HYDROLOGIC FORECASTING IN THE TRUCKEE-CARSON RIVERWARE SYSTEM

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ABSTRACT The Truckee-Carson RiverWare system is being developed as a joint effort between the Bureau of Reclamation (BOR) and the Truckee River Operating Agreement Implementation Coordinator's Office. The framework of the current system consists of three interlinked RiverWare models that perform water accounting, hydrologic forecasting, and river-reservoir operations scheduling. The operations model requires daily streamflow (naturalized reservoir inflows and streamflow forecasts at both gaged and ungaged locations) and reservoir evaporation forecasts at numerous forecast points throughout the basin. The forecast model is used to provide these hydrologic forecasts to the operations model. The Truckee-Carson RiverWare system is currently used for general short-term planning purposes, but not for official water accounting or scheduling reservoir operations. In the future the RiverWare system will be crucial for water accounting and operations scheduling under implementation of the new Truckee River Operating Agreement.

The current configuration of the forecast model was designed around the use of volume forecasts at three key forecast points in the basin. The forecast model distributes all of the input volumes by time into daily flow hydrographs, and also distributes the Truckee River at Farad volumes spatially to upstream forecast points. A "similar-years" approach is used to generate the daily flow hydrographs. The model determines similar years from historic runoff volumes and peak flow dates. The forecast model can also be configured to allow daily forecasts at any forecast point from a variety of other sources. Other sources of daily forecasts are the U.S. Geological Survey's (USGS) Modular Modeling System model for the Truckee Basin, National Weather Service models for several forecast points in the basin, as well as any future models that may be developed.

INTRODUCTION

AREA OF STUDY

While two separate river basins, the Truckee and Carson basins are often considered as a single river basin for the purposes of water management and modeling. The primary reason for this is due to the Truckee Canal, which brings Truckee River water to the Carson River basin. The Truckee River flows from the outlet of Lake Tahoe in the Sierra mountain range of California to its terminus at Pyramid Lake in the desert plains of Nevada. The river is approximately 105 miles long, and contains two distinct regions with differing physical characteristics. In the lower portion of the basin, the river slows progressing towards its terminus, passing through the metropolitan areas of Reno-Sparks before terminating in Pyramid Lake. The Carson River also originates in California, but as two main forks, an east fork and a west fork. The two forks are largely unregulated by reservoirs, but are regulated by irrigation diversions as flows reach Nevada. The two forks join in the Carson Valley of Nevada, where significant irrigation diversions regulate the flow of the Carson River. The river passes near Carson City before flowing into Lahontan Reservoir. Prior to the development of the Newlands project downstream of Lahontan Reservoir, the Carson River reached its terminus at Carson Lake. With the Newlands Project, the vast majority of the storage in Lahontan Reservoir is used to meet water rights for the project. The upper portions of the Truckee and Carson River basins are characterized by cold, rapid flowing water in mountainous valleys and canyons. These portions of the basin receive the majority of precipitation reaching the basin, and thus produce the majority of the runoff. A map of the Truckee-Carson Basin is shown in Figure 1.

There are seven significant storage reservoirs located in the upper reaches of the Truckee River in California. These reservoirs control approximately 70% of the flow in the Truckee River. Two are owned by private interests to provide water storage for the cities of Reno and Sparks and the Truckee-Carson Irrigation District for irrigation in the Newlands Project. One is a flood control reservoir owned by the US Army Corps of Engineers (COE). The remaining four are Bureau of Reclamation (BOR) facilities used to provide storage for agricultural irrigation, municipal use, industrial use, and threatened and endangered fish in Pyramid Lake. There are two large structures on the main stem of the river. These are Derby Diversion Dam and Marble Bluff Dam. Derby Diversion Dam is located downstream of Reno, and provides irrigation water for the BOR's Newlands Project. Additionally, water taken from the Truckee at Derby Dam flows into Lahontan Reservoir on the Carson River, and is used to irrigate agricultural lands in the Carson basin as well as supply water to a wildlife refuge. Marble Bluff Dam was constructed to check the downcutting and erosion of the river channel upstream from Pyramid Lake and to assist in the recovery of threatened and endangered fish (Rieker, et. al, 2005).

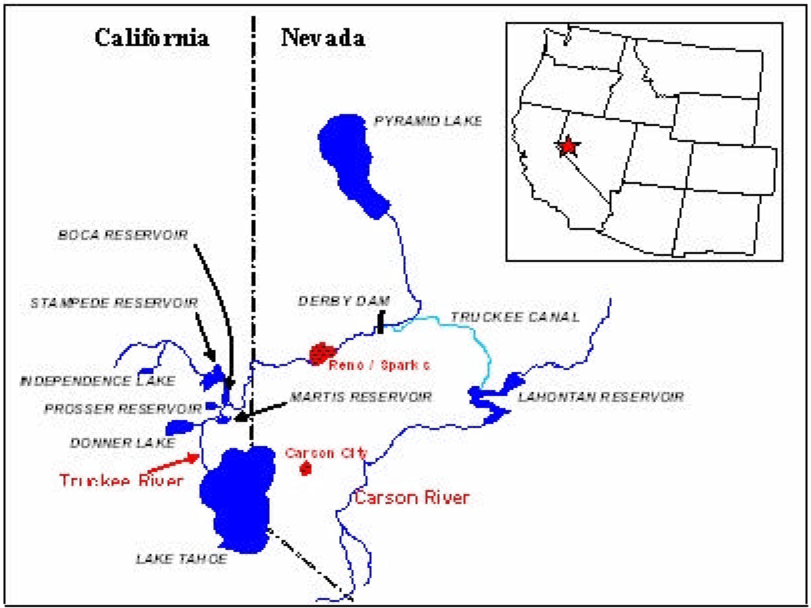

Figure 1. Map of Truckee-Carson Basin

HYDROLOGIC FORECASTING FOR THE TRUCKEE-CARSON BASIN

RiverWare is a comprehensive reservoir and basin modeling system that is ideal for modeling complex river and reservoir operations. RiverWare provides a generalized modeling environment for building basin-specific river and reservoir models (Zagona et al., 2001). RiverWare operations models have been applied to several river basin projects including BOR projects on the Colorado, Upper Rio Grande, and Yakima River basins. The Truckee-Carson RiverWare Modeling System is currently being developed by the BOR for water accounting, forecasting, operations/scheduling, and long-term planning for river and reservoir operations within the Truckee-Carson River System (Rieker, et al., 2005). The Truckee-Carson RiverWare Modeling System is made up of three separate RiverWare models: a water accounting model, a hydrologic forecasting model, and a river-reservoir operations model, as shown in Figure 2. The three models, while separate, are linked together as a system for the purpose of water accounting, forecasting, scheduling, and long-term planning for Truckee-Carson Basin river and reservoir operations. The system is currently under development, and is intended to be used for implementation of the new basin operating policy, the Truckee River Operating Agreement (TROA). The current RiverWare system simulates current basin policy, and is being used for water-supply forecasting. Development work is focusing on combining the accounting and operations models into a single accounting-operations model. Future development of the system will replace current basin policy with TROA policy.

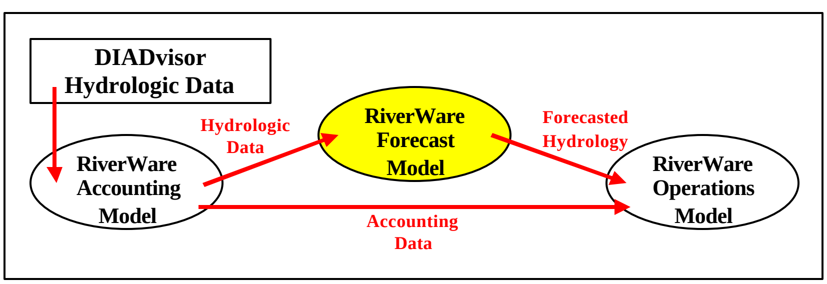

Figure 2. Schematic of Truckee-Carson RiverWare System

Hydrologic forecasting in the Truckee-Carson RiverWare System is performed using the Truckee-Carson RiverWare forecast model. The forecast model generates daily streamflow forecasts and reservoir evaporation forecasts at numerous forecast points within the Truckee-Carson basins. The daily streamflow forecasts include unregulated reservoir inflows and localized inflow forecasts at gaged and ungaged locations along the stream. The streamflow and evaporation forecasts provided by the forecast model are used to drive the RiverWare operations model. The operations model provides river and reservoir operations forecasts (based on forecasted hydrology) for the Truckee-Carson basins. The current forecasting model will be similar to the model used to implement TROA. Future forecast model development will focus upon improving accuracy of forecasts and incorporating daily streamflow forecasts from sources such as the Modular Modeling System (MMS) and the National Weather Service's (NWS) Ensemble Streamflow Prediction (ESP) model.

The Truckee-Carson RiverWare forecast model is different from a "typical" RiverWare river-reservoir operations model because there is no simulation between physical objects (i.e. river reaches, confluences, and reservoirs) throughout the system. Physical simulation objects in the forecast model are not linked (i.e. where outflow from upstream object is linked to inflow to downstream object), and are used primarily as placeholders for recent hydrologic data. RiverWare typically uses a rule-based simulation approach, thus the majority of the forecasting calculations are completed using a ruleset written with RiverWare's scripting language, known as the "RiverWare Policy Language" (RPL). Because the physical objects are not linked or used for physical simulation, they do not interact during the rule-based model run. In other words, flow does not travel from upstream points to downstream points in the model, as the model is used to generate independent hydrologic forecasts for each forecast point. Forecast model calculations show more similarity to a complex spreadsheet than a river-reservoir model. Slots that hold data interact in the forecast model only when directed to by the ruleset, not as a result of physical simulation of water flow.

HYDROLOGIC FORECASTING PROCESSES IN FORECAST MODEL

VOLUME FORECASTS

The current forecast model configuration was designed around the use of volume forecasts at three key forecast points in the Truckee-Carson basin. The three forecast points are Lake Tahoe, the Truckee River at Farad, and the Carson River at Fort Churchill. The volume forecasts are used by the model to generate daily streamflow forecasts at those three forecast points as well as several others. The volume forecasts used by the forecast model are both January-to-March (JM) and April-to-July (AJ) runoff volume forecasts. At present the JM volume forecasts are produced by the BOR, and AJ volume forecasts are provided by the Natural Resources Conservation Service (NRCS). The JM input volumes are runoff volumes at the at the Farad gage (unregulated flow volume) and at the Fort Churchill gage. The AJ input volumes are runoff volumes at those same gages as well as the April-to-High Gates Closed Rise (GCR) for Lake Tahoe. The GCR is defined as the maximum rise, starting April 1, expected at Lake Tahoe if no flow were to be released from the outlet. August-to-December (AD) volumes are not provided to the forecast model. This rise can be directly converted to a runoff volume, but the end date ("High" date) for the runoff period is not explicitly known. The model generates forecasted volumes for the AD forecast period for the Truckee River at Farad and Carson River at Fort Churchill forecast points based upon the AJ input volumes at those forecast points.

SIMILAR-YEAR ANALYSIS

The forecast model generates daily inflow forecasts independently for three time periods during a calendar year that generally correspond with the timeframe of the runoff volume forecasts. For Lake Tahoe outlet to Truckee River at Farad forecast points and the Carson River at Fort Churchill forecast point, the model generates forecasts for the JM, AJ, and AD periods. For Tahoe forecasts the model generates forecasts for the JM, April-to-August (GCR period), and September-to-December (SD) periods. As daily inflow forecasts are made independently for each forecast period, similar years are selected for each of the forecast time periods.

The forecast model generally uses a similar-year analysis in generating daily inflow forecasts. In this method historic naturalized streamflow data are used to generate forecasts. This involves selecting historic data from years with hydrologic conditions most similar to the current year's forecasts. The user can determine how many similar historic years to use in making forecasts. If only one year were used, the model would recreate that year's hydrograph, and would include specific runoff events. For water-supply forecasting it is not generally desirable to forecast specific runoff events, as such events are considered to be random and independent with respect to time. Therefore generally three to seven similar historic years are used in order to reflect average runoff timing.

Similar-year analysis by the forecast model is based upon the Truckee River at Farad forecast point. That is, it is assumed that runoff at this forecast point is indicative of runoff throughout the entire Truckee-Carson Basin. While runoff conditions can vary within the Truckee basin and also between the Truckee and Carson basins, in general the runoff conditions are similar regionally. For determination of similar years, the model uses either a comparison of historic and forecasted runoff volumes or a comparison of historic and forecasted peak dates.

The forecast model independently generates Farad and Fort Churchill forecasts for the JM, AJ, and AD time periods. For each of these time periods the user sets how many similar historic years the model should use. For JM forecasts the model selects similar years based upon historic and forecasted Farad JM runoff volumes. The model will select historic years with Farad runoff volumes closest in magnitude to the forecasted Farad volume. For AJ forecasts, the user has the option to use either runoff volume comparison (e.g. JM forecasting) or peak date comparison for similar years selection. The California-Nevada National Weather Service River Forecast Center (RFC) provides peak date forecasts for the Truckee River at Farad during the runoff season. When these forecasts are available the peak date forecast comparison is generally used when running the forecast model. In this comparison the historic years selected by the model are the years with peak dates closest to the forecasted peak date. As AD runoff forecasts are not currently available, the similar years selected by the model for AD forecasts are based upon the AJ similar years.

For AJ forecasting the model can be set to automatically exclude historic years from the similar-year analysis. This feature is used to exclude historic years that may have already peaked by the start date of the model run when the peak for the current year has not passed, or for excluding historic years that had not yet peaked by the model start date when the peak for the current year has already passed. The user can set a switch to use automated exclusion of historic years for AJ forecasting, whereby the model will automatically exclude all historic years falling into those categories. The model is generally run with the automation to exclude those years from AJ forecasting.

Another feature of the forecast model is the ability for the user to input specific historic years (for each forecast period) to include or exclude from the similar-year analysis. The user may determine that one or more historic years' runoff patterns were similar to the current year runoff pattern, and can input these years into the model. The model will override model-determined similar years with the user-input years. The user can also input historic years that should not be used by the model. For example it may be desirable to exclude 1997 from JM forecasting in order to avoid forecasting a major flood event that occurred in 1997. The model is generally run with user-input excluded years for the JM and AD forecast periods. These historic years are years that had significant rain-on-snow flood events, and it is generally not desirable to forecast such events.

DAILY INFLOW FORECASTS

Using the daily inflow data for historic years selected by the model, the forecast model generates daily naturalized flow hydrograph forecasts at the Truckee River at Farad and Carson River at Fort Churchill forecast points. The forecasting routine combines historic daily inflows at each forecast point and uses the volume forecasts as adjustment factors so that for each forecast period the volume forecasts are met. The daily forecasting calculation used by the forecast model is:

$$\text{Forecasted Daily Inflow (cfs)} = A \times \frac{B}{C}$$

Where:
A = Volume Forecast for Forecast Period (AF)
B = Sum of Historic Years' Daily Inflow at Forecast Point (cfs)
C = Sum of Historic Years' Runoff Volume for Forecast Period (AF)

The Farad volume forecasts provided by the NRCS are partially naturalized flow forecasts that ignore the effects of precipitation and evaporation from each of the upstream reservoirs. This basically means that upstream reservoir inflows are computed as "net inflow", which is the simple mass balance as:

Net Inflow = ?Storage + Outflow

Net reservoir inflows include all losses and gains (e.g. precipitation and evaporation). Conversely, hydrologic inflow (fully naturalized flow) does not include precipitation and evaporation, and is computed as:

Hydrologic Inflow = ?Storage + Outflow + Evaporation - Precipitation

While the forecast model was designed around the use of NRCS volume forecasts, it was also designed to be flexible with other input forecasts. Thus the user has the option to use hydrologic or net inflow data in forecasting. Since NRCS volumes are generally used to drive the model, the net inflow forecasting option is generally used when running the model. The hydrologic inflow forecasting option is intended for forecasts from other sources that may be expressed as hydrologic inflow.

FARAD FORECAST DISTRIBUTION TO UPSTREAM FORECAST POINTS

While the Fort Churchill volumes and Tahoe GCR correspond with the forecast point for which daily streamflow hydrographs are required by the operations model, the Farad volume must be distributed to nine upstream forecast points. These nine points include six unregulated reservoir inflows and three local ("sidewater") inflows that do not pass through any of the reservoirs. The sidewater inflows that contribute to the Farad natural flow are summed at three forecast points and correspond with three distinct reaches on the Truckee River. The six reservoir inflow forecast points are Donner Lake, Martis Reservoir, Prosser Reservoir, Independence Lake, Stampede Reservoir, and Boca Reservoir. The three sidewater forecast reaches are: 1. Truckee River from Lake Tahoe outlet to Truckee River near Truckee streamgage, 2. Donner Creek from Donner Lake outlet to Donner Creek at Highway 89 streamgage, and 3. Truckee River from Donner Creek confluence to Truckee River at Farad streamgage.

The daily forecasted flow at Farad is distributed to each of the previously listed forecast points by the forecasting model, using a fractional method based on historic records for each of the points. As the historic record for the three localized inflow reaches is not as long as for the rest of the historic inflows and a longer historic record exists for the total localized inflow, the daily forecasted fractions for the localized inflow reaches are computed as functions of the total localized inflow. Thus the model computes forecasted daily fractions for the six reservoir inflows and the total localized inflow, and then makes forecasts for the three localized inflow reaches based on that total localized inflow.

INDEPENDENT LAKE TAHOE FORECASTING

Similar-year analysis for Lake Tahoe forecasting is similar to the Farad-Fort Churchill similar-year analysis; however it is done independently due to several issues. JM volume forecasts are not provided for Lake Tahoe. Thus, for the JM forecast period, Lake Tahoe's similar years are the same similar years that were selected for Farad-Fort Churchill forecasting. The "high" date in GCR forecasts can vary, and possibly extend beyond the July 31 end date for spring runoff forecasts at other forecast points. Thus, for Lake Tahoe forecasts, the GCR forecast period is set between April 1 and August 31, as it is extremely unlikely that spring runoff would continue beyond August 31. Similar years for the GCR period are based upon the forecasted Lake Tahoe GCR. The similar years selected for GCR period Lake Tahoe forecasts are historic years with GCRs closest in magnitude to the forecasted GCR. For September-to-December forecasting the similar years selected for forecasting are the same years selected for Farad and Fort Churchill AD forecasting.

Another reason for independently forecasting Lake Tahoe inflow is due to an inherent problem with computed net inflow hydrographs for reservoirs. This problem is especially prevalent for Lake Tahoe computed net inflow hydrographs. The problem is a result of the large change in volume for a small increment of Lake Tahoe elevation, which is on average 1200 AF per 0.01 foot. When daily inflows are computed using Lake Tahoe change in storage and releases, the computed daily inflow hydrograph tends to swing wildly from day-to-day between large positive and large negative values. The large day-to-day swings are not realistic (cannot be explained by the hydrology of the system) and cause operational problems if used in the RiverWare operations model. Lake Tahoe inflow is generally positive during the winter and spring (when stream inputs are dominant over lake evaporation) and negative during summer and fall (when lake evaporation is dominant over stream inputs). Even if the user desires not to use smoothed net inflows for other reservoirs, it is important to use hydrograph smoothing for Lake Tahoe.

Unlike Farad and Fort Churchill daily inflow forecasting, the volume forecasts are not used as adjustment factors in the forecasting equation. For the GCR period the daily inflow forecasts are adjusted so that the sum of the daily inflow forecasts (converted to lake elevation) meets the forecasted GCR. However, this adjustment is performed independently from the initial daily inflow forecasts due to complications with the varying "high" date for the GCR forecast. This adjustment routine is described in a following section.

HYDROGRAPH BLENDING

As the daily inflow forecasts are generated for JM, AJ, and AD (or SD for Tahoe) forecast points independently there tend to be discontinuities in daily inflow forecast hydrographs at the boundary dates between forecast periods. There also tends to be a flow discontinuity between recent inflow data (up to date of model start) and forecasted inflows. In order to eliminate the discontinuities between forecasted daily inflows on either side of the boundary dates, weighting factors (blending factors) are applied to daily inflows to add or subtract flow. The values of the blending factors depend upon both the user-determined number of days (1 to 15 days) to perform hydrograph blending and the day number into the blending period. The blending factors are applied to forecasted daily inflows via the following equation:

$$\text{Blended Daily Inflow (cfs)} = A + (B \times C)$$

Where:
A = Forecasted Daily Inflow (cfs)
B = Flow difference between forecasted inflows at boundary dates (cfs)
C = Blending factor

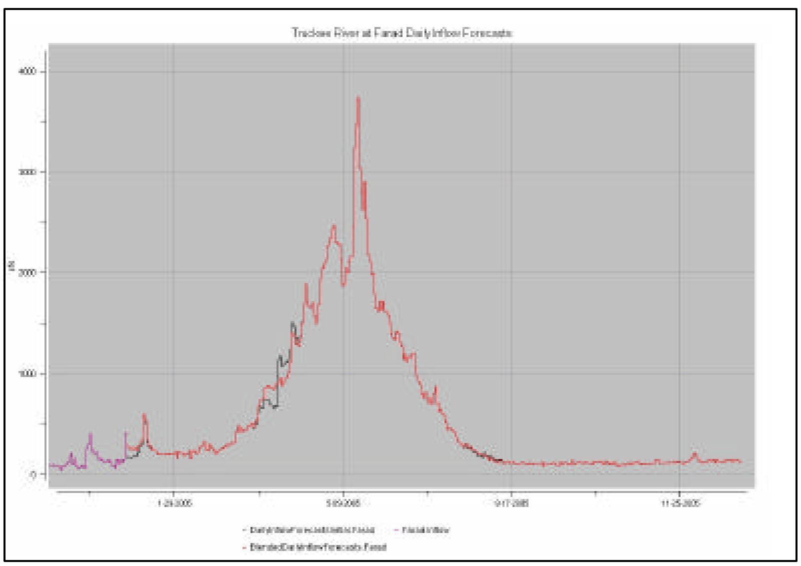

Figure 3. Truckee River at Farad: Initial and Blended Forecast Hydrographs

Hydrograph blending is applied (in order) for the recent-to-forecast boundary period, the January-March to April-July forecast boundary period, and the April-July to August-December forecast boundary period. Figure 3 shows recent (magenta), initial forecasted inflows (black), and blended forecasted inflows (red) for the Truckee River at Farad forecast point, where a 15-day blending routine was applied to forecasts. The discontinuities at forecast period boundaries can be seen where the initial (black) hydrograph differs from the blended (red) hydrograph. In this example the blended hydrograph has eliminated the abrupt transition in forecasted hydrographs for each forecast period. Once hydrograph blending is performed, the daily inflow forecasts for each forecast period will not sum up to the forecasted volumes for each forecast period. An additional step is required to adjust the hydrographs for each forecast period such that the forecasted daily inflows will sum up to the forecasted volumes. These methods are described in the following section.

HYDROGRAPH ADJUSTMENT TO MEET VOLUME FORECASTS

Once the hydrographs have been adjusted with the blending routines, the forecasts usually do not sum up to the volumes for the forecast period. Additional calculations are applied to daily inflow forecasts for each forecast period to force the forecasted daily inflows for each forecast period to sum up to the volume forecasts. In this adjustment routine, the blended daily inflows are summed up for each forecast period and compared with volume forecasts. The difference between the blended daily forecast volume and the forecasted volume is applied to each blended daily forecasted inflow as follows:

$$\text{AdjustedDailyInflow(cfs)} = A + \left(\frac{B}{C}\right) \times D$$

Where:
A = Blended Forecasted Daily Inflow (cfs)
B = Volume difference between sum blended daily inflows and volume forecast (AF)
C = Number of days remaining in forecast period
D = Conversion factor (converts acre-feet per day to cfs)

Thus, while hydrograph blending added or subtracted volume from the forecast period, this adjustment was performed over the 1 to 15 day period set by the user to perform blending. The final adjustment of the hydrograph is performed over the entire forecast period, and this daily inflow adjustment is therefore smaller in magnitude than the daily adjustment for the blending routine. While this final adjustment will cause discontinuities between forecasted hydrographs for each forecast period at the boundary dates, these discontinuities are usually far smaller than with the initial daily inflow forecasts, thus a blended hydrograph is achieved with volumes that match the forecasted volumes.

For Lake Tahoe, once blending methods have been applied, the GCR period forecasted hydrograph is adjusted so that the forecasted GCR is met. While this adjustment is similar in concept to the adjustment of Farad and Fort Churchill forecasts, the variable “high” date of the GCR period creates additional complications. The GCR is, in a sense, the sum of the daily inflows, converted to feet, between April 1 and the date that inflows change from positive to negative. This date varies from year to year, but is known for the forecast year once initial and blended daily inflow forecasts have been generated. This date is used in making daily adjustments to the forecasted Lake Tahoe hydrograph for the GCR period. For Lake Tahoe the volume needed to meet the forecasted GCR is applied only to days up to the “high” date. That is, it is only applied to days within the period when inflows are primarily positive. The same volume that is used to adjust daily inflows up to the “high” date is applied to days after the high date, but in the opposite direction. That is, if a volume equivalent to 0.1 feet of lake rise is required to be added to daily inflows up to the “high” date, then that volume is subtracted from daily inflows after the “high” date. The primary reason for this is that if that volume were added to the entire GCR period, a portion of that volume would be applied during the period when inflows are negative, and the forecasted hydrograph would not meet the forecasted GCR.

TRUCKEE RIVER DAILY INFLOW FORECASTS BELOW FARAD

Daily inflow forecasts for Truckee basin forecast points below Farad are also made independently in the forecast model. There are no volume forecasts provided for any forecast points below Farad. Many of the local inflows in the lower part of the basin are difficult to accurately determine, due to the many unknown factors in the water balance in this portion of the basin. While major diversions are regulated by the Truckee River Federal Watermaster, historic daily diversion data is often lacking (especially for concurrent periods). In addition, concurrent streamgage records are often lacking in this portion of the basin. Daily return flows have never been accurately characterized throughout the Reno-Sparks metropolitan area and on Truckee River from Reno to Pyramid Lake, thus water balancing methods to separate local inflows (i.e. stream inputs) are subject to large degrees of error, and are most accurately characterized on a monthly basis.

In terms of forecasting, there are three primary types of local inflow reaches below Farad. Type 1 local inflows are where the inflows are measured, such as the outflow from the local wastewater treatment plant, the Truckee Meadows Water Reclamation Facility (TMWRF). These are directly input into the forecast model as monthly average flows, and are updated when new measured data is available. Type 2 local inflows are defined as where a relationship between local inflow and total Farad natural flow can be determined. This relationship is characterized in the forecast model as a monthly factor of the Farad total natural flow. This relationship is often poor on a daily basis, and more accurately depicts monthly inflows. Type 3 local inflows are defined as reaches where the stream inputs are unknown, but are typically small in magnitude or negligible. These local inflows are directly input into the forecast model as a constant flow, and range 0 to 20 cfs.

For Type 1 and 3 local inflow forecasts the forecast model uses the input monthly average inflows directly for making daily inflow forecasts. For Type 2 local inflow forecasts the forecast model uses the following equation:

$$\text{Forecasted Daily Inflow (cfs)} = A \times B$$

Where:
A = Truckee River at Farad Forecasted Daily Inflow (cfs)
B = Monthly average factor of Truckee River at Farad natural inflow (expressed as fraction)

While such forecasting methods do not generally result in reliable daily flow forecasts, monthly runoff volumes are generally reasonable. Additional water balancing problems are incurred during operation of the system (operations model). Water balancing methods are applied in the operations model, and often adjust the inflow forecasts made in the forecast model. The water balance on the lower Truckee River (particularly in the Truckee Meadows) is an area identified for future research.

DAILY EVAPORATION FORECASTS

The operations model requires daily evaporation-rate forecasts for all reservoirs in the Truckee-Carson system. While historic daily evaporation volume data is non-existent for most reservoirs in the basin, historic daily evaporation rates were reconstructed for all reservoirs in the system except Lake Tahoe, using available evaporation data. Lake Tahoe historic evaporation is not used in the forecast model since daily net inflow forecasts (includes evaporation) are always provided for Lake Tahoe. For the Truckee River reservoirs, all historic evaporation data were obtained from the Boca Reservoir evaporation pan, as no other evaporation data was available. For Lahontan Reservoir, a combination of evaporation data from the Fallon Experiment Station and Lahontan Dam evaporation pans were used to reconstruct historic evaporation data. Future research work will investigate basin-wide evaporation in order to characterize and quantify evaporation at all of the reservoirs. This effort will be important for TROA implementation, and will be incorporated into the forecast model as data becomes available.

The number of similar years used by the model for evaporation forecasting is set by the user, and is independent of the number of similar years used for daily inflow forecasting. The model will use a portion or all (depending on how many similar years of evaporation the user defines) of the similar years selected for daily inflow forecasting to make daily evaporation forecasts. The model generates daily evaporation-rate forecasts as an average of the historic daily evaporation rates for each date in the forecast period. If the net inflow forecasting method is selected by the user, the forecast model will forecast zero inches per day for evaporation-rate forecasts. If MMS forecasts (discussed in section below) are used in the forecast model, the evaporation-rate forecasts will not be forecasted at 0 inches per day, regardless of what the switch is set to.

INCORPORATION OF DAILY INFLOW FORECASTS FROM OTHER SOURCES

The RiverWare forecast model was designed with flexibility in mind to accept daily forecasts from other forecasting models. It is desired by BOR to investigate other forecast sources in order to reduce dependence upon NRCS volume forecasts. The model can be configured to allow forecasts from any daily forecasting model and for any combination of forecast points in the Truckee-Caron basin. The current configuration of the model is designed to allow the use of Truckee Modular Modeling System (MMS) daily inflow forecasts. The Truckee MMS model (Jeton, 2000) provides daily inflow forecasts (total inflow) for forecast points below the Tahoe outlet to the Farad forecast point. If MMS forecasts are bought into the forecast model, the MMS forecasts replace RiverWare forecasts for those particular forecast points. Possible future configurations of the forecast model may incorporate other MMS model forecasts that may become available (i.e. Lake Tahoe, Carson basin, or lower Truckee River forecasts). Another potential forecast source is the California-Nevada National Weather Service River Forecast Center (RFC). The RFC has developed several daily forecasting models (National Weather Service Ensemble Streamflow Prediction) for forecast points within the Truckee-Carson basin. These forecasts will be evaluated by BOR for accuracy, and incorporated into the forecast model if warranted.

SUMMARY

Hydrologic forecasting in the Truckee-Carson RiverWare System is performed using the Truckee-Carson RiverWare forecast model. The forecast model is a part of the RiverWare modeling system that is under development by BOR and the TROA Implementation office. The Truckee-Carson RiverWare System will be crucial for implementation of TROA. The RiverWare forecast model provides daily streamflow and evaporation forecasts at several forecast points throughout the basin to the RiverWare operations model. The daily streamflow forecasts include unregulated reservoir inflows and localized reach inflow forecasts (at both gaged and ungaged locations). The forecast model was designed around the use of volume forecasts, but was also designed to be flexible in allowing daily forecasts from other forecasting models and sources. The forecast model uses "similar-years" analyses to provide hydrologic forecasts based upon historic hydrologic data. That is, the model uses historic data from years most similar to forecasted hydrologic conditions to provide daily forecasts. Future enhancements to the model will involve improving accuracy of forecasts (especially at forecast points below the Farad streamgage) and configuring the model to allow forecasts from other sources as they become available.

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