RECENT IMPROVEMENTS IN STATISTICAL WATER SUPPLY FORECASTING IN THE KLAMATH BASIN, OREGON

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ABSTRACT

The Klamath Basin has had recent national focus for water supply issues in the West. This focus began in 2001, the 5th driest year since the early 1900s, which provided the backdrop of water supply shortages, pitting irrigation, fish, tribal needs and wildlife against each other in an effort to procure enough water for their competing needs. Since that time, efforts by the US Geological Survey and Natural Resources Conservation Service, supported by the Bureau of Reclamation, have improved the statistical forecasting techniques to increase water supply forecast accuracy. The accuracy improvements and the error reduction of the forecasts support improved water management decision making in the basin. Recent changes have included using spring temperature, groundwater measurements and climate indices. The Trans-Niño Index is a new climate index that has improved the forecasts early in the season, where other climate indices are not well correlated. Spring temperatures provide a measure of snowpack conditions that drive runoff in the basin. The two groundwater parameters provide long term basin baseflow characteristics and recent climate effects on the groundwater resources that support surface water runoff in the spring and summer. These improvements have increased the accuracy of the water supply forecasting by 5 to 10 percent for the Upper Klamath Basin.

INTRODUCTION

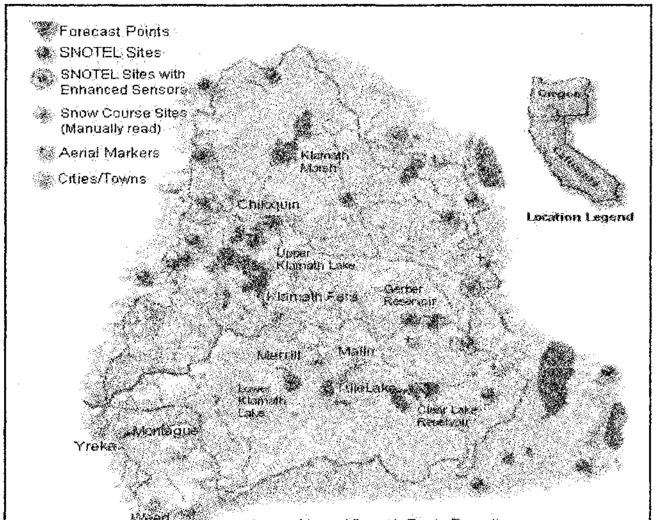

Figure 1. Upper Klamath Basin location with climate and forecast points indicated

A water supply forecast has traditionally been a volume of water expected into a lake, reservoir or past a stream gage in a multi-month time step or season. Seasonal water supply forecasts are used for water management decision making for flood management, irrigation, municipal use, wildlife and fish, hydropower, and recreation. The seasonal volume is often used as an input into daily water management models.

The Klamath Basin, located in southwest Oregon (Figure 1.) is a highly complex basin on the east slope of the Cascade Mountains. For many decades, the water supply forecasts have been provided to the Bureau of Reclamation (BOR) and PacifiCorp, a hydropower company, for water management. In the 1990s, two sucker species (Lost River Sucker : *Deltistes luxatus* and Short Nose Sucker: *Chasmistes brevirostris)* in Upper Klamath Lake were determined to be endangered species by the US Fish and Wildlife Service (USFWS). Coho Salmon in the Klamath River below the lake were also listed as threatened by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service. Water management plans were developed to provide the appropriate amount of water to improve these fish populations. In 2001, the 5th driest year on record, there was a very limited supply of water for the irrigation, power and endangered fish needs. Based on the April 1 water supply forecast, the BOR determined that to comply with the endangered species laws, no irrigation water would be available for the farmers in the BOR Project, though other farmers in the area were able to irrigate. This decision caused many protests throughout the local, state and national agricultural community and received the attention of the White House. The resulting legislation provided federal funds to

Paper presented Western Snow Conference 2006
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enhance and conserve water supplies in the basin. The immediate actions included emergency well drilling, water conservation as well as long term projects such as irrigation efficiency improvements, and vegetation management. There was also funding to support improvements in water supply predictions from which water conservation and management decisions are made (Risley et al., 2005). These improvements include additional data collection stations, hydrologic modeling efforts, and studies on the accuracy of the statistical water supply forecasts and ways to improve them. Statistical forecast improvements used techniques developed by Garen (1992). There is also a continuing effort to educate the water managers and public on the use and limits of water supply forecasts in predicting future water supplies.

VARIABLES USED TO IMPROVE THE STATISTICAL WATER SUPPLY FORECAST

To improve the water supply forecasts, variables in addition to the traditional snow, precipitation and streamflow data were used. These other variables were chosen to try to have additional information in the statistical equation that would explain other climatic and hydrologic phenomena in the basin.

Current variables used in water supply forecasts:

Snow water equivalent (SWE) from SNOTEL, Snow courses/Aerial markers.
National Weather Service and SNOTEL Precipitation (fall and spring).
Streamflow, reservoir and diversion data

New Variables:

Spring data (Groundwater)
Well level data (Groundwater)
Temperature (Climate)
Trans-Niño Index (TNI). (Climate)
Areal Precipitation (Climate)

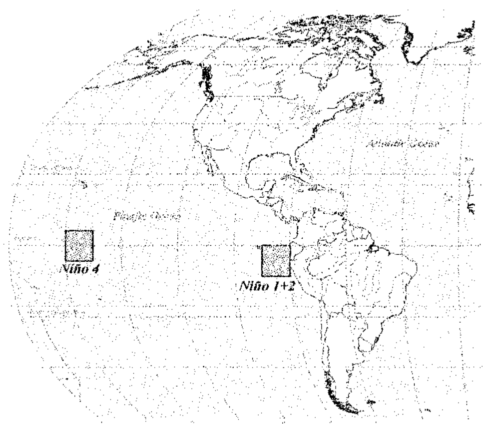


Figure 2. The TNI is the standardized equatorial sea surface temperature gradient between Niño 1+2 and Niño 4 regions *(Trenberth and Stepaniak, 2001)*

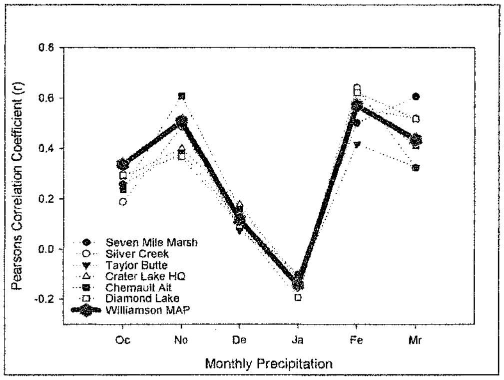
Climate Indices

There are several standard climate indices that are used in water supply forecasting in the western US and elsewhere. The Southern Oscillation Index (SOI) is used in the Pacific Northwest and in the Southwest. There is a middle region between these two areas that does not have a strong relationship with the SOI, and the Klamath Basin falls within this area. The Pacific Decadal Oscillation (PDO) is also not directly well correlated, but it is used to define climate regimes, the most recent of which is the warm phase that started in 1978.

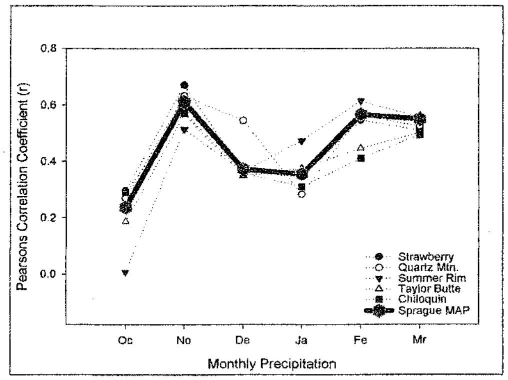
A relatively new index was the focus of our work. The Trans-Niño Index (TNI) is the standardized equatorial sea surface temperature (SST) gradient between the Niño 1+2 and Niño 4 regions (Figure 2; Trenberth and Stepaniak, 2001). The TNI does provide a good correlation to streamflow in the current warm PDO phase. This relationship between the TNI and Klamath basin streamflow, has r-values of 0.4 to 0.7 during the months September through January prior to the snowmelt runoff season. The TNI variable improved the forecast equations by reducing the standard error by 7 to 13 percent (Kennedy, A. M., 2006). Recent regional work has shown that the TNI is significantly correlated with streamflow in a broad regional pattern, including the Klamath Basin (Kennedy et al, 2005).

Mean Areal Precipitation

Mean areal precipitation was based on the Parameter-Regressions on Independent Slopes Model (PRISM; Daly et al. 1994), which is used to interpolate spatially distributed fields of monthly precipitation from ground based observations. The historical time series of monthly PRISM precipitation grids was obtained, and monthly arithmetic means for each basin were computed. The correlation of the these data to the observed streamflow for the Williamson and Sprague basins is shown in Figure 3 along with the correlations from individual stations. These plots show that the PRISM mean areal precipitation data are more consistently and robustly correlated to the streamflow than any individual station. Individual stations may have a better correlation for certain months, but for the season, the more robust and consistent correlation of the mean areal precipitation is preferred.



Mean areal precipitation correlation to the Sprague subbasin.



Mean areal precipitation correlation to the Williamson subbasin.

Figure 3. Comparison of the correlation of the station data and the basin mean areal precipitation to streamflow for the Sprague and Upper Williamson basins

Spring Temperature

While spring temperature is a critical element to physically based models, it has rarely been used in statistical models. Since the Klamath basin has some high elevation areas, temperatures in the Cascade Mountains may be valuable to forecast streamflow. This is indeed the case, where using data from the high elevation National Weather Service station at Crater Lake National Park H.Q. improved late season forecast accuracy for the Klamath Lake Inflow. Obviously this is a negative correlation, where warmer temperatures correlate with lower streamflow.

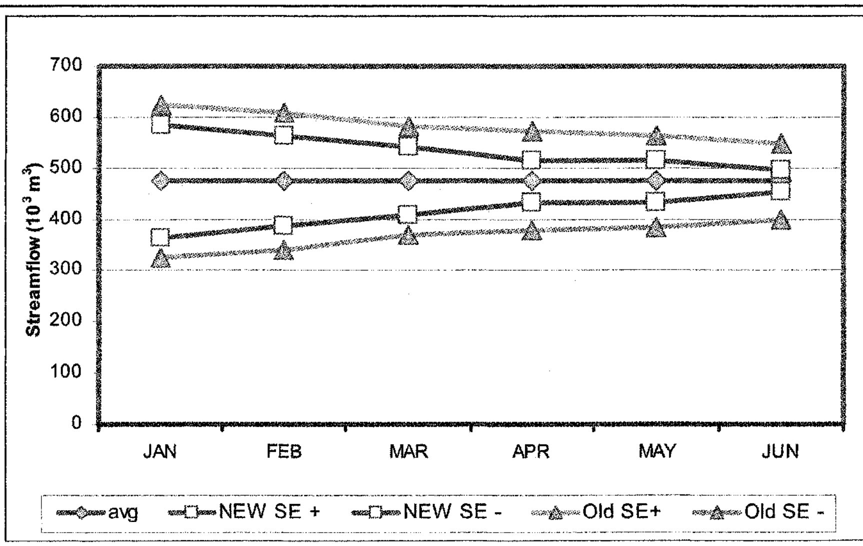


Figure 4. Williamson River forecast standard error improvement from spring temperature and groundwater variables

Well and Spring Data

Other studies in the Klamath basin have determined that the groundwater flow and storage in the basin is a large component of the basin hydrology due to its volcanic geology. The Oregon Department of Water Resources (OWRD) well and spring data in the basin was reviewed, and it was determined that there was one spring data set that was robust and quality controlled, and one state observation well that had a long term dataset that could be used. The spring data was a streamflow gage that measured a large spring shortly after it begins to flow. The observation well has a long term record and is located in the eastern part of the Sprague basin, away from much of the new volcanic material and not affected by irrigation pumping. When included in the forecast equations, the spring and well data were both well correlated and provided an improvement in the Williamson River forecast. Figure 4 shows the overall improvements with groundwater and spring temperature variables.

RESULTS

The new variables combined with the snowpack, precipitation and observed streamflow reduce the standard error significantly. The inclusion of the groundwater components improve the forecasts in all months, and will provide added accuracy in multi-year climate events. The TNI provided good improvement early in the year when the annual snowpack has only begun to build. The combined mean areal precipitation variable combines the station data to a more uniform and overall better picture of the basin precipitation while removing any bias towards any one station. Spring temperature provides information on the snowpack melt efficiency and spring weather on the overall seasonal runoff. There will always be a somewhat large standard error associated with the forecasts since the basin is highly variable in terrain, snowpack and precipitation, so climate and surface water data as variables provide only a small picture of the variability of the basin. The volcanic nature of the basin also reduces the forecast accuracy, as the complex groundwater, which is a large component of the hydrology, is not well understood or measured.

CONCLUSIONS

Statistical water supply forecasts continue to be relied upon to make key water resource decisions. Improved streamflow forecast accuracy was achieved with additional variables to reduce the standard error of the statistical models. These new variables include temperature, groundwater and spring data, the Trans-Niño Index and mean areal precipitation. Forecasting future streamflow will always have error due to the chaotic components of predicting future hydrologic and weather events in a complex watershed environment. We currently limit our forecast season to January through June based on our knowledge of snowpack characteristics, though relevant climate indices can stretch the forecast to the pre-snowpack autumn months of October-December for a general trend outlook. The TNI can play a key role in early season forecasting, especially in the middle-West locations where other climate indices are not relevant. Seasonal water supply forecasts continue to be the key for the operation of western water projects, and investigating additional relevant variables will continue to improve these basic ingredients to water management.

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