Integrated Hydrometeorological and Water Management Modeling:

Russian River Tributaries Project

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For basin-wide water management, we are coupling the GHM generated "natural" flows with the GeoMODSIM model to obtain "managed" flows at any location. Together, the coupled natural and managed flow models provide an estimate of the total water budget, allowing researchers and stakeholders together to better understand the relationships between reservoir storage, streamflow, agricultural diversions, and return flows at any location in the basin.

GeoMODSIM

GeoMODSIM is a GIS-based version of the MODSIM generalized river basin management decision support system (DSS) tool (Labadie, 2012; Triana and Labadie 2007; Triana, et al 2010), developed by Dr. John Labadie in the Civil and Environmental Engineering Department at Colorado State University. GeoMODSIM allows the user to efficiently model complex stream networks and to evaluate management strategies with consideration of water rights, agricultural diversions, and environmental flow requirements, while taking advantage of the spatial data base management and modeling tools available in the GIS environment.

Integration of a gridded hydrologic model (GHM) for flow data with the stream network structure of the MODSIM river basin management software is a key to developing a fully coupled model of the system that combines MODSIM with GHM and gridded demand models within GeoMODSIM. Shown here is the integration of a map layer for the National Weather Service gridded hydrologic model (GHM) into the custom ArcMap TM (ESRI, Inc.) interface with GeoMODSIM for providing spatially distributed natural or unregulated inflows generated from quantitative precipitation information (QPI) fields. In addition, we are working to generate vineyard irrigation demands for grape frost and heat protection from a high resolution gridded frost and heat model (Reynolds et al 2014). Integration of the gridded U.S. Geological Survey Modular Ground-Water Flow Model (MODFLOW) into GeoMODSIM has also been accomplished (Triana et al, 2010; Morway et al, 2015).

Prototype Tributary Water Management Model

To demonstrate the potential of a full-scale tributary model, a prototype model was developed for a tributary within the Russian River basin. The selected tributary is characterized by the proximity of vineyards to the stream as well as its classification as critical endangered species habitat. Overall, the tributary watershed encompasses 14.6 square miles, with the stream network model automatically created in GeoMODSIM using NHD-Plus hydrography data readily available from the USGS. GeoMODSIM can be applied to planning the geospatial placement of proposed irrigation ponds, allowing analysis of the best locations for proposed instream and off-stream pond storage.

Recent water management trends in the Russian River basin include increased restrictions on agricultural diversions in order to sustain environmental flows for fisheries. In 2010, the California State Water Resources Control Board (SWRCB) adopted new policies intended to maintain environmental flows for the protection of fishery resources, in particular threatened and endangered anadromous salmonids (SWRCB, 2010). Additionally, in 2011 the SWRCB adopted further restrictions on diversions and groundwater pumping for purposes of frost protection against late-spring frost events (SWRCB, 2011). Although legal proceedings surrounding these restrictions are ongoing, there is increasing recognition by all stakeholders of the need for better understanding of the effects of agricultural activities on tributary flows and how to improve water management so as to mutually benefit both interests.

Agricultural aspects of the system include demands for both irrigation and frost protection, as well as on-stream and off-stream agricultural ponds for enhancing timely water supply for irrigation as well as maintaining environmental flows. Although irrigation water demands for vineyards are relatively small in terms of total streamflow rates, during the dry season, even small diversions from a stream can be detrimental to environmental flows.. In the early spring, vineyards spray irrigate to form a protective layer of ice on the developing grape buds when a frost event is predicted. While there are generally only 5-6 frost events per season, their sporadic nature and the high flow rates required for frost protection can have significant impacts on streamflow.

For this demonstration, environmental flow requirements in the system were approximated based on minimum estimated streamflow rates in the tributary. Future work will focus on developing environmental streamflow requirements based on California State Water Resources Control Board guidelines for minimum flow requirements. For this demonstration, proxy input flows were estimated throughout the system based on scaled streamflow gage data from the main stem Russian River, whereas future work will focus on use of the gridded RDHM model for spatially distributed natural inflow prediction.

The system was modeled based on two scenarios – the historic case and a managed case. The historic scenario does not include any environmental instream flow requirements on the tributaries but does impose irrigation and frost agricultural demands, as well as hypothetical on-stream ponds for supply and diversion. The historic simulation was run in daily time steps over a one year period, revealing that downstream of the agricultural diversions, instream flows were frequently reduced to zero during periods of peak demand associated with frost events, as well as during extended dry periods that are prevalent during the summer irrigation season. At the same time, most agricultural ponds remained at or near capacity.

Development of the managed scenario starts with the same base assumptions of the historic scenario, but then includes two key modifications. First, instream flow requirements are imposed downstream of each agricultural pond. Second, the on-stream agricultural ponds are modified to include improved operations that allow more flexibility for downstream releases. The results of the managed scenario demonstrates that with improved operation of the agricultural ponds, the environmental needs of the endangered fish species can be met while satisfying nearly all of the agricultural demands.

Future Work

Given the successful demonstration of the prototype tributary model, further development of the model is warranted. Current efforts include the coupling of the GHM gridded model with GeoMODSIM to provide a capability for forecasting flows and support adaptive water management strategies. Similarly, the gridded frost model is being integrated to help refine the timing of frost and heat demands. Additionally, the GHM model will be used evaluate of a variety of hydrologic scenarios (wet, dry, normal, etc.). Management scenarios will also be improved by further refining the agricultural demands as well as the instream environmental flow demands. The prototype tributary model not only demonstrates use of GeoMODSIM for guiding management decisions, but also informs the design process of potential watershed improvements, such as incorporation of new on-stream and off-stream ponds in the basin for improved water management.

The ultimate goal of this research is to provide a means for collaborative learning of water management alternatives by competing stakeholders in the agricultural and environmental protection stakeholders in the basin. The GIS platform that the GeoMODSIM model is built on will be helpful for creation of an internet-based tool for the visualization of model results and the dissemination of information to stakeholders. With the availability of these powerful on-line tools, competing stakeholders can be presented with easily comprehended information for developing a "shared vision" of how water resources in the basin can be managed in an integrated manner as a means formulating strategies with the potential for satisfying the requirements of all stakeholders.