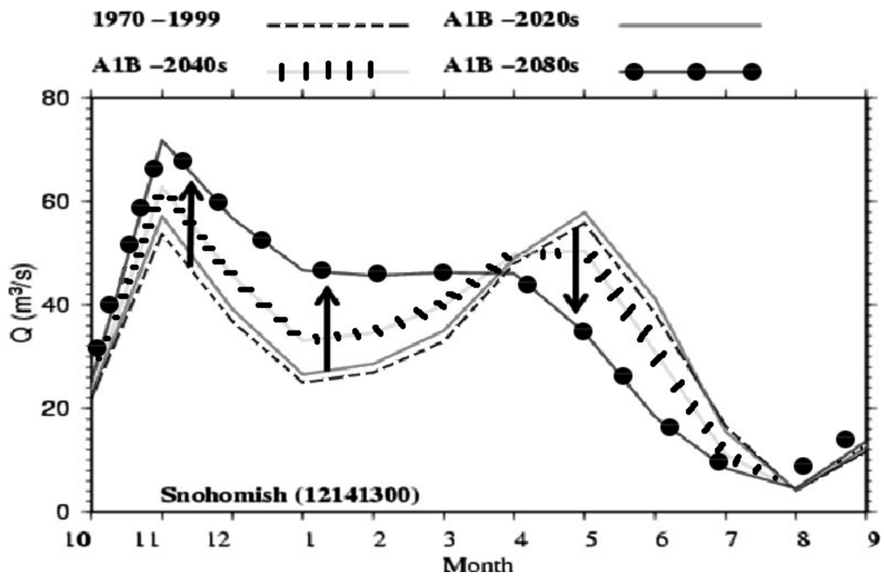

Figure 1. Projected impacts of climate change on streamflow in the Snohomish River (WA) for the 2020s, 2040s, and 2080s using temperature changes from the A1B greenhouse gas emissions scenario. All changes are relative to average annual streamflow for the period 1970-1999.

- ***Increasing vulnerability to drought.*** The region's vulnerability to drought increases due to the combined effects of declining snowpack, shifts in streamflow timing, limited surface water storage, and growing demands from population growth and warming temperatures. Declining snowpack and changes in streamflow timing are likely to make it more difficult to satisfy competing water demands, especially during the summer months.[5]

- ***Changes in flood risk.*** Warmer temperatures and the potential for more winter rain increase the risk of winter flooding in many western Washington and Oregon watersheds.[6] The risk of spring flooding, which is more common in the interior PNW, decreases as a result of lower spring snowpack. Changes in urban storm water flooding are unknown at this time because these types of flood events are driven by the frequency and intensity of individual storm events. These individual storm events are

5. *Id.* at 14.

6. Alan F. Hamlet & Dennis P. Lettenmaier, *Effects of 20th Century Warming and Climate Variability on Flood Risk in the Western* U.S.. 43 WATER RES. RESEARCH (2007).

difficult to capture in global climate models that are designed to capture changes in seasonal averages.[7]

- ***Increasing threats to forests.*** Unless summer precipitation increases, warmer summer temperatures and earlier spring snowmelt will increase the risk of forest fires in the PNW by increasing summer moisture deficits. Drought stress and warmer temperatures will decrease tree growth in most low- and mid-elevation forests. It will also increase the frequency and success of mountain pine beetle and other insect attacks, further increasing fire risk and affecting timber production. Over longer periods of time, forest composition and extent are expected to change as species' biogeography adapts to climate changes. The benefits to forest productivity of increased carbon dioxide concentrations in the atmosphere are uncertain but are likely to be limited, and will be nonexistent in areas where summer moisture deficits limit productivity.[8]

- ***Changes in agriculture.*** Decreasing irrigation supplies and increased competition from weeds, pests, and disease are likely to affect agricultural production, although impacts and the potential for adaptation will vary strongly by crop type.[9]

- ***Increasing threats to salmonids.*** The PNW is home to 19 threatened and endangered salmonid species, including the first listing of a threatened species in a heavily populated area (Puget Sound Chinook).[10] Salmon are affected by climate change across all life stages. In the freshwater environment, higher winter streamflows increase the risk for more streambed scouring events that damage salmon spawning nests. Earlier peak streamflows may flush juvenile salmon into estuaries before they are physically mature enough for the transition, increasing the risk of predation and other stresses. Lower summer streamflows and warmer water temperatures increase the

7. CLIMATE IMPACTS GROUP, *supra* note 1, at 32.

8. *Id.* at 33.

9. *Id.* at 39.

10. NOAA FISHERIES, ENDANGERED SPECIES ACT STATUS OF WEST COAST SALMON & STEELHEAD (2008), *available at* http://www.nwr.noaa.gov/ESA-Salmon-Listings/upload/snapshot0208.pdf.

potential for more unfavorable summer stream conditions for salmon in many parts of the PNW. Climate change impacts in the marine environment, where salmon spend one to four years of their life, are uncertain at this time.[11]

- ***Changes in hydropower production***. Approximately 70 percent of the PNW's energy needs are provided by hydropower. Warmer winter temperatures will likely reduce winter electricity demand while higher winter streamflows increase winter electricity generation. Conversely, warmer summer temperatures will likely increase summer electricity demands while reduced summer streamflows decrease summer electricity generation. Management tradeoffs between summer hydropower production and other water uses are expected to increase.[12]

- ***Increasing threats to human health***. Climate change is expected to lead to more frequent and/or more intense summer heat waves in the PNW. Warmer air temperatures are also expected to contribute to higher ground-level ozone concentrations in urban areas and alter the habitat and range of disease reservoirs and vectors (e.g., mosquitoes). The most vulnerable populations to these and other human health impacts include infants, children, the elderly, the mentally ill, and the poor.[13]

Sea level is also projected to rise in the region. Sea level rise in the PNW is determined by global rates of sea level rise, changes in vertical land elevation associated with plate tectonics, and atmospheric dynamics that influence wind-driven "pile up" of waves along the coast. A medium estimate of sea level rise for the Puget Sound basin, which holds the greatest concentration of the region's population, is 13 inches by 2100. However, higher levels (up to 50 inches by 2100) cannot be ruled out in part due to uncertainties about accelerating rates of ice melt from Greenland and Antarctica in recent years.[14] Increasing sea levels will lead to permanent inundation of low-lying areas and may increase the risk of flooding, erosion, salt water intrusion into coastal aquifers, and loss of valuable near-shore habitat.

11. CLIMATE IMPACTS GROUP, *supra* note 1, at 35.

12. *Id.* at 24.

13. CLIMATE IMPACTS GROUP, *supra* note 1, at 43.

14. PHILLIP MOTE ET AL., SEA LEVEL RISE SCENARIOS FOR WASHINGTON STATE 1, 10 (2008), *available at* http://www.cses.washington.edu/db/pdf/moteetalslr 579 .pdf.

The Case for Adaptive Planning at the State and Local Level

Growing evidence that climate change is underway[15] and the realization that substantive reductions in greenhouse gas emissions will not be made in time to avoid many of the projected impacts of climate change are contributing to an emerging awareness of the need to prepare for climate change impacts. The case for adaptive planning at the state and local level is clear when considering the following points:

- Significant climate change impacts are projected, and the impacts expected within the next few decades are largely unavoidable due to current and projected greenhouse gas concentrations in the atmosphere.[16]

- Local, regional, and state governments are on the "front line" for dealing with climate change impacts. Managing the risks associated with climate change is an inherent part of what a government is expected to do, as part of ensuring the safety, health, and welfare of the community.[17]

- Decisions with long-term impacts are being made every day, and today's choices will shape tomorrow's vulnerabilities.

- Significant time is required to motivate and develop adaptive capacity and to implement changes. This is not only a matter of changing rules and regulations, but also of changing institutional cultures so that planning for climate change is a function of risk management, not simply of "being green."[18]

- Preparing for climate change may lead to new economic opportunities and reduce future costs. In many (if not

15. Intergovernmental Panel on Climate Change, *Contribution of Working Group II to the Fourth Assessment Report of the International Panel on Climate Change*, *in* CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY 976 (Martin Parry et al. eds., Cambridge University Press 2007).

16. AMY K. SNOVER ET AL., PREPARING FOR CLIMATE CHANGE: A GUIDEBOOK FOR LOCAL, REGIONAL, AND STATE GOVERNMENTS 1, 15-20 (2007), *available at* http://www.cses.washington.edu/cig/fpt/guidebook.shtml.

17. *Id.* at 27-28.

18. *Id.*

most) cases, it will cost more to retrofit for climate resilience than to build for it in the first place.[19]

- Planning for climate change can benefit the present. For example, more comprehensive water conservation planning provides benefits for present-day droughts as well as future droughts that may become more intense and/or frequent as a result of climate change.[20]

Adapting to Climate Change in the Pacific Northwest

The PNW is well-positioned for adapting to climate change for several reasons. First, current information on *regional and local* climate change impacts is available from a trusted source. The CIG began research on PNW climate impacts in 1995. The CIG's longevity has allowed the team to develop a comprehensive body of ongoing research that is available to decision makers as they begin evaluating the need for adaptive planning. This longevity has also given PNW decision makers time to become familiar with climate impacts, and has established the CIG as a trusted resource on climate science and impacts.

A central purpose of CIG's research is to support adaptive planning in the PNW. The CIG has developed (or is developing) a wide array of decision support materials to facilitate planning for climate change in the PNW, including the following:

- **CIG website**. The CIG website is a resource for the public and the media. Features such as overviews of PNW climate and climate change impacts, summaries of ongoing CIG research, the CIG's quarterly electronic newsletter, a comprehensive listing of CIG publications, sample presentations from the CIG, the monthly climate outlook, and free access to regionally downscaled climate change data help keep the public informed of the latest developments in regional climate change science.[21]

- **Climate change scenarios for planning**. The CIG makes freely available on its website all temperature and precipitation data from its downscaled global climate model simulations to support planning efforts in the

19. *Id*. at 12, 26.
20. *Id*. at 27.
21. *See* http://www.cses.washington.edu/cig.

PNW.[22] Additionally, climate change streamflow scenarios for more than 200 streamflow locations around Washington State will be made available on the website in 2009.

- **Publications.** The CIG publishes its research results extensively in peer-reviewed scientific journals, as well as producing white papers and other technical support documents for PNW decision makers.[23]

- **Adaptation planning guidebook**. In September 2007, the CIG and King County Washington, in partnership with ICLEI–Local Governments for Sustainability, released *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*.[24] The guidebook, which is written for a national audience, provides detailed guidance on developing and implementing a climate change adaptation plan. More than 900 copies of the guidebook have been downloaded and 250 hard copies distributed by the CIG to interested parties around the world since its release in September 2007.

- **Presentations, guest lectures, and briefings.** CIG researchers and staff give over 150 presentations annually to a wide variety of Federal, State, local, and tribal decision makers, private sector leaders, the general public, researchers, and the academic community.

- **Consultancies and technical assistance.** CIG researchers often work directly with resource managers and policy makers on issues related to assessing and integrating climate impacts into planning processes. This includes working with decision makers on issues related to the use of climate forecasts and planning tools, assisting with specific planning studies, and fielding general questions from decision makers on an as-needed basis.

Through these and other activities, the CIG has forged important relationships with its stakeholder community that have helped the region become a national leader in addressing the climate change problem.

22. *See* http://www.cses.washington.edu/cig/fpt/ccscenarios.shtml.

23. *E.g.*, MOTE ET AL., *supra* note 14; CLIMATE IMPACTS GROUP, *supra* note 1.

24. SNOVER ET AL., *supra* note 16.

Additional climate research groups in Oregon and Idaho will bolster the region's knowledge base. The Oregon State Legislature established the Oregon Climate Change Research Institute (OCCRI) in 2007 to coordinate research on Oregon climate change impacts within the state's university system. OCCRI will develop Oregon's research agenda with input from university researchers, business leaders, government officials, and others. OCCRI will also serve as a clearinghouse for climate change information, provide climate change information to the public, and provide technical assistance to local governments on mitigating and preparing for climate change.[25]

In Idaho, a new research program on climate and water has been funded through the National Science Foundation's EPSCoR Research Infrastructure Improvement grant program. The *Water Resources in a Changing Climate* program will support research at the University of Idaho, Boise State University, and Idaho State University on the hydrologic impacts of climate change in Idaho. This includes research aimed at improving modeling of surface and ground water resources affected by climate change, integrating hydrology and economic modeling in the Snake River basin, and integrating hydrology and ecological change in the Salmon River basin. The program also includes an active outreach component linking the research community with state and federal agencies, irrigation districts, Idaho Power, the agricultural community, and other stakeholders.

Second, the science on regional climate change impacts is compelling. Research from the CIG and others clearly demonstrates the need for adaptation planning. Declining snowpack-dependent water supplies, greater wildfire risk, additional stresses on threatened and endangered salmon species, additional stress on aging stormwater infrastructure, and the long-term threat of sea level rise to coastal communities (including many of the region's largest population centers) carry tangible costs to local economies.

Third, a strong environmental ethic exists in many parts of the PNW, particularly in the heavily populated Puget Sound region of Washington State and Oregon's Willamette Valley.[26] This environmental ethic, which is carried into regional and state politics, creates a culture that is generally supportive of efforts to address climate change and effectively gives government leaders a "green light" for taking action on climate change.[27]

25. *E.g.*, CLIMATE IMPACTS GROUP, HB 1303 INTERIM REPORT: A COMPREHENSIVE ASSESSMENT OF THE IMPACTS OF CLIMATE CHANGE ON THE STATE OF WASHINGTON (2007), *available at* http://www.cses.washington.edu/db /pdf/cighb1303interim580.pdf.

26. Allen Mazur & Eric W. Welch, *The Geography of American Environmentalism*, *in* 2 ENVIRONMENT SCIENCE & POLICY 389, 392-95 (1999).

27. *Id.* at 395.

In fact, the PNW provides several examples of early leadership in preparing for climate change. The City of Olympia, Washington, is a low-lying city at the southern end of Puget Sound and is Washington's State Capitol.[28] Much of Olympia's downtown sits one to three feet above the current highest high tides.[29] Sea level rise projections increase the risk of flooding and other damage to the downtown area, the Port of Olympia, and the city's primary drinking water source.[30] Concern about sea level rise contributed to the city's decision to relocate its primary drinking water source from a low-lying surface water source to an upgradient wellfield.[31] The city also moved the planned location of a new City Hall to an area that is less vulnerable to sea level rise than the originally proposed location, and raised the building's foundation by one foot to reduce the potential for damage.

In February 2008, the City of Olympia allocated $150,000 to improve the geophysical and hydrologic data needed to monitor and prepare for sea level rise.[32] In particular, the city will install two Global Positioning System stations in downtown Olympia to monitor changes in vertical land elevation (e.g., subsidence).[33] The city will use LIDAR technology to improve the accuracy of downtown topographical elevations; improve modeling of downtown stormwater pipes, streams, and marine waters for evaluating the interaction of the stormwater system and streamflows with rising sea level.[34] The city will also develop a three- to ten-year work plan for quantifying risks and implementing adaptive actions.[35]

King County, Washington, is another leading community in the PNW. King County is home to more than 1.8 million people and includes Seattle, the PNW's most populous city.[36] In March 2006, King County Executive Ron Sims issued an executive order directing the county to reduce greenhouse gas emissions and to anticipate and adapt to projected climate change impacts.[37] The county now has a climate change adaptation team and

28. SNOVER ET AL., *supra* note 16, at 86.

29. *Id.* at 85.

30. *Id.*

31. *Id.*

32. CITY OF OLYMPIA. SEA LEVEL RISE ANALYSIS: 2008 DRAFT SCOPE OF WORK 2 (2008), *available at* http://www.ci.olympia.wa.us/documents/OlympiaPlanningCommission/050508/040708DRAFT.pdf.

33. *Id.*

34. *Id.*

35. CITY OF OLYMPIA. *supra* note 32, at 2.

36. SNOVER ET AL., *supra* note 16, at v.

37. *Id.* at 63.

develops an annual climate mitigation and adaptation plan.[38] Recognizing the need for guidance on preparing for climate change, King County partnered with the CIG in 2006 to write a guidebook for local governments on preparing for climate change as described previously.

Adaptation actions within the county include efforts to address the increased flood risk associated with climate change.[39] In 2007, King County approved plans for a regional flood district funding source to fund repairs to more than 500 levees and revetments in the county. Additionally, the county will also widen the span of more than 57 "short span" bridges to allow more debris and floodwater to pass underneath. The county is also incorporating low impact development techniques such as porous concrete and rain gardens into road projects to better manage stormwater runoff during heavy rains, which may increase with climate change.

Leadership on adaptation planning is also evident at the state level. In 2007, Washington State convened five stakeholder working groups to develop state-level adaptation recommendations in five key sectors: water, agriculture, forests, coasts and infrastructure, and human health.[40] Recommendations included improving drought planning, improving monitoring of diseases and pests that may affect humans, forests, or agriculture, incorporating sea level rise in state-mandated coastal planning, and public education. The recommendations were forwarded to the governor in February 2008. An implementation strategy for the recommendations is currently being developed.

The State of Oregon released its recommendations for climate change mitigation and adaptation in January 2008.[41] The report, developed through a multi-stakeholder working group process, provided ten key recommendations for improving Oregon's capacity to mitigate and adapt to climate change.[42] The first recommendation called for beginning preparation for climate change immediately. Another recommendation, noted previously, calls for developing a coordinated research agenda in the Oregon university system to investigate climate change impacts in Oregon. Other recommendations include developing and implementing a public education and outreach program, incorporating climate change into planning processes, and providing the support and infrastructure needed to help Oregon institutions and businesses prepare for climate change.

38. *Id.* at 62.

39. *Id.* at v.

40. *Id.* at 32.

41. OR. CLIMATE CHANGE INTEGRATION GROUP, OR. DEP'T OF ENERGY, FINAL REPORT TO THE GOVERNOR: A FRAMEWORK FOR ADDRESSING RAPID CLIMATE CHANGE (2008), *available at* www.oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf.

42. *Id.* at 7-11.

Government interest in adapting to climate change has shifted dramatically in the PNW over the last several years. Leading efforts by Olympia, King County, Washington State, Oregon State, and other communities around the region demonstrate that preparing for climate change is both possible and is an inherent responsibility of local and state government. However, adapting to climate change will require a sustained commitment to monitoring developments in global and regional climate change science, integrating this information into planning, and periodically re-evaluating and adjusting the assumptions that have shaped adaptation plans. Difficult choices will have to be made. While it is too early to know if this commitment will be sustained over the long run, the fact that a growing number of communities are starting an adaptation dialogue is encouraging and has the potential to bring about substantive improvements in the PNW's capacity to adapt to climate change.

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