Accounting for Uncertainty in Predicted Benefits of Freshwater Flow Diversion to Coastal Marshes

S. Kyle McKay, J. Craig Fischenich[1], Ronald Paille, and Tamieka Armstrong[2]

[1]U.S. Army Corps of Engineers [2]US Fish and Wildlife Service

Background

•Coastal Louisiana losing marsh greater than 30 sq miles per year (Figure 1) due to: river/floodplain disconnection, sea level rise, subsidence, coastal erosion, and other factors

•Hurricanes Katrina and Rita (2005)

•U.S. Congress directed the U.S. Army Corps of Engineers (USACE) to "conduct a comprehensive hurricane protection analysis and design…to develop and present a full range of flood control, coastal restoration, and hurricane protection measures"

•The Louisiana Coastal Protection and Restoration (LACPR) project sought to develop comprehensive plans for each of five basins to achieve these objectives

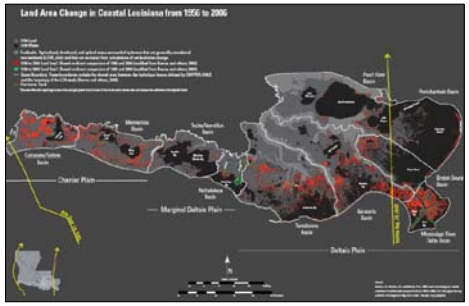

Figure 1. Wetland loss in Louisiana 1956-2006 (from Barras et al. 2008).

Developing Restoration Plans

Coastal restoration alternatives were developed and analyzed for each basin by an interagency Habitat Evaluation Team (HET) consisting of federal, state, and local partners. The HET not only collaboratively developed alternatives, but also worked side-by-side in analyzing these alternatives. Partnership between entities throughout the planning process created a transparent environment where decisions and analyses were discussed openly rather than developed and presented by one entity.

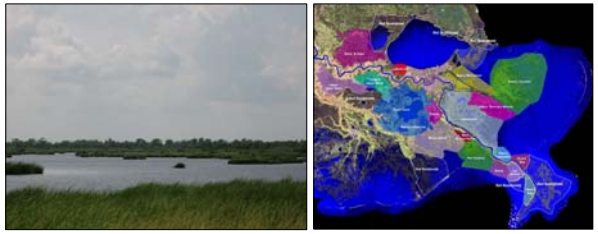

Figure 2. (a) Photo of typical marsh community (b) Sample restoration plan showing area sustained through proposed flow diversions.

Freshwater Flow Diversions

Freshwater flow diversion to coastal marshes is often employed to create new marsh communities and sustain existing communities. Flow diversion benefits are derived from two major mechanisms: 1) addition of inorganic suspended sediment from the source water and 2) addition of nutrients which stimulate marsh vegetative growth and increase organic accretion.

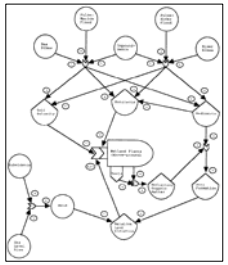

Figure 3. Conceptual model of marsh accretion (from Day et al. 1995)

Figure 4. Freshwater flow diversions (a) Davis Pond schematic (b) Caernarvon diversion structure (Figures from USACE New Orleans District and www.lacoast.gov)

Modeling Freshwater Flow Diversions

The HET required a rapidly applicable model of flow diversion benefits that would account for both organic and inorganic benefits to compare alternative locations, magnitudes, structure types, and operational scenarios (Figure 5). A spreadsheet model of diversions accounting for both organic and inorganic benefits on an annual time scale was previously developed under the auspices of the Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA; Boustany 2007); however, the limited temporal resolution was of concern due to variability in inputs and operational criteria on finer time scales. The CWPPRA model was adapted for rapid application to LACPR by improving sediment retention calculations and adding intra-annual temporal variability in hydrologic and sediment inputs.

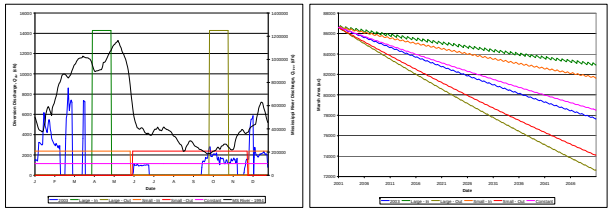

Figure 5. Application of flow diversion model for operational considerations (a) diversion hydrographs of equal volume and varying duration and magnitude (b) resultant marsh area of different operational scenarios

Why Uncertainty Analysis?

Many ecosystem restoration planning efforts provide little more than qualitative description of potential uncertainties. Uncertainty may generally be couched in terms of model, quantity (or parameter), and scenario uncertainty. In LACPR, parameter and scenario uncertainty were incorporated quantitatively into analyses, and model uncertainty was qualitatively addressed through documentation and peer-review.

Scenario Uncertainty Analysis

When elements of the future are uncertain (e.g. climate change, land use, invasive species), different scenarios may be analyzed in an effort to capture uncertainty and inform decision making. Two sea level rise (SLR) scenarios were incorporated into LACPR planning (Figure 6a).

Parametric Uncertainty Analysis

LACPR restoration analyses relied on a variety of input parameters, each carrying uncertainty. Each parameter was assigned a range of normally distributed values. Using Monte Carlo analysis, parameters were randomly perturbed and input to the wetland forecasting model for 10,000 iterations. This provided the HET with estimates of the impact of parametric uncertainty on acreage forecasts (Figure 6b).

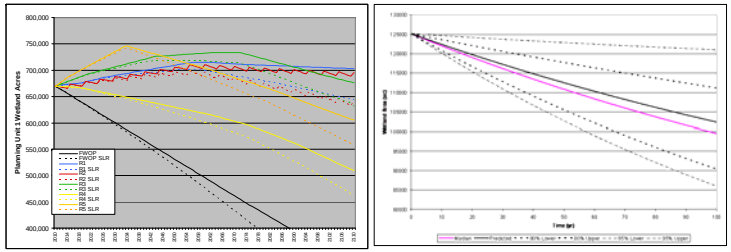

Figure 6. Uncertainty analyses (a) sea level rise scenarios and (b) parameteric uncertainty in wetland forecasts.

Conclusions

Although uncertainty analyses are often excluded because of a perceived increase in complexity and cost, this case study demonstrates practical incorporation of uncertainty in a massive, regional planning effort and the ability of uncertainty analyses to inform decision making.

Acknowledgements

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