CALIBRATION OF THE NWS MODEL IN THE NORTHWEST: A STATUS REPORT

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ABSTRACT

The Northwest River Forecast Center has been using the SSARR model for four decades to forecast streamflows in the Columbia River and Western Oregon and Washington basins. A major effort is now underway to calibrate Pacific Northwest basins with the National Weather Service River Forecast System (NWSRFS) model, including the NWSRFS snow model. Staff of the NWRFC have calibrated more than half of the basins of northwestern Washington, and should have all of Western Washington finished by fall 1995. Calibrations must address both the winter flood forecast season and the spring snowmelt season (emphasis on both floods and multi-purpose water management). Some parameters, such as seasonal melt rates, reflect unique Pacific Northwest climatology. In the Columbia River Basin, many calibrations have been done for the Bonneville Power Administration (BPA) by a private contractor, and those results will be available for use by the NWS.

INTRODUCTION

Purpose of This Presentation

The change from SSARR to the NWSRFS model in forecasting at the Northwest River Forecast Center will potentially provide new or improved products for a wide variety of resource managers in the Pacific Northwest. The purpose of this presentation is to inform western water users that this change is taking place.

Water Management in the Pacific Northwest

Pacific Northwest rivers include the Columbia River, the Coastal tributaries of Oregon, and the coastal and Puget Sound tributaries of Washington. The Columbia River dominates the region from its headwaters in Canada through its course of 1,953 km (1,214 mi) to the Pacific Ocean. Major tributaries include the Snake, Spokane, Flathead/Pend Oreille, Kootenai, and Willamette Rivers. The Columbia River drains 671,000 km^2 (259,000 mi^2), ranking 32nd in the world and fourth in North America behind the Mississippi, MacKenzie, and St. Lawrence.

Initial development of water resource projects was primarily authorized for flood control, irrigation, transportation and hydropower. Other purposes include fish and wildlife enhancement, recreation, low-flow augmentation, and municipal and industrial water supply. Damages prevented in the Columbia basin due to reservoir regulation in the decade 1981-1990 totaled $538 million. Irrigation service from US Bureau of Reclamation projects in 1992 delivered $1.2x10^{10}$ m^3 (9.9 maf) to approximately 11,000 km^2 (2.7 million acres). The 1992 crop production was estimated at gross value of $2.3 billion. Federal hydropower generation in the Columbia basin comprises a large fraction of the nation's hydropower resource. Growing concerns about salmon and steelhead fisheries have put intense pressure on water managers. The National Marine Fisheries Service's Biological Opinion on the "operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years" calls for a Technical Management Team to be established to advise the operating agencies on dam and reservoir operations to optimize passage conditions for juvenile and adult anadromous salmonoids.

With many competing interest in the Columbia River basin, good flow forecasts are critical for successful water management. The Columbia's treasure of snow accumulates during the winter season and runs off in the spring and summer season. This gives opportunity for effective system operation based on forecasts made several months in advance. Other major rivers of the west such as the Colorado and Upper Missouri have storage capacities several times their annual flow volume. In the Columbia, system storage capacity is less than half of the mean annual flow volume, so careful management is critical.

Historical Perspective

Several events sparked development of the present forecasting system. First, the Vanport flood of 1948 in Portland, Oregon, provided impetus both for development of flood control projects on the Columbia and initiation of the Weather Bureau's Portland River Forecast Center. Second, detailed snow investigation studies were made at three western federal snow laboratories in the late 1940's and early 1950's. Two of these labs, the Upper Columbia Snow Lab and the Willamette Snow Lab, were located in the Columbia River basin. The classic book Snow Hydrology was published in Portland (Corps of Engineers, 1956). The Streamflow Simulation and Reservoir Regulation (SSARR) model (Corps of Engineers, 1987) was originally implemented on an IBM 650 in 1956 for reservoir regulation and routing studies. In 1960, an IBM 1620/1401 version included a snow depletion model following seasonal volume depletion relations identified in the snow investigations. Shortly after, the soil moisture accounting portion was added, predating the more well-known Stanford Model by several years. Most of the current features of SSARR were included in a 1967 revision running on an IBM 360. The program was developed and maintained by

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the US Army Corps of Engineers in cooperation with US Weather Bureau personnel. In the early 1960's, the model was modified for use in winter floods, and two-model operation has continued to the present (Bissell and Orwig, 1984). "Zone Mode" SSARR was developed in the late 1970's using a slightly modified version of the NWS Snow Model (Kuehl, 1979). The "Zone Mode" SSARR was shown effective in forecasting both floods and water supply, but for a variety of reasons was never incorporated into wide operational use. Today, the Northwest River Forecast Center continues to change over between the winter model and the spring depletion model twice per year. SSARR has many stong points, but also has serious shortcomings. Two are: (1) no dynamic accumulation and depletion of snowcover, and (2) the winter model is not skillful in intermittent snow areas. The National Weather Service River Forecast System (NWSRFS) software (National Weather Service, 1972) is a key element in the NWS Modernization and Restructuring program. The NWSRFS models handle dynamic snowcover well, while also permitting the same model to be used continuously through the season. These are features needed for modern water management. For these and other reasons, it seems the time has come for a change.

CALIBRATIONS

Plans

When the Northwest River Forecast Center (NWRFC) calibration work began in Fall 1993, the Bonneville Power Administration (BPA) was already in the process of obtaining calibration parameters for most Columbia River Basin sites by contract. NWRFC is concentrating resources on calibration of rivers in Western Oregon and Washington not addressed by the BPA contract. NWRFC will evaluate calibrations done by the BPA contractor for consistency and for adherence to NWS criteria (which must include flood forecasting capability).

When calibrations began at NWRFC, the raw historical data sytems and models resided on the NOAA Computing Facility (NCF) at Suitland, Maryland, accessed by Remote Job Entry (RJE). Turnaround was slow due to operational program contention and the size of calibration printouts. The process was speeded up considerably when the calibration program was installed on NWRFC workstations. Now, the Mean Areal Temperature (MAT), Mean Areal Precipitation (MAP), and Mean Daily Flow files are obtained on the NCF and transferred by RJE to the NWRFC where calibration runs are performed.

Developing calibration guidelines was important. Most basins in Western Washington have an elevation range requiring at least two subbasins (and usually three subbasins plus a "glacier" basin to keep up summer flows). First, two basins representative of low and middle-to-higher elevation drainages were calibrated. These helped establish initial parameters for subbasins calibrated at different elevations. Guidelines are still being developed as NWRFC staff gain experience calibrating Washington Cascade drainages.

An important post-process is to supply calibration data sets to the Snow Estimation and Updating System (SEUS) developed by the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) in Minneapolis, MN (McManamon et al, 1994). Weights are computed by SEUS to provide estimates each month of basin snow water equivalent from snow courses. It is desired to evaluate if this process should become more interactive with the calibration process instead of being merely a post-calibration process. It also remains to evaluate how to weight the snow water equivalent obtained by SEUS as opposed to that simulated by the model from temperature and precipitation inputs.

Approach

Western Washington's winter flood season and spring snowmelt season are distinct. The calibration approach has been to (1) estimate some soil moisture accounting parameters from the runoff hydrograph (maximum upper zone tension water, maximum upper zone free water, and primary and secondary groundwater recession constants and maximum capacities); (2) match the monthly flow means (see Figure 3) by varying parameters of the NWSRFS Snow Model; (3) optimize Sacramento soil moisture accounting model parameters; (4) fine-tune parameter values to minimize RMS and bias errors.

Data Used

Simulations are done on a 6-hourly time step with 6-hourly precipitation and 6-hourly temperatures (inferred from daily max and min). Calibration compares observed mean daily flows against simulated by (1) visual comparison and (2) using a multiyear statistical summary which provides ten different statistics for each month, including bias, percent bias, and daily RMS error. A utility has been developed at NWRFC to also get 6-hourly storm statistics.

Full Hydrograph Forecasting

A primary objective in switching to NWSRFS was to give continuous forecasts through the year for routine water management as well as for flood and drought. A useful tool in the calibration program is the flow interval error summary, which selects seven historical flow ranges and provides seven different statistics for each flow range, including percent bias and percent RMS error. These are carefully used so that no flow range suffers inordinate bias.

Unique Elements of Calibration in Northwest Washington

Besides two-season runoff and the need to use "glacier" subbasins for most major rivers in NW Washington, other perhaps regional "peculiarities" have been seen. The default (sine curve) melt rate curve in NWSRFS does not work well, presumably due to early spring clouds. Simulated March flows were usually oversimulated by ten percent or more using the default melt rate curve. Most actual melt rate curves are now modified to significantly postpone spring melt.

CALIBRATION STATUS

On the Learning Curve

Calibrations for almost all basins in northwestern Washington are complete. Insights gained will aid calibration of basins in southwestern Washington and the Olympic Peninsula. Details include:

(1) Individual approaches varied in getting temperature normals at different elevations. The "regional temperature" concept will be used in southwestern Washington, providing more consistency in lapse rates.

(2) The approach to which variables to vary and by how much and when is becoming more consistent. This can never be subject to an exact formula, but a more consistent approach should also lead to more consistent parameter values.

(3) Freezing levels will be used, which should give improvement in modeling the rain-snow elevation. This should be very helpful in winter flood events.

(4) A consistent naming convention has been adopted, allowing use of standard templates in preparing calibration control files. Use of global name changes will reduce calibration startup time.

The Numbers for NWRFC

In northwestern Washington, 44 basins were to be calibrated. Of these, 24 are now approved or ready for approval, and 14 have completed segment definitions for installation into the Operational Forecast System. The rest are expected complete by October, 1995. Operational forecasts should be made in northwestern Washington by Fall 1995 in parallel with SSARR. Full operational implementation also depends on several other milestones not addressed here.

In southwestern Washington, 26 basins are designated to be calibrated. Preliminary temperature plots using the "regionalized temperature" approach are now completed and ready for use.

Approximately 74 sites in western Oregon will be calibrated.

The Numbers for Columbia Basin Points

A total of 148 Columbia River subbasins have been calibrated by private contractor for the Bonneville Power Administration. Of these, most will be reviewed and used by NWRFC. In addition, there are about 60 Columbia subbasins not calibrated for BPA which will likely be required for NWRFC operations, mostly in the Upper and Middle Snake River area.

FUTURE PERSPECTIVES

Improvement of Winter Flood Forecasting Operations

Computing dynamic snowcover in middle elevations will provide significant model skill improvement in winter floods of Western Oregon and Washington over the current SSARR winter model. Also, improved data handling in NWSRFS should reduce time for input data preparation. A variety of graphical features in the new NWS Advanced Weather Information and Processing System (AWIPS) should significantly reduce time needed to review forecasts and get them disseminated.

Another Tool for Water Supply Forecasts

The snow accumulation and ablation model in NWSRFS transforms precipitation and temperature data into powerful estimates of mountain snow resources. Also, its design permits explicit future inputs of temperature and precipitation. Combined with the Snow Estimation and Updating System (SEUS) and improved extended and long-range climatological forecasts, NWSRFS skill in forecasting seasonal water supply is expected to provide a significant (and perhaps primary) new tool in forecasting water supply in the Pacific Northwest.

ESP Encodes Uncertainty of Future Streamflows

A powerful feature of NWSRFS is the Extended Streamflow Prediction (ESP) module, which uses current model conditions in combination with future precip/temperature scenarios to produce probability ranges for a variety of future variables. The seasonal water supply forecast discussed above is only one instance of this capability. For example, a power company may wish to know the probability range for flows during a certain critical period next week when a generating unit outage is scheduled. The use of the model and forecasted inputs provides a more skillful "conditional" distribution of future flow probabilities rather than a purely "historical" one. In itself, the ESP approach is very powerful and useful. Two key developments are still needed, however, to realize the full potential of this approach. First, objective techniques are needed to weight historical weather sequences to reflect known conditions on the date of forecast. Second, techniques are needed in regulated systems to invoke appropriate reservoir operating decisions for each different ESP scenario.

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