DECISION SUPPORT FOR WATER QUALITY RELEASES ON THE TRUCKEE RIVER

Jeffrey D. Rieker, Bureau of Reclamation – Denver, CO, jrieker@do.usbr.gov

Abstract: The federal government, in association with several local governments in and around Reno, NV, is purchasing water rights for water within the Truckee River basin. The purchased water is to be used for the purpose of augmenting Truckee River flows to improve water quality. The decisions for the release of the purchased water from storage reservoirs will be made by a group of coordinating agencies. This paper presents a prototype decision support system (DSS) that will be able to assist the group in finding a strategy for the release of the newly purchased water. A review of the issues affecting the river is presented, along with a summary of current modeling and monitoring efforts. A prototype decision support system is introduced that assists in the scheduling of releases of the purchased water to improve water quality throughout the entire year. The decision support system works in conjunction with existing hydrologic and water quality models of the Truckee River.

INTRODUCTION

Area of Study

The Truckee River flows from the outlet of Lake Tahoe high 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. The upper half of the basin is characterized by cold, rapid flowing water in mountainous valleys and canyons. In the lower portion of the basin, the river slows progressing towards its terminus, passing through the metropolitan areas of Reno-Sparks, Fernley, Wadsworth, and Nixon before terminating in Pyramid Lake (United States Department of the Interior 2002; Rieker, et. al., 2005).

There are seven large storage reservoirs located in the upper reaches of the 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 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 (Rieker, et. al 2005).

Pyramid Lake is the terminal lake of the Truckee River, located on the Pyramid Lake Indian Reservation. Due to increased consumptive use of the river over the last one hundred years, Pyramid Lake's water surface elevation has declined greatly at times. The lake is home to two fish that are on the federal threatened and endangered species list, the cui-ui and the Lahontan cutthroat trout (LCT). A map of the area of study is shown in Figure 1 (Rieker, et. al 2005).

Figure 1. Map of the Truckee River Basin

Review of Water Quality Issues on the Truckee River

Historically, the waters stored in the upper reservoirs of the Truckee system have been appropriated to a variety of consumptive uses through a system of water rights. The stored water is generally released as necessary to provide flows in the river sufficient for diversion to the various uses. Some return flows exist from the uses, however much of the diverted water never returns to the river. It is either used consumptively, or transferred for use in the Carson River basin. Instream flow requirements exist on the main channel of the river, however generally the flow levels in the river are dictated by water user demands.

The upstream reaches of the Truckee are generally characterized by good water quality. The river upstream of the California-Nevada state line and the city of Reno generally does not have water quality problems, with the exception of occasional temperature problems. These problems are typically caused by releases from some of the upper reservoirs made when the reservoir water surface elevations are low. Dissolved oxygen (DO) in the river is typically very high, nutrient concentrations are low, and amounts of total dissolved solids (TDS) are generally constant with respect to streamflow (Neumann, 2001).

From the state line to Derby Dam downstream of the metropolitan area of Reno-Sparks, the river slows greatly, and receives return flows from many of the water uses. These include flows from the wastewater facility for the cities (Truckee Meadows Water Reclamation Facility – TMWRF), as well as agricultural return flows and municipal runoff. Water quality in this portion of the river is significantly impacted by the combination of an erratic flow pattern and the introduction of pollutants from the return flows. Concentrations of TDS, nitrogen, and phosphorus increase greatly, and water temperatures rise (United States Department of the Interior, 2002). At Derby Dam, large portions of the pollutant loadings are diverted away from the river, along with large portions of the river water itself (Brown et. al, 1986).

Downstream of Derby Dam, concentrations of TDS, nitrogen, and phosphorus remain high due to the effects of the upstream constituent loadings combined with agricultural return flows and inflows from groundwater. This stretch of the river generally has lowered stream velocities. Due to the various pollutant loadings, algal growth increases. Increased algal growth results in decreased DO due to an increase in organic matter (dead algae). The problem becomes worse due to increased water temperatures caused by low flows during hot summer months and reduction in riparian vegetation. Often the water temperatures and DO levels are harmful or deadly to the cui-ui and LCT living in the river (Neumann, 2001). The overall result is significant degradation of water quality in the river, particularly in the reach from Reno-Sparks to Pyramid Lake (United States Department of the Interior, 2002; Brown et.al, 1986).

Concentrations of water quality variables such as TDS, nitrogen, phosphorus, and DO have been determined to be related to streamflow in the lower basin, however, and can sometimes be improved with higher flowrates. Water temperature is generally lowered with increased flows as well. For these reasons, increased flows in the river are hypothesized to potentially reduce the negative impacts that consumptive uses have on the lower reaches of the river (Reno et al., 1996).

Water Quality Settlement Agreement

In response to the ongoing degradation of water quality in the Truckee River entering the Pyramid Lake Indian Reservation, the Pyramid Lake Paiute Tribe (Tribe) filed several litigations against Reno, Sparks, the Environmental Protection Agency (EPA), and the Nevada Division of Environmental Protection (NDEP). To settle the litigation, an agreement was reached by Reno, Sparks, Washoe County, the US Department of the Interior (DOI), the US Department of Justice (DOJ), EPA, NDEP, and the Tribe. The agreement is known as the Truckee River Water Quality Settlement Agreement (WQSA), and was signed by all involved parties in 1996 (Reno et al., 1996). The agreement states that a total of twenty-four million dollars ($24,000,000) is to be expended by several of the involved parties to purchase water rights on the Truckee River. The water purchased under the agreement is to be stored in the federally owned reservoirs in the upper Truckee basin, and used as necessary to augment instream flows in the Truckee River to improve water quality in the river and increase flows to Pyramid Lake.
Specifically, the water will be used to:

- assist in compliance with water quality standards
- improve water quality
- maintain and preserve the lower Truckee River and Pyramid Lake for the following purposes:
    - fish and wildlife
    - threatened and endangered species

- recreation

The agreement stipulates that the water will be stored in three of the upper basin reservoirs; Stampede Reservoir, Boca Reservoir, and Prosser Reservoir. The water will be released from the reservoirs according to a release schedule cooperatively developed by Reno, Sparks, Washoe Co., and DOI. The releases will be scheduled to meet the purposes of the agreement, and will use the following priority order of goals to gain the most benefit from the available water:

- meet water quality standards in the reach from the USGS gage at Vista to Pyramid Lake
- improve water quality in that reach when sufficient water is not available to meet the standards
- maintain habitat for fish and riparian species downstream of Derby Dam
- add to aesthetic and recreational value of the river from Reno-Sparks to Pyramid Lake

Basin Decision Support System

An effort is currently underway to create an improved decision support system (DSS) for the Truckee basin (Rieker, et.al, 2005). The effort includes the work of hydrologists and engineers from the BOR and the Truckee River Operating Agreement Implementation Coordinator's Office. The effort centers around a hydrologic model known as RiverWare (Zagona et al. 2001). Currently, the decision support system assists in hydrologic and operations forecasting for the basin, in an attempt to improve decisions made on the operations of the upper reservoirs for the multiple uses of the river water. In the future, the system will assist in the development of daily, monthly, and long-term operational plans and strategies for the limited water resources of the basin. The system is discussed in detail in related papers submitted to the 2006 Federal Interagency Hydrologic Modeling Conference (Boyer, 2006; Mann, 2006; Coors, 2006).

Since the water acquired and used under the WQSA will become a part of the operating procedure for many of the upper basin reservoirs, it must be considered in the development of the decision support system. It will be necessary to develop a set of operating rules for the water stored under the WQSA, and these rules must attempt to optimize the use of the water for the intended goals of the WQSA. For this purpose, the system must be able to predict the water quality in the critical lower reaches of the river, identify the existence of water quality problems based on the modeling, and provide suggested releases of the WQSA-stored water to attempt to improve water quality given the limited amount of water that will be available for the season. The process is illustrated in Figure 2.

Additionally, it is expected that the decision support system will eventually be used to make real-time decisions on the release of the WQSA-stored water, thus an extensive water quality monitoring network will be required. The monitoring network will provide historic data for the development of prediction methods, and real-time data for determinations of the optimal reservoir releases.

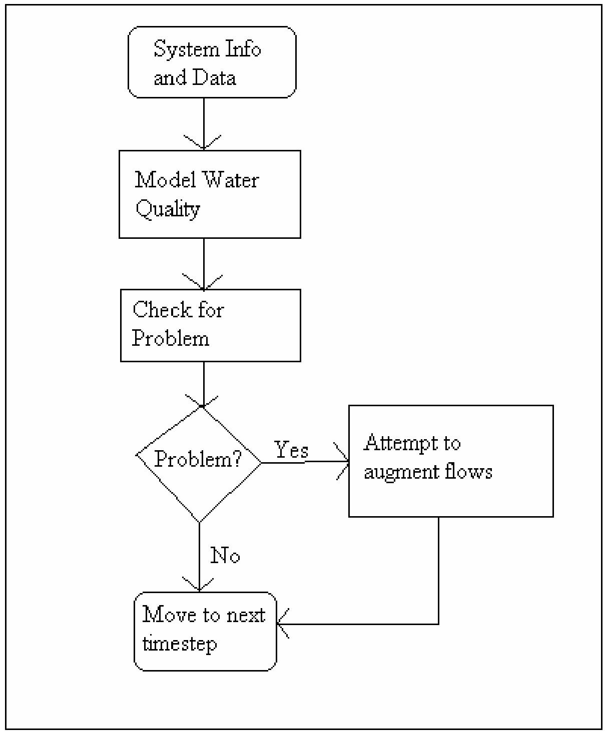

Figure 2. Decision making process for flow augmentation

Current Water Quality Modeling and Monitoring Efforts on the River

Water quality modeling will be required for the prediction of water quality on the river by the decision support system. There has been an extensive amount of water quality modeling on the Truckee in the past, and many modeling efforts are currently underway. One of the major efforts currently underway is the development of a water quality model by the Cities of Reno and Sparks, using the Hydrologic Simulation Program – Fortran (HSPF) modeling framework. The model has been adapted to use periphyton algorithms developed originally in the Dynamic Stream Simulation and Assessment Model with temperature (DSSAMt), which was historically used to develop total maximum daily loads (TMDLs) on the river. The Truckee River HSPF model (TrHSPF) simulates many different water quality constituents such as DO, TDS, temperature, and nutrients (Limno-tech, 2003).

The amount of historic monitoring data on the Truckee is immense. Large amounts of data can be found in the Environmental Protection Agency's (EPA) STORET database. This study requires data primarily for constituents such as discharge, temperature, specific conductance, TDS, DO, and nutrients. Monitoring for these constituents below Reno is primarily carried out by the TMWRF, the United States Geologic Survey (USGS), the Dessert Research Institute (DRI), and the Pyramid Lake Paiute Tribe. Of particular interest to this study are the nine continuous monitoring stations used by the TMWRF. Several of the sites provide real-time information through telemetry. These sites may be important for future real-time determination of WQSA water releases from the upper reservoirs. The stations provide hourly measurements of temperature, pH, specific conductance, and DO (TMWRF, 2002).

PROTOTYPE DECISION SUPPORT SYSTEM

Water Quality/Quantity Models

To provide decision support for releases of WQSA-stored water, a prototype linkage was created between the RiverWare hydrologic model and the TrHSPF water quality model. This linkage provides a complete water quality/quantity model for the environment that will serve as the basis for the water quality release DSS. The linkage was developed on a timestep-by-timestep basis, using a historic model run period. At each timestep, the RiverWare hydrologic model provides the water quality model with current and forecast streamflow conditions, as well as diversion quantities. The water quality model then uses constituent loading data from its own historic database as input, and provides an estimate of the downstream water quality. In this manner, a basic water quality forecast can be provided to the decision support mechanism to assist with a water quality release decision.

Water Quality Benefit Model

Based on the output of the water quality/quantity models, a mechanism will need to exist that identifies the presence of a water quality problem, and illustrates the marginal benefits gained by flow augmentation. This will either be a simple water quality index (WQI), or a fish habitat type model. It will operate using the output from the water quality model, and give a quantitative account of the quality of water in the river for the given uses. At the time of the writing of this document, the water quality benefit model was currently in design, and expected to be developed in the near future.

Flow Augmentation DSS

A DSS will be necessary to decide on the optimal augmentation of flows using the purchased water. The system will activate in the event that the water quality benefit model identifies a problem, and it will attempt to optimize the benefits from an immediate flow augmentation given the constraint that limited water is available for the remainder of the season.

At the time of the writing of this document, research was currently underway into methods utilized by computer scientists to provide adaptive decision support based on computer learning algorithms. The basis for these learning algorithms is a model of the environment, which the computer can act upon and perceive the results of its actions. By repeatedly attempting different solutions and perceiving the results, the computer can "learn" which actions provide positive results, and which actions do not. Based on this learning, the computer can then evaluate near real-time situations and suggest an action that should achieve positive results. A prototype framework for the DSS in its "learning" mode is shown in Figure 3, and a prototype framework for the DSS in its "operating" mode is shown in Figure 4.

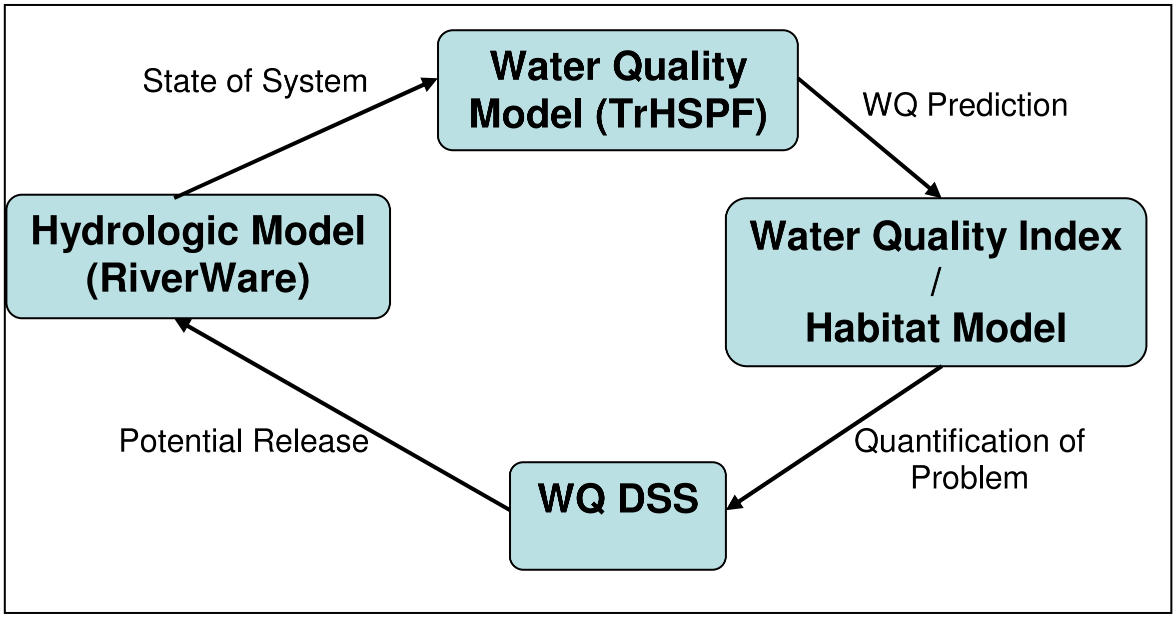

Figure 3. Prototype framework in "learning" mode

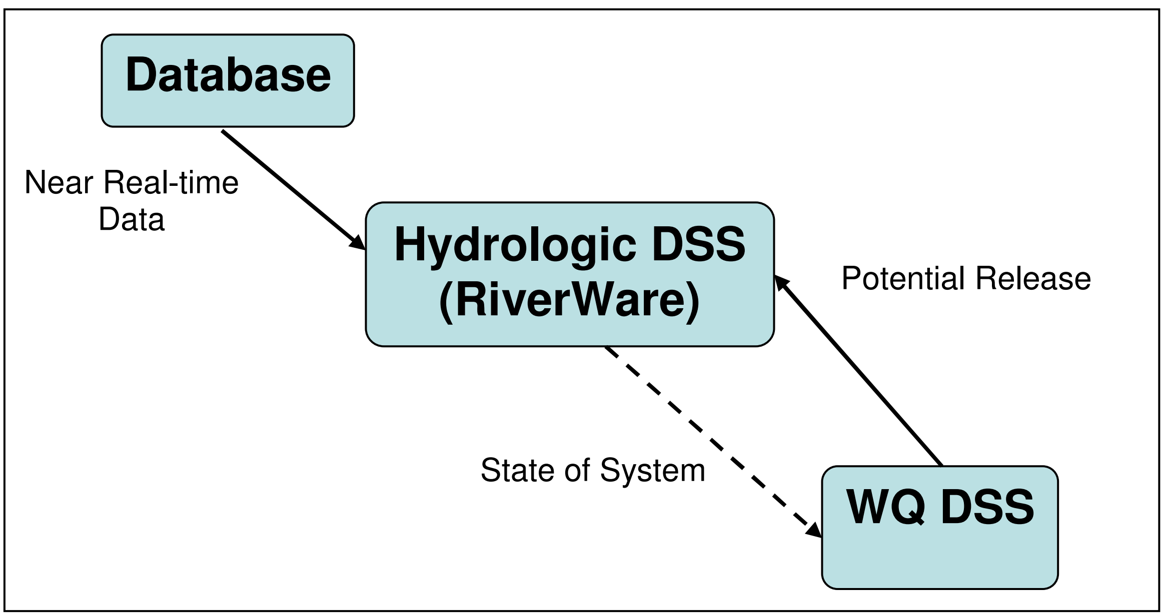

Figure 4. Framework in "operating" mode

CONCLUSIONS

Conclusions

The goal to appropriately use the WQSA-stored water in the Truckee River Basin provides a unique opportunity to test newer methods for computer learning to provide decision support. Based on the RiverWare hydrologic model and the TrHSPF water quality model, a prototype decision support system is currently in development that is expected to provide near real-time suggestions for the release of the WQSA-stored water. The system will be able to adapt to changing conditions within the basin by continuously learning how the river will react to augmented streamflows.

Upcoming Work

At the time of the writing of this paper, research was continuing into the computer learning methods that will be used to fully implement the prototype presented in this paper. The final design of the DSS will be the next step in the process, after the appropriate algorithms have been identified and developed. Additionally, the design of the water quality benefit model was currently underway, and a more robust linkage between the hydrologic and water quality models was being developed. Research was also being conducted on the development of methods to forecast water quality model input data, such as constituent loadings.

REFERENCES

Brown, W.M., Nowlin, J.O., Smith, L.H., Flint, M.R. (1986). "River-Quality Assessment of the Truckee and Carson River System, California and Nevada – Hydrologic Characteristics". U.S. Geological Survey, Open File Report 84-576.

Boyer, J.T. (2006). "Water Accounting in the Truckee Basin RiverWare Model", Proceedings of the 2006 Federal Interagency Hydrologic Modeling Conference, Las Vegas, NV.

Coors, A. S., (2006). "Truckee-Carson Basin RiverWare Operations Model," Proceedings of the 2006 Federal Interagency Hydrologic Modeling Conference, Las Vegas, NV.

Limno-tech, Inc. (2003) "Truckee River HSPF Model Training Session Manual," Manual for the December 3-5, 2003 training session, Ann Arbor, MI.

Mann, M.P.. (2006). "Hydrologic Forecasting in the Truckee-Carson RiverWare System", Proceedings of the 2006 Federal Interagency Hydrologic Modeling Conference, Las Vegas, NV.

Neumann, D. (2001). "An Operations Model for Temperature Management of the Truckee River Above Reno, Nevada" (M.S. Thesis). Civil Engineering. Boulder, University of Colorado**:** 121.

Reno, C. o., C. o. Sparks, C. o. Washoe, USDOI, USDOJ, EPA, NDEP and P. L. P. T. o. Indians (1996). "Truckee River Water Quality Settlement Agreement."

Rieker, J.D., Coors, S., Mann, M., Scott, T. "Modeling in Support of Water Operations in the Truckee River Basin", Proceedings of Watershed Management 2005, EWRI and ASCE, Williamsburg, VA, July 2005.

TMWRF (2002). "Truckee Meadows Water Reclamation Facility <http://www.tmwrf.com/rivermonitoring.htm> <http://www.tmwrf.com/rivermonitoring.htm>

United States Department of the Interior, B. o. I. A. (2002). "Final Environmental Impact Statement - Truckee River Water Quality Settlement Agreement - Federal Water Rights Acquisition Program". Phoenix, AZ.

Zagona, E., T. Fulp, R. M. Shane, T. Magee, and H. M. Goranflo (2001). "RiverWare: A Generalized Tool for Complex River System Modeling," Journal of the American Water Resources Association, 37(4) pp 913-929.