Exhibit ___ (YKGM-5)
Docket Nos. UE-040640, et al.
Witness: Yohannes K.G. Mariam

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, Complainant, v. PUGET SOUND ENERGY, INC. Respondent.	DOCKET NO. UG-040640 DOCKET NO. UE-040641 *(consolidated)*

EXHIBIT TO TESTIMONY OF

Yohannes K.G. Mariam

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

Streamflow Publications

September 23, 2004

Declining Mountain Snowpack in Western North America

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Abstract.

In western North America, snow provides crucial storage of winter precipitation, effectively transferring water from the relatively wet winter season to the typically dry summers. Manual and telemetered measurements of spring snowpack, corroborated by a physically-based hydrologic model, are examined here for climate-driven fluctuations and trends during the period 1916-2002. Much of the mountain West has experienced declines in spring snowpack, especially since mid-century, and despite increases in winter precipitation in many places. Analysis and modeling shows that climatic trends are the dominant factor, not changes in land use, forest canopy, or other factors. The largest decreases have occurred where winter temperatures are mild, especially in the Cascade Mountains and Northern California. In most mountain ranges, relative declines grow from minimal at ridgetop to substantial at snowline. Taken together, these results emphasize that the West's snow resources are already declining as Earth's climate warms.

Capsule.
The West's snow resources are already declining as the climate warms.

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ABSTRACT

Hydroclimate of the Western United States Based on Observations and Regional Climate Simulation of 1981–2000. Part II: Mesoscale ENSO Anomalies

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(Manuscript received 13 March 2002, in final form 22 August 2002)
ABSTRACT

The hydroclimate of the western United States is influenced by strong interannual variability of atmospheric circulation, much of which is associated with the El Nin˜o–Southern Oscillation (ENSO). Precipitation anomalies during ENSO often show opposite and spatially coherent dry and wet patterns in the Northwest and California or vice versa. The role of orography in establishing mesoscale ENSO anomalies in the western United States is examined based on observed precipitation and temperature data at 1/88 spatial resolution and a regional climate simulation at 40-km spatial resolution. Results show that during El Nin˜o or La Nin˜a winters, strong precipitation anomalies are found in northern California, along the southern California coast, and in the northwest mountains such as the Olympic Mountains, the Cascades, and the northern Rockies. These spatial features, which are strongly affected by topography, are surprisingly well reproduced by the regional climate simulation.

A spatial feature investigated further is the positive–negative–positive precipitation anomaly found during El Nin˜o years in the Olympic Mountains, and on the west side and east side of the Cascades in both observations and regional simulation. Observed streamflows of river basins located in those areas are found to be consistent with the precipitation anomalies. The spatial distribution of the precipitation anomalies is investigated by relating flow direction and moisture to the orientation of mountains and orographic precipitation. On the west side of the north–south-oriented Cascade Range, the increase in atmospheric moisture is not enough to compensate for the loss of orographic precipitation associated with a change in flow direction toward the southwest during El Nin˜o years. In California, both the increase in atmospheric moisture and shift in wind direction toward the southwest enhance precipitation along the Sierra, which is oriented northwest to southeast. The spatial signature of the interactions between large-scale circulation and topography may provide useful information for seasonal predictions or climate change detection.

VARIABILITY AND TRENDS IN MOUNTAIN SNOWPACK IN WESTERN NORTH AMERICA

Philip W. Mote1, Martyn Clark, and Alan F. Hamlet

5. CONCLUSIONS

We have demonstrated that the widespread decline in springtime SWE noted by Mote (2003) in the Northwest is broadly true in the West. In parts of the southwest, large increases in winter precipitation have successfully offset the decreases driven by warming. The Oregon Cascades experienced the largest losses in the region owing to a combination of high temperature sensitivity and declines in precipitation.

Owing to the uneven distribution of snow course locations, and their tendency to be sited in relatively flat locales in the mountains (valleys and benches), it is not possible to aggregate these data up to a regional scale. However, simulations with a hydrological model to be presented elsewhere (see Paper P2.8) corroborate the main snow course results and permit valid regional averaging.

CHAPTER 9
POTENTIAL CONSEQUENCES OF CLIMATE VARIABILITY AND CHANGE FOR THE PACIFIC NORTHWEST

Edward A. Parson[1,2], with contributions from members of the Pacific Northwest Assessment Team: Philip W. Mote[3],Alan Hamlet[4], Nathan Mantua[5],Amy Snover[6], William Keeton[7], Ed Miles[8], Douglas Canning[9], Kristyn Gray Ideker[10]

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Climate of the Past Century

• Over the 20th century, annual-average temperature in the Northwest rose 1 to 3°F (0.6 to 1.7°C) over most of the region,with nearly equal warming in summer and winter.

• Annual precipitation increased nearly everywhere in the region, by 11% on average,with the largest relative increases about 50% in northeasternWashington and southwestern Montana.

• Year-to-year variations in the region's climate show a clear correlation with two large-scale patterns of climate variation over the Pacific,the El Niño/Southern Oscillation (ENSO),and Pacific Decadal Oscillation (PDO). The region-wide pattern associated with these phenomena is that warm years tend to be relatively dry with low streamflow and light snowpack,while cool ones tend to be relatively wet with high streamflow
and heavy snowpack. This has clear ef fects on important regional resources:warmer drier year s tend to have summer water shortages,less abundant salmon,and increased risk of forest fires.

Climate of the Coming Century

• Regional warming is projected to continue at an increased rate in the 21st century, in both summer and winter. Average warming over the region is projected to reach about 3°F (1.7°C) by the 2020s and 5°F (2.8°C) by the 2050s.

• Annual precipitation changes projected through 2050 over the region range from a small decrease (-7% or 2") to a slightly larger increase (+13% or 4").

• Projected precipitation increases are concentrated in winter, with decreases or smaller increases in summer. Because of this seasonal pattern, even the projections that show increases in annual precipitation show decreases in water availability.

Jeffrey T. Payne, Andrew W. Wood, Alan F. Hamlet, Richard N. Palmer, and Dennis P. Lettenmaier

ABSTRACT

The potential effects of climate change on the hydrology and water resources of the Columbia River Basin (CRB) were evaluated using simulations from the U.S. Department of Energy and National Center for Atmospheric Research Parallel Climate Model (DOE/NCAR PCM). This study focuses on three climate projections for the 21st century based on a "business as usual" (BAU) global emissions scenario, evaluated with respect to a control climate scenario based on static 1995 emissions. Time-varying monthly PCM temperature and precipitation changes were statistically downscaled and temporally disaggregated to produce daily forcings that drove a macro-scale hydrologic simulation model of the Columbia River basin at ¼ degree spatial resolution. For comparison with the direct statistical downscaling approach, a dynamical downscaling approach using a regional climate model (RCM), was also used to derive hydrologic model forcings for 20-year subsets from the PCM control climate (1995-2015) scenario and from the three BAU climate (2040-2060) projections. The statistically downscaled PCM scenario results were assessed for three analysis periods (denoted Periods 1-3: 2010-2039, 2040-2069, 2070-2098) in which changes in annual average temperature were +0.5, +1.3 and +2.1 °C, respectively, while critical winter season precipitation changes were -3, +5 and +1 percent. For RCM, the predicted temperature change for the 2040-2060 period was +1.2 °C and the average winter precipitation change was -3 percent, relative to the RCM control climate. *Due to the modest changes in winter precipitation, temperature changes dominated the simulated hydrologic effects by reducing winter snow accumulation, thus shifting summer and autumn streamflow to the winter*. The hydrologic changes caused increased competition for reservoir storage between firm hydropower and instream flow targets developed pursuant to the Endangered Species Act listing of Columbia River salmonids. We examined several alternative reservoir operating policies designed to mitigate reservoir system performance losses. In general, the combination of earlier reservoir refill with greater storage allocations for instream flow targets mitigated some of the negative impacts to flow, but only with significant losses in firm hydropower production (ranging from -9 percent in Period 1 to -35 percent for RCM). Simulated hydropower revenue changes were less than 5 percent for all scenarios, however, primarily due to small changes in annual runoff.