Investigation of hydrologic variability on the Colorado River using prehistoric tree-ring data and the Reclamation CRSS long-range planning model

RiverWare User Group Meeting
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March 7, 2006
Introduction

- Recent conditions in the Colorado River Basin
  - Below normal flows into Lake Powell 2000-2004
  - 62%, 59%, 25%, 51%, 51%, respectively
    - 2002 at 25% was lowest inflow ever recorded since completion of Glen Canyon Dam
  - Lakes Powell and Mead were over 90% full in Spring 1999
  - April 2005 they were 33% and 60% full, respectively
- Some relief in 2005
  - February 2006 they were 46% and 60% full, respectively
  - Flows into Powell 105% of normal
  - Will it last?
Motivation

• How unusual is the current dry spell?
• How can we simulate stream flow scenarios that are consistent with the current dry spell and other realistic conditions?
Can we provide answers?

• What is done currently
  – ISM: captures natural variability of streamflow
    • Only resamples the observed record
    • Limited dataset

• What can be done?
  – Incorporate Paleoclimate information
Paleostreamflow reconstruction

- First reconstruction
  - Stockton and Jacoby, 1976
  - Colorado Rv. at Lees Ferry

- Dataset increased fivefold

- Improved frequency analysis

- Higher than normal flow during 1922 Compact
Annual Paleo-Reconstructions for Colorado River at Lees Ferry, Arizona - 10-year running average
Appling Disaggregation

- **Colorado River Basin**
  - Upper Colorado River Basin
    - Nonparametric disaggregation
    - 20 gauges
  - Lower Colorado River Basin
    - KNN resampling of natural flows
    - 9 gauges

- **Dataset**
  - 5 sets of annual paleo-based reconstructed streamflows for Colorado River at Lees Ferry, Arizona

- **Simulation horizon 2006-2060**

- **Number of traces equal to length of reconstructed streamflows**
Disaggregation scheme

Index gauge

(Colorado River at Lees Ferry)

temporal disaggregation
annual to monthly at index gauge

spatial disaggregation
monthly index gauge to monthly gauge

1 Colorado River at Glenwood Springs, Colorado
2 Colorado River near Cameo, Colorado
3 Colorado River near Lees Ferry, Arizona
4 San Juan River near Bluff, Utah
5 Colorado River near Lees Ferry, Arizona

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RECLAMATION
Lees Ferry

- Total Flow
Lees Ferry
- May flows
- Total Flow
Conclusions – Part 1

- A flexible, simple, framework for space-time disaggregation is presented
  - Obviates data transformation
  - Parsimonious
  - Ability to capture any arbitrary PDF structure
  - Preserves all the required statistics and additivity
- Easily be conditioned on large-scale climate information
- Can be developed in various scheme to fit needs
Annual Flow at Lee's Ferry (10-yr smoothing)
Stockton & Jacoby and Gauge Data

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RECLAMATION
Applying Paleo Traces to CRSS

- Using monthly CRSS as of 11/01/2005
  - Before States Shortage Negotiations

- Implementing disaggregated hydrologic inflows
  - One “disaggregation” of Lee’s Ferry Flows

- Still Using Index Sequential Method (ISM) through entire paleo-trace record

- Testing the “robustness” of CRSS
  - Stress Tests - Where does it break?
    - Model Mechanics?
    - Operational Policy Assumptions?
What are the Results?

- Made 7 minor modifications to the rule set and model file
  - Reservoir operations under near empty conditions
    - Handling evaporation
    - Meeting downstream demands with multiple reservoirs
  - Handling of reach losses / mass balance issues
  - Minimum flow criteria failures

- Mead and Powell Reservoir Elevations

- Deliveries to Water Users
Average Annual California Depletions

acre-feet

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Conclusions – Part 2
Using Paleo Traces for Decision Making

• Looking beyond the gauged record
  – An additional tool... perhaps ultimately the most useful
  – Magnitude vs. frequency of drought conditions

• Managing Uncertainty
  – 6 Interpretations of Paleo-record
    • All show a similar trend
  – Multiple temporal and spatial “disaggregations”
    • Once is good, 1000 times is better
  – ISM vs. Monte Carlo simulation

• Policy informed by the Best Available Science