

**American Water Resources Association**  
**2009 SUMMER SPECIALTY CONFERENCE**  
***Adaptive Management of Water Resources II***  
**June 29 – July 1, 2009**  
Snowbird, UT

**Tuesday, June 30**

**1:30 PM – 3:00 PM**

**Session 24: Uncertainty Analysis Supporting Adaptive Management**

**1. Weather Derivatives as a Potential Risk Management Tool for Irrigators - Chris Thompson,** University of Nebraska, Lincoln, NE (co-authors: Ray Supalla, Derrel Martin, Brooks Neely, Brain McMullen)

Groundwater management policies in the Republican basin of Nebraska use five year allocations to limit pumping for irrigation. Allocations range from 45 inches in the Lower Republican Natural Resource District to 65 inches in the Upper Republican Natural Resource District where rainfall is lower. Using multi-year rather than annual allocations gives groundwater irrigators the flexibility to manage their groundwater in ways which reflect expected rainfall variability. In the semi-arid Great Plains region rainfall variability is the most unpredictable weather variable in irrigated agriculture. Irrigators must learn to incorporate multiple year drought risk in their management plans as they adapt to the limitations imposed by five year pumping allocations. A major concern is the implications of being water short during the later years of the allocation period because of an accumulative rainfall shortage or drought. Producers can either ignore the risk of substantially lower incomes if their allocation is exhausted too soon, or use less water early in the period by adjusting their production practices. This approach reduces total net income over the five year period, but also reduces the risk of experiencing one or more very low income years. Income variability can be reduced using production strategies such as minimum tillage, cropping pattern changes, irrigation system improvements, deficit irrigation, or by reducing the number of irrigated acres. Alternatively it may be possible to use weather derivatives or other insurance arrangement to manage income risk. The probabilities for multi-year rainfall shortages can be easily and reliably calculated from long term weather station data that is available in the region. This paper evaluates the economics of risk reducing production practices and assesses the prospects for using weather derivatives as an alternative multi-year risk management strategy. Attention is also given to the adaptive learning process which must occur as producers modify their traditional management practices based on annual weather and unlimited pumping to adjust to the implications of multi-year weather and multi-year pumping limits.

**2. Manatee River Minimum Flows and Levels Model - Jason Love, RESPEC, Rapid City, SD**

The Manatee River, flowing approximately 45 miles to the Lower Tampa Bay over a watershed of 360 square miles, is located almost entirely in Manatee County in the urbanizing Tampa Bay region of west-central Florida. The Manatee River estuary is a high-priority waterbody that requires the adoption of Minimum Flows and Levels (MFLs) that are defined as the limit at which further freshwater withdrawals would be significantly harmful to the water resources or ecology of the area. MFLs for the Manatee River estuary will be evaluated by the Southwest Florida Water Management District (SWFWMD) using a hydrodynamic model of the estuary. To assess the impact of freshwater inflows on salinity and other ecological issues of concern with the hydrodynamic model, flow inputs must be assigned to quantify watershed runoff to the tidal reaches of the Manatee River Watershed. A complete characterization of freshwater flow discharges to the estuary requires the development of a continuous hydrologic watershed model of the watershed to provide flow predictions for input to the hydrodynamic model. The modeling package selected for this application is the U.S. Environmental Protection Agency Hydrological Simulation Program-FORTRAN (HSPF). HSPF is a complex, environmental simulation model that can be subjected to the difficulties of parameter identifiability and sensitivity common to such models. Many alternate sets of parameters may result in an acceptable level of calibration; calibrating at multiple gages within a region will reduce the uncertainty in the parameters that result from the calibration process. However, significant uncertainty can still exist because of factors such as heterogeneity within the watershed and data available to conceptualize the system. Because of the complexity associated with models like HSPF, few applications attempt to quantify this uncertainty. This paper describes the

sensitivity analysis (SA) and uncertainty analysis (UA) performed on the calibrated and validated HSPF model application. The SA and the UA analyzed the daily flows for the following metrics: (1) mean annual flow (cubic feet per second (cfs)), (2) 10 percent highest flows (cfs), and (3) 25 percent lowest flows (cfs). This framework is readily reproducible for other watershed applications, metrics, and pollutants of interest.

### **3. Benefit Cost Analysis of Water Conservation: Considering Uncertainty - Md Rashid**, University of Southern Indiana, Evansville, IN (co-authors: William O. Maddaus, Michelle Maddaus, Faridul Islam)

Benefit cost analysis (BCA) is a powerful tool to determine if the benefits of water conservation outweigh its cost. The economic benefits of conservation include reduced water consumption and thus reduced wastewater generation, savings from delaying or eliminating capital investment projects that would be necessary in the absence of conservation. The costs include conservation plan preparation, capital investments for program implementation and operation and maintenance of conservation efforts. The benefits may flow over a long period of time while the costs may incur even prior to the project. To justify the costs against the anticipated benefits, BCA provides a meaningful answer. From the perspectives of public policy BCA is considered highly relevant. The conceptual framework of BCA has been widely applied by the government and the private sectors alike. Despite its simplicity, the methodology has not found broad application in the area of water conservation programs. In some studies, the analysis is totally ignored at the risk of wasting limited resources, while in other cases benefit and cost are described only qualitatively. This paper attempts to demonstrate that BCA can be conducted without unreasonable claim on resources and at the same time produce an efficient outcome in resource allocation. The analysis requires quantification of various parameters, such as, water supply and demand estimates, and cost for water treatment and conservation planning effort, among others. The time value of money and the impact of climate change are two major factors in these estimates. Therefore, there are uncertainties in this analysis. The availability of future supply is uncertain, especially new surface water supplies both in the amount of water a new project may provide as well as the ability to obtain permits, funding, etc. Future water demand is dependent upon future growth and drivers such as future population are always uncertain. The uncertainty can be addressed using Bayesian probability and statistics, estimating parameters as a range of values (i.e., optimistic to pessimistic) instead of single value, and conducting sensitivity analyses, to name a few. This work will attempt to identify the uncertainties and address them in a meaningful way.

### **4. Uncertainty Analysis Using the Method of Morris on a Hydrologic Model in the Okavango Basin - Anna Cathey**, University of Florida, Gainesville, FL (co-authors: Rafael Muñoz-Carpena, Gregory Kiker)

The Okavango Basin is a large transboundary watershed located in southern Africa that is shared between three countries: Angola, Namibia, and Botswana. River flow in the basin originates in the Angolan headwaters, continues through a sliver of land in Namibia, and finally empties into the Okavango Delta, the largest inland delta in the world, located in Botswana. This water spreads out over the flat alluvial fan that is the Okavango Delta and is evaporated on the border of the Kalahari desert. The Okavango Delta may be one of the most pristine large wetlands in all of Africa. Future development and climate change in the area threaten the system. An Adaptive Management (AM) approach is especially applicable for the Okavango Basin because of its large size, transboundary nature, and the resulting complexity. Models are an integral part of the AM process in that they are able to simulate large scale experiments, investigate relationships, explore scenarios, and consider management tradeoffs. Models by nature are simplifications of reality and are thus built in the presence of uncertainty. Uncertainty analysis is used to propagate various uncertainties associated with parameters onto a model output. Sensitivity analysis is more refined than uncertainty analysis and is used to determine how the possible range of each uncertain input factor affects the model output. This research applies the Method of Morris, a qualitative sensitivity analysis technique, to a hydrologic model of the Okavango Delta. The Method of Morris is a one-at-a-time sensitivity screening method. Each model parameter is assigned a probability distribution function (pdf) which is then divided into  $p$  levels. A matrix is formed that describes the region of experimentation with  $k$  factors and  $p$  levels. Values are randomly selected from this matrix for model runs. The method uses two sensitivity indices:  $\mu$  and  $\sigma$ .  $\mu$  represents the general magnitude of effect that the uncertainty of a parameter has on the model output.  $\sigma$  estimates higher-order relationships such as nonlinear and interaction effects. These results can be used to illuminate gaps in knowledge and ultimately lead to the development of strategic monitoring plans and more reliable models.