Incorporating Uncertainty into Adaptive, Transboundary Water Challenges: a Conceptual Design for the Okavango Basin

Anna Cathey, Gregory A Kiker, Rafael Muñoz-Carpentra, Andrea E Gaughan
University of Florida, Agricultural and Biological Engineering Department

The objective of this work is to provide a conceptual framework for incorporating systematic uncertainty and decision analysis tools into adaptive transboundary management in the Okavango Basin. These tools can build upon previous modeling and monitoring efforts to allow researchers, decision makers, and stakeholders to work together in addressing functional decision-relevant issues within highly variable environments.

Transboundary Issues
- The Okavango Basin is shared between 3 countries: Angola, Botswana, Namibia.
- Okavango Delta and surrounding area world’s largest protected area under RAMSAR.
- Complex hydro-political dynamics create important fundamental to implementing and maintaining a collaborative adaptive management framework in the Okavango Basin.

A Review of Previous Hydrological Modeling in the Basin
- Modeling efforts in the delta have been much more extensive than in the river.
- Modeling in the Okavango River has largely involved the Pitman model (Pitman, 1971)
- Pitman model was developed for southern Africa and is a rainfall-runoff model.
- Most of the basin-level modeling efforts have sought to provide a fundamental rainfall dataset (Wolski et al., 2006) and a basic hydrological model platform (Hughes et al., 2006) for simulating future development and climate change scenarios in the upstream areas.

Adaptive Management Strategy
- Water resources management in the Okavango Basin is a complicated task due to hydro-political dynamics, the complexity of the system, and its transnational character. Adaptive management (AM) is a management framework that explicitly addresses the uncertainty that exists in complex and variable systems by basing decisions on learning-by-doing experiments. Adaptive management recognizes that the nature of conservation plans is often experimental rather than proven.

Strategic Issues
- What are the interactions among basin components?
- What can we understand and/or forecast with our models?
- What are our realistic options in the basin?
- What consensus policies are worth pursuing?

Model Integration with SIMLAB
- The dynamicpackage: SIMLAB (C2, microbes et al., 2001) is used in the global sensitivity and uncertainty analysis of the Okavango QuaD application. SIMLAB is designed for pseudorandom number generation and for linking models into a user-friendly model/Scenario framework.

Tools for Incorporating Uncertainty into Hydrological Modeling
- Global Uncertainty and Sensitivity
- Uncertainties analyses include the key contributors to uncertainties, while uncertainty analysis quantifies the overall uncertainty and together it contributes to a reliable quantification of the model. Global sensitivity analysis evaluates input factors of a model concurrently over the whole parameter space (described by probability distribution functions). The use of global sensitivity methods can yield four main products for the Okavango application:
  - Assurance on the model’s behavior
  - Ranking of importance of the parameters for different outputs
  - Effect of changing modeling structure
  - Type of influence of the important parameters

Decision Analysis and Bayesian Tools for Uncertainty Analysis
- Decision analysis is a tool for contributing to better decisions by helping managers to structure the problem, balance risks, and compare options based on outcomes and expressed preferences. The primary focus of these decision analysis techniques is the identification of trade-offs among alternatives.

Management-focused, integration models: The QuaD system
- The Quarters and Decisions (QuaD) system is a decision support tool that incorporates ecosystem, management, economic and socio-political issues into a user-friendly model/Simulation framework.

Wider Implications and Next Steps
- Provide a beginning-to-end integration of environmental data, models, analysis tools and decision methods.
- Imparting complex management concepts such as model uncertainty to stakeholders in an understandable way.
- Systematically incorporate uncertainty into management level understanding of the inherent risks within the basin.

Table 1. Modeling efforts in the Basin.

<table>
<thead>
<tr>
<th>Author/Date</th>
<th>Title</th>
<th>Region of Basin Modeled</th>
<th>Model Conceptualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitman, 1973</td>
<td>A mathematical model for generating the flow from the watersheds of South Africa</td>
<td>Okavango upstream from the Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Hughes et al. 2006</td>
<td>Hydrologic simulation of the Pitman model for the Okavango basin</td>
<td>Okavango River Basin model</td>
<td></td>
</tr>
<tr>
<td>Assmann et al. 2005</td>
<td>Water flow dynamics in the Okavango River Basin and Delta</td>
<td>Okavango River Basin model</td>
<td></td>
</tr>
<tr>
<td>SMBC, 1998</td>
<td>Southern Okavango Integrated Water Development</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Dein et al. 1997</td>
<td>A simple mathematical model of a complex hydraulic system</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Ewing et al. 1998</td>
<td>The SCS approach to the Okavango Delta</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Geraghty 1997</td>
<td>Assessing surface runoff in the Okavango Delta</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Schoenfeld et al. 2000</td>
<td>Alkalinity monitoring in the Okavango Delta</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Wolko et al. 2002</td>
<td>Assessing the monitoring of the Okavango Delta</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Wolko et al. 2005</td>
<td>Assessing the impact of climate change in the Okavango Delta</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
<tr>
<td>Wolski et al. 2006</td>
<td>A spatially distributed hydrological model for the Okavango Delta</td>
<td>Okavango Delta and Panhandle model</td>
<td></td>
</tr>
</tbody>
</table>

References

Acknowledgements
We are grateful for the computing and funding resources provided by NSF/IGERT Adaptive Management: Wise Use of Water, Wetlands & Waterbodies. Funding for this project was obtained from the South Florida Water Management District.