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Managing Water in the West

High Flow Experiment Protocol Workshop – Hydrologic Modeling

June 17-18, 2010

U.S. Department of the Interior
Bureau of Reclamation

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Presentation Overview

- Hydrologic Modeling- the general approach
- Hydrologic Model Overview
  - CRSS general assumptions
  - Inflow hydrology scenarios
  - Demands
  - Presentation of Results
- Types of Analyses

Hydrologic Modeling

Modeling Approach

CRSS
-Overview
-Inflows
-Demands
-Results

Analyses

- Question: Time scale? Spatial Scale?
- Use Reclamation's long-term planning model CRSS for broad hydrologic analysis
- Use output from CRSS to drive additional analyses / models
  - Water quality (temperature, TDS, etc.)
  - Hydropower, economics
  - Sediment
  - Other resources (cultural, recreation…)

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CRSS Overview

Modeling Approach

CRSS
-Overview
-Inflows
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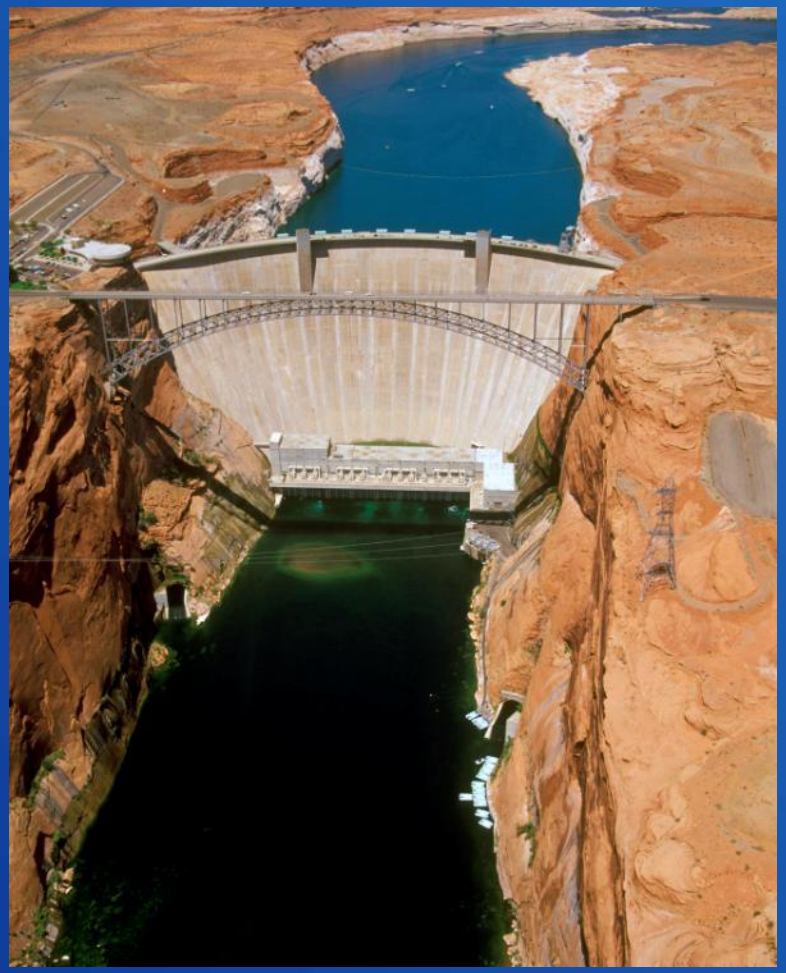
Analyses

- Planning model
- Monthly timestep
- ~50+ years into future
- Typically used for comparative analysis between alternatives
- Probabilistic: provides a suite of potential future elevations, releases, river flows, etc.



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CRSS Assumptions (typical run)

Modeling Approach

CRSS
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Analyses

- Run duration: 2010-2060
- Policy: Runs revert to the Shortage EIS No Action alternative in 2027
- Initial conditions: Jan 2010 res elevations
- Future Inflows: several methods to estimate
- Future Water Use: UCRC schedule, LB States schedules
- <u>Results are most sensitive to future inflows</u>

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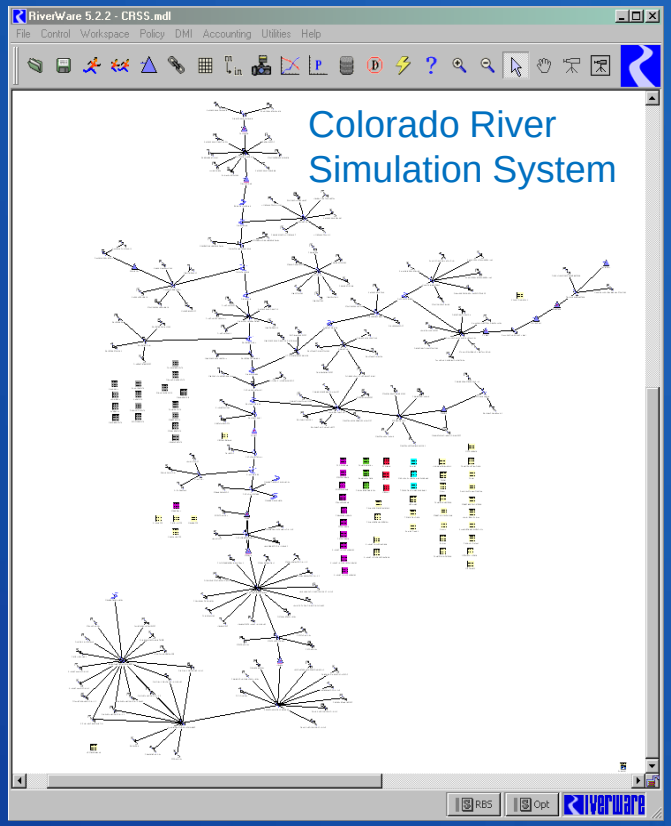
Spatial Configuration

- Full basin: headwaters of mainstem and major tributaries down to Mexico border
- Reservoirs: 12
- Diversions: ~225
- Natural inflow points: 29



Modeling Approach

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Hydrologic Inflow Scenarios

- Direct Natural Flows
- Direct Paleo Flows
- Paleo-Conditioned Flows
- Climate Change Scenarios

Modeling Approach

CRSS
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Analyses

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Direct Natural Flow

Modeling Approach

CRSS
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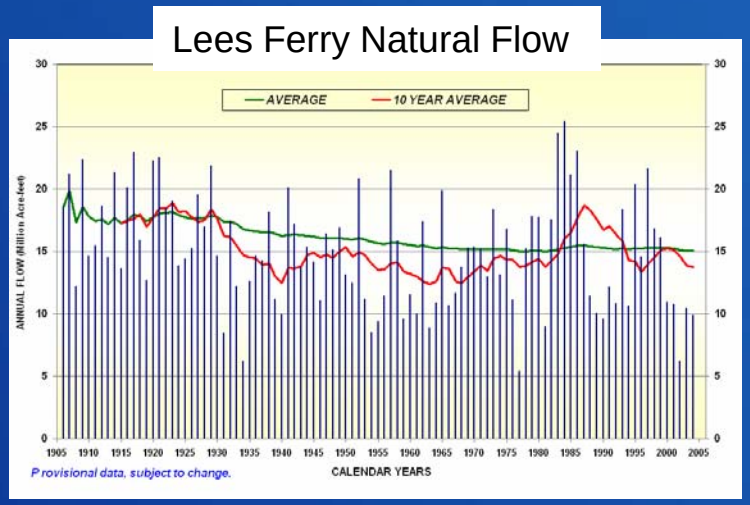
Analyses

- Historic natural flow record: 1906-2007
  - Flow that would have occurred w/o reservoirs and diversions (human influence)
- Index Sequential Method (ISM), block bootstrap
- 102 inflow traces



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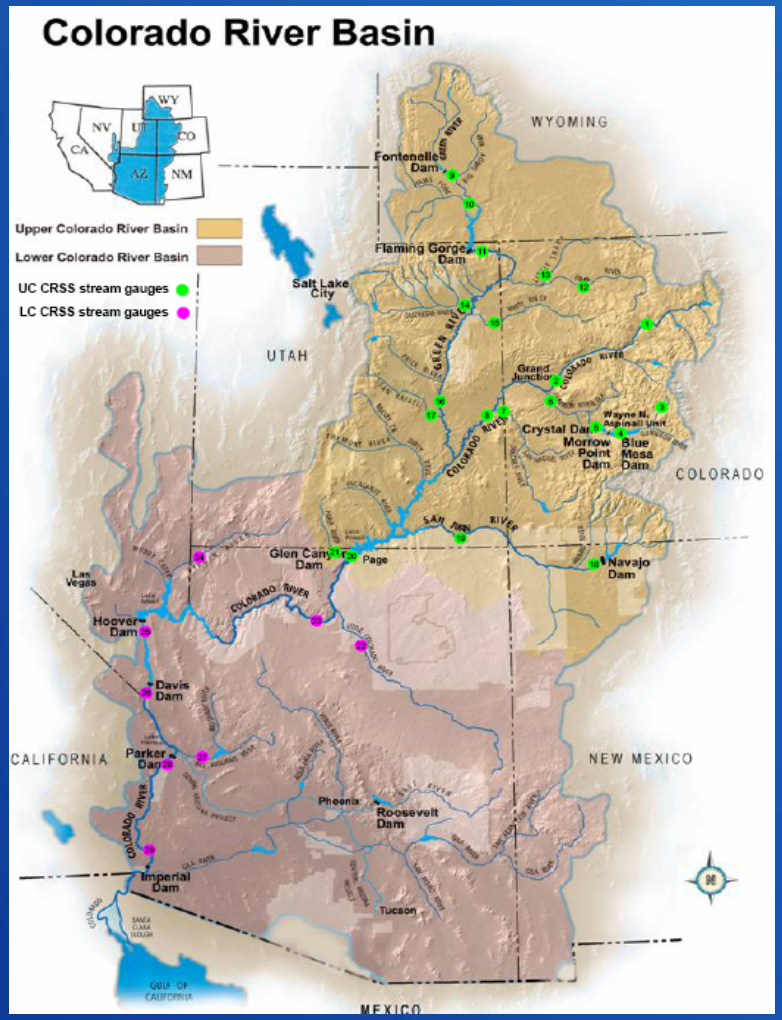
Direct Natural Flow Nodes

Modeling Approach

CRSS
- -Overview
- -Inflows
- -Demands
- -Results

Analyses

1	Colorado River at Glenwood Springs, CO
2	Colorado River near Cameo, CO
3	Taylor River below Taylor Park Reservoir, CO
4	Gunnison River below Blue Mesa Reservoir, CO
5	Gunnison River at Crystal Reservoir, CO
6	Gunnison River near Grand Junction, CO
7	Dolores River near Cisco, UT
8	Colorado River near Cisco, UT
9	Green River below Fontenelle Reservoir, WY
10	Green River near Green River, WY
11	Green River near Greendale, UT
12	Yampa River near Maybell, CO
13	Little Snake River near Lily, CO
14	Duchesne River near Randlett, UT
15	White River near Watson, UT
16	Green River at Green River, UT
17	San Rafael River near Green River, UT
18	San Juan River near Archuleta, NM
19	San Juan River near Bluff, UT
20	Colorado River at Lees Ferry, AZ
21	Paria River at Lees Ferry, AZ
22	Little Colorado River near Cameron, AZ
23	Colorado River near Grand Canyon, AZ
24	Virgin River at Littlefield, AZ
25	Colorado River below Hoover Dam, AZ-NV
26	Colorado River below Davis Dam, AZ-NV
27	Bill Williams River below Alamo Dam, AZ
28	Colorado River below Parker Dam, AZ-CA
29	Colorado River above Imperial Dam, AZ



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Direct-Paleo Flows

Modeling Approach

CRSS
-Overview
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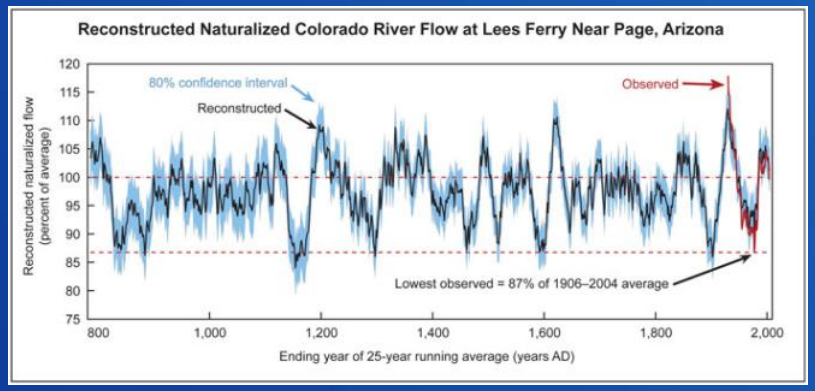
-Results

Analyses

- Tree ring chronologies: 762-2005 (Meko, 2007)
- Reconstructed annual flow at Lees Ferry
  - Spatially, temporally disaggregated
- Index Sequential method
- 1,244 inflow traces
- Simulates long-term climate variability



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Paleo-Conditioned Flows

Modeling Approach

CRSS
-Overview
-Inflows
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-Results

Analyses

- Uses paleo hydrologic state information (wet or dry) to sample from historic record
  - Benefit of extended dry and wet spells combined with observed flow volumes
- 500 inflow traces
- Simulates long-term climate variability

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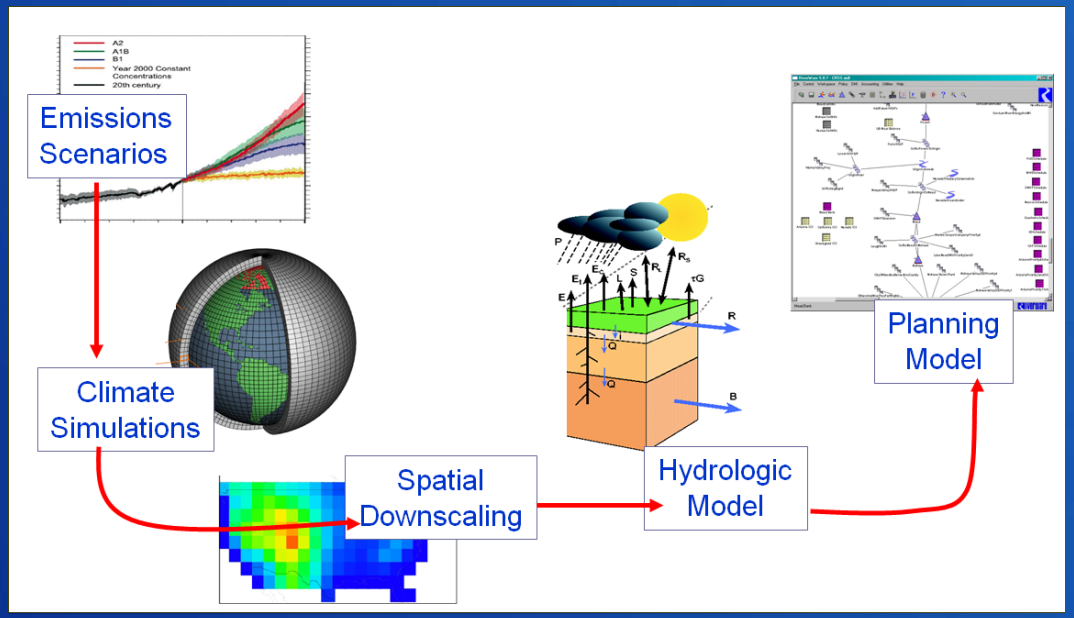
Climate Change Scenarios

- Work currently underway (complete ~Dec '10)
- Establish a framework to evaluate existing and future climate change scenarios
- Understand the potential range of impacts
- 112 traces



Modeling Approach

CRSS
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Analyses

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Future Water Use

- Upper Colorado River Commission (UCRC) schedule (2007)
  - States' projected development through 2060
- Lower Basin States use
  - Total use stays constant

Modeling Approach

CRSS
-Overview
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Analyses

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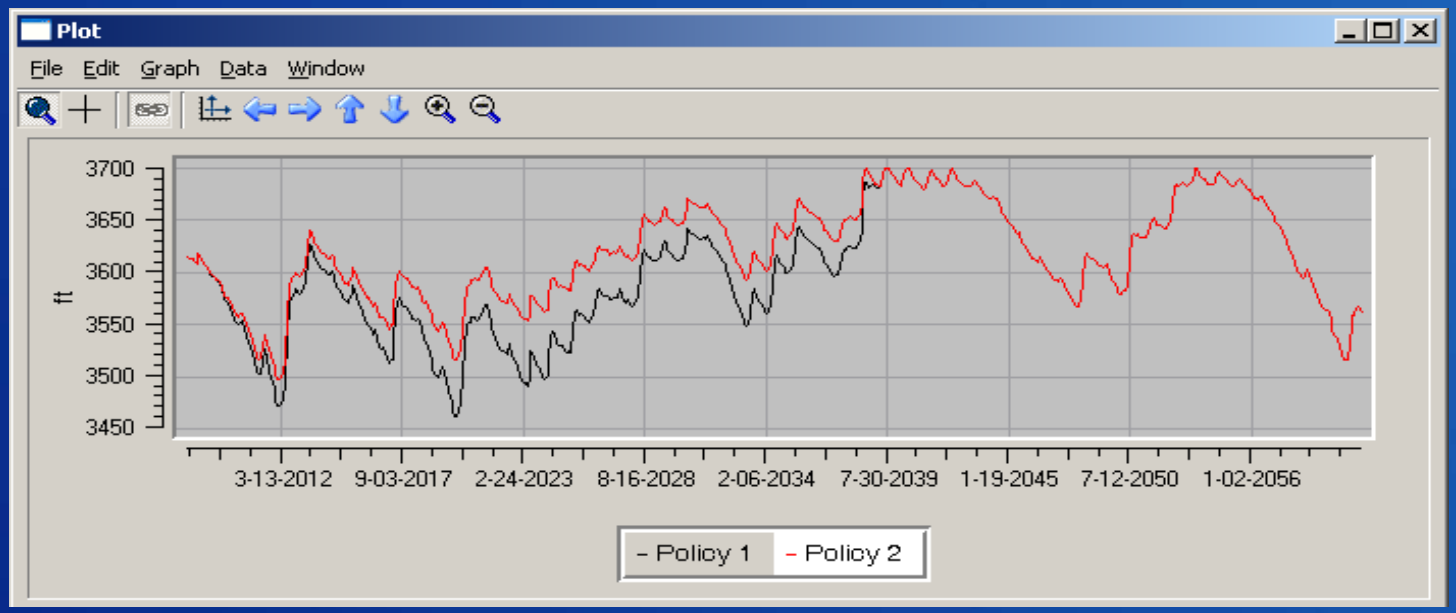
Results

- Probabilistic in nature – range of potential future res elevations, releases, river flows
- Excellent for comparative analysis between two alternatives



Modeling Approach

CRSS
-Overview
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Analyses

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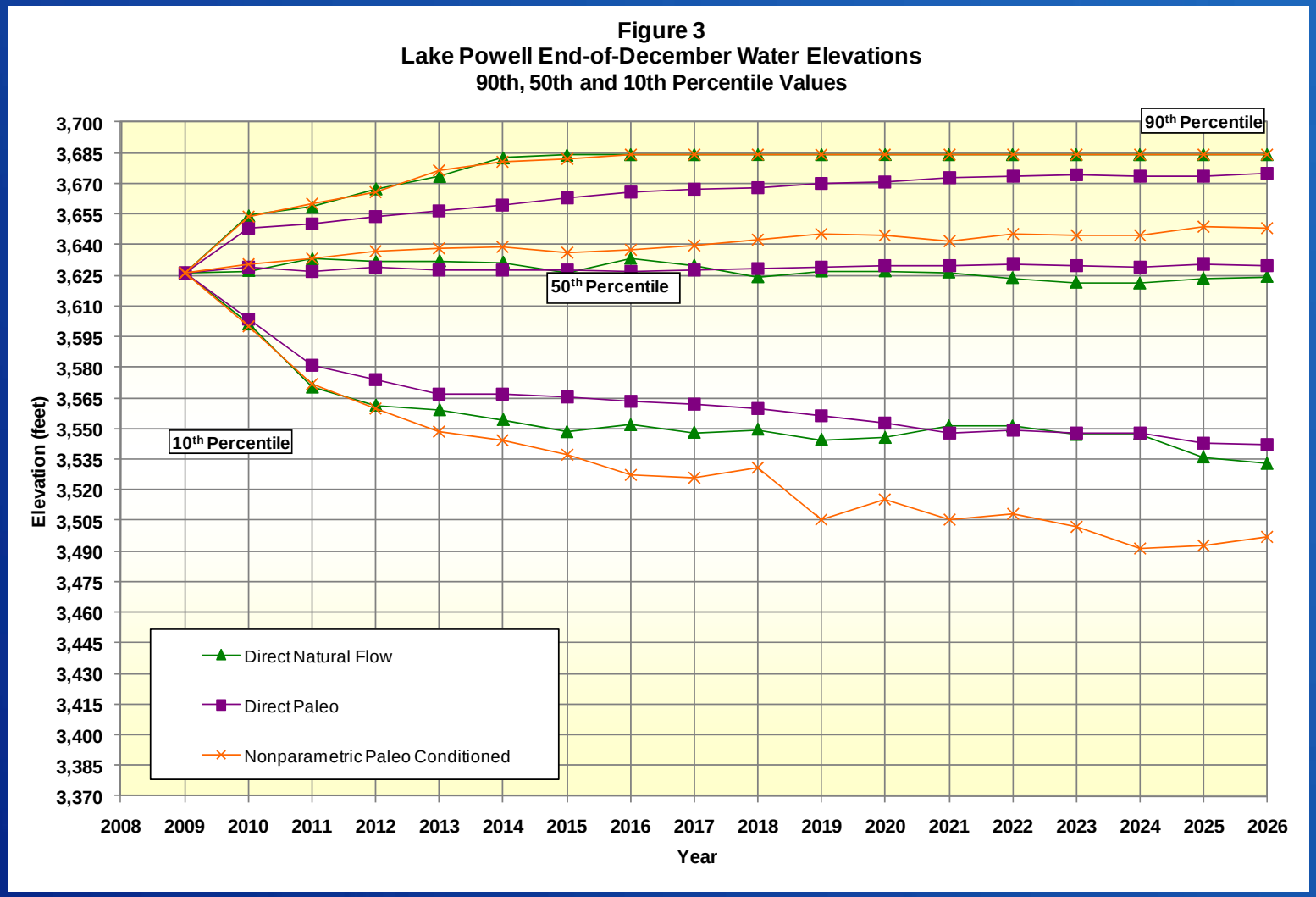
Powell Elevation

Modeling Approach

CRSS
- -Overview
- -Inflows
- -Demands
- -Results

Analyses



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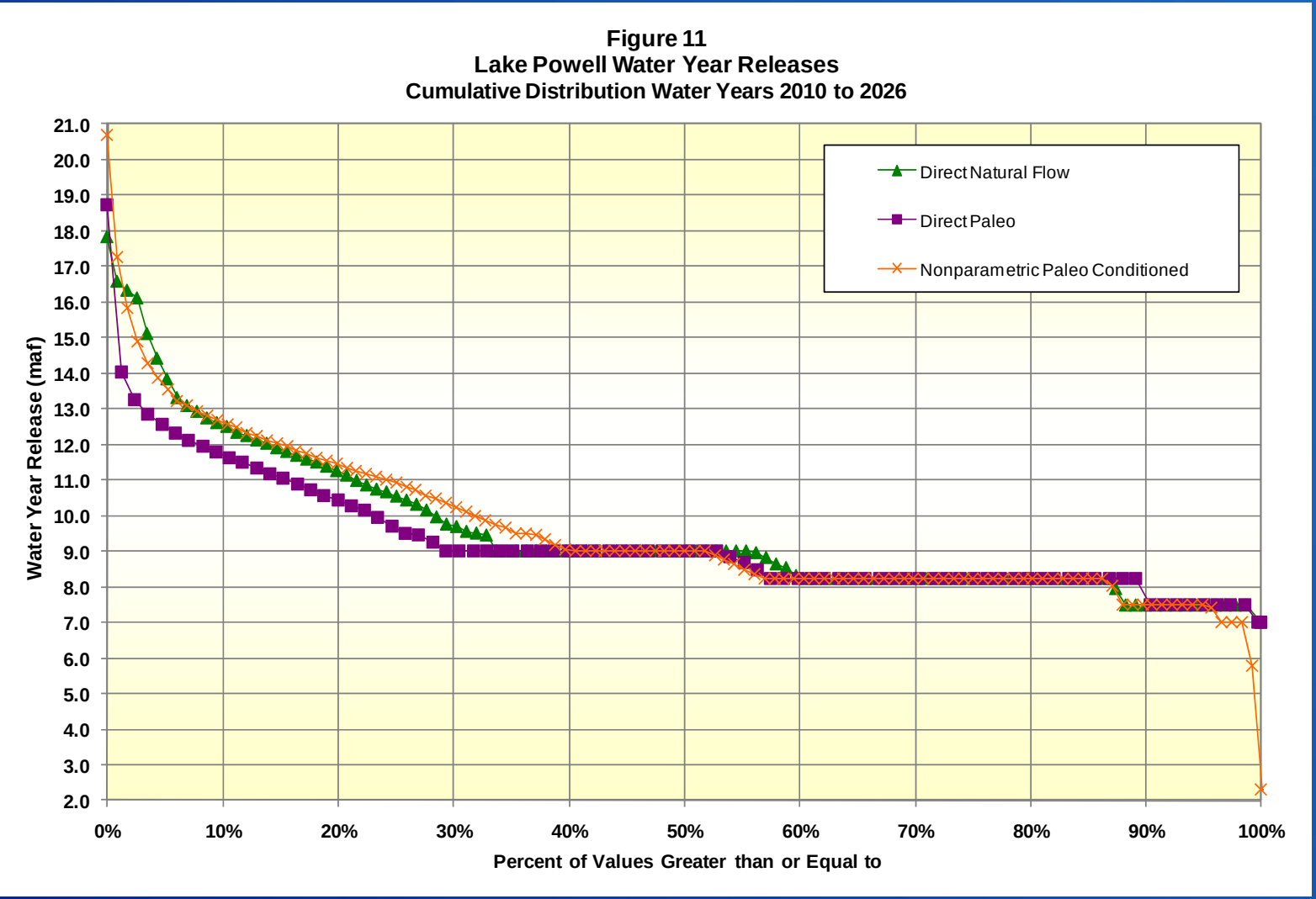
Powell WY Release

Modeling Approach

CRSS
- -Overview
- -Inflows
- -Demands
- -Results

Analyses



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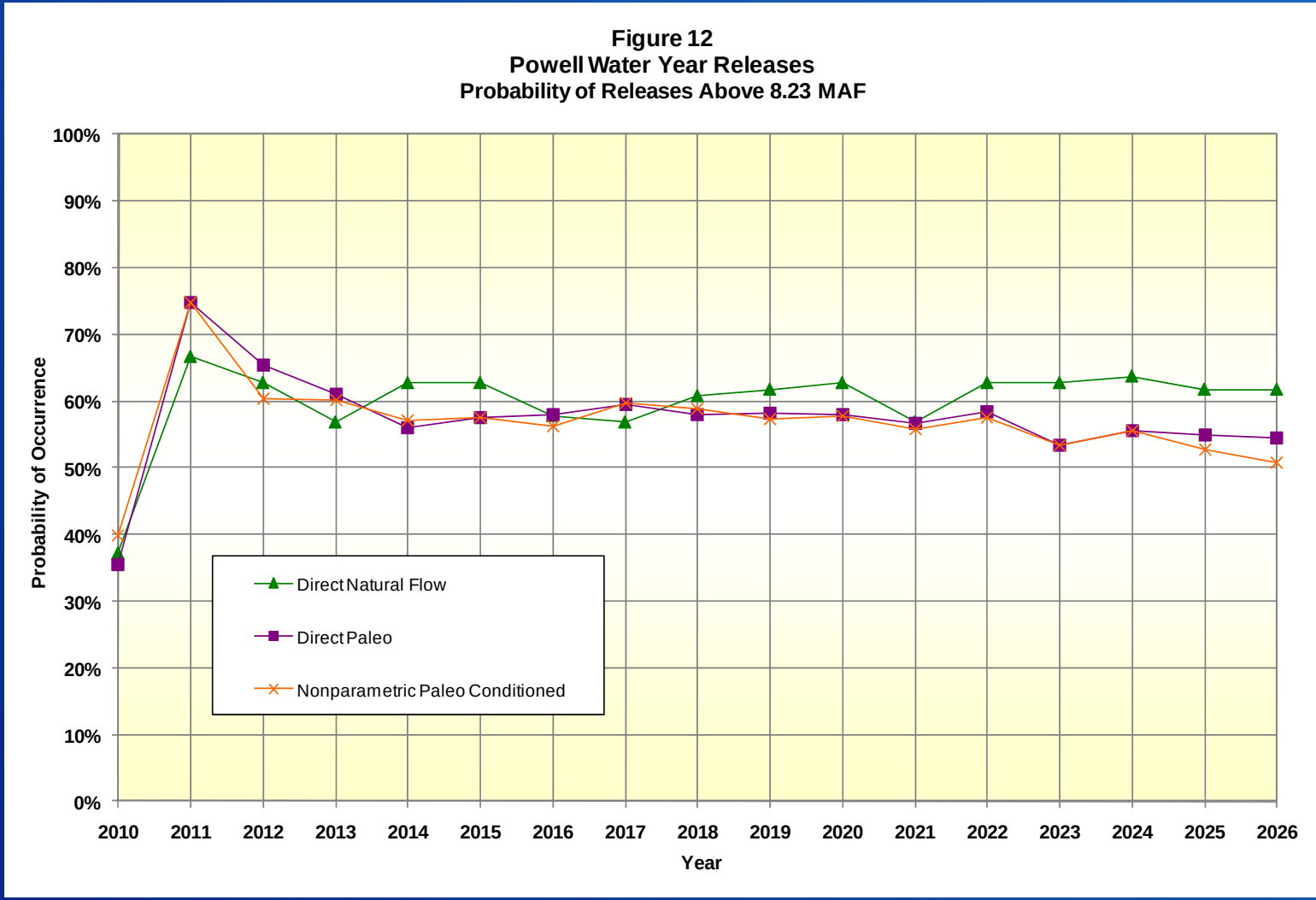
Powell WY Release > 8.23 MAF

Background

Methodology
- -Model
- -Inflows
- -Alternatives
- -Analyses

Results
- -Direct nat inflows
- -Paleo-cond inflows



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Powell WY Release

Modeling Approach

CRSS
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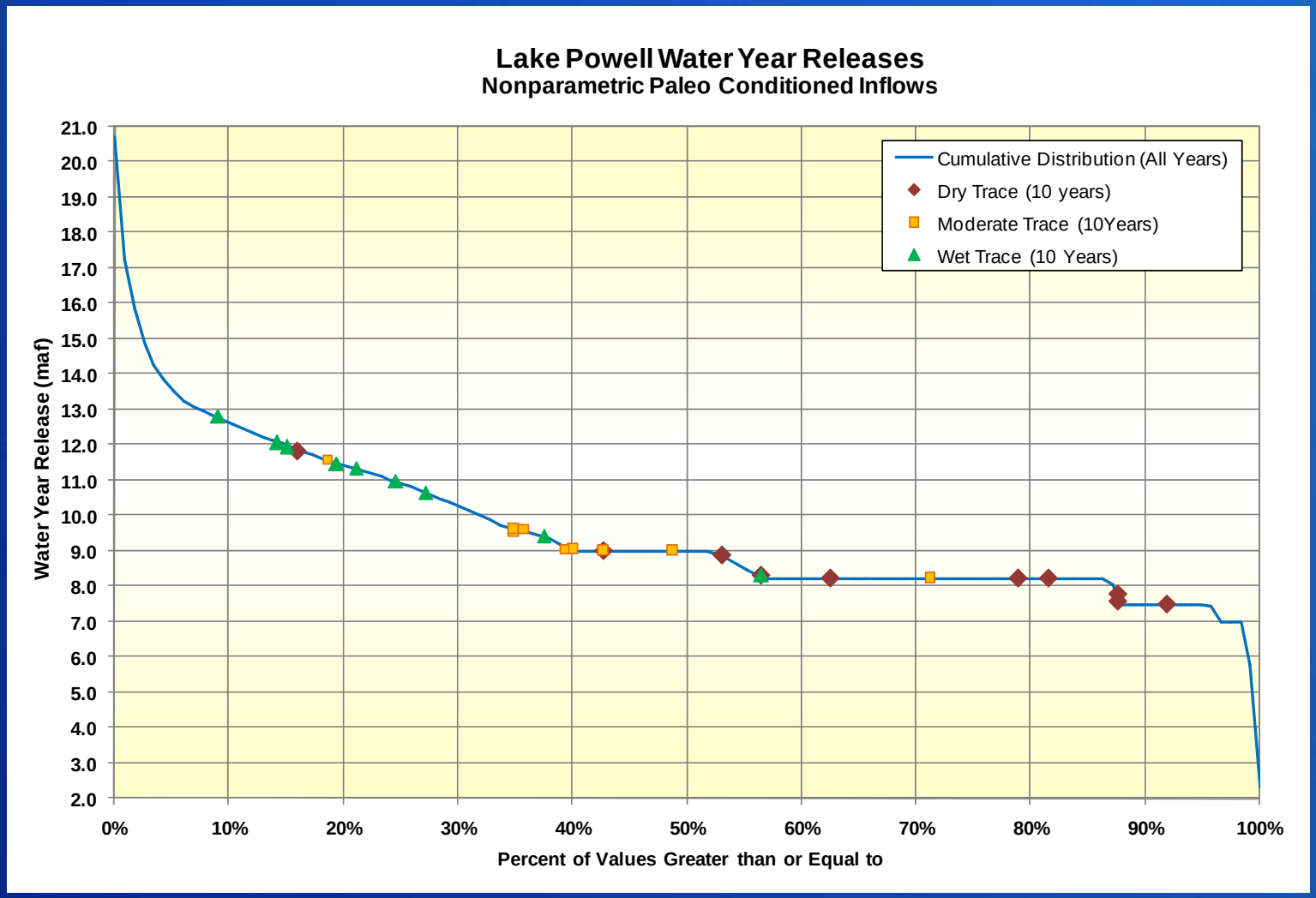
Analyses



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Analyses

Modeling Approach

CRSS
-Overview
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Analyses

- How estimate hourly releases from Glen Canyon powerplant?
  - Max daily change in flow, mix/max releases
  - Turbine release cap based on hydraulic head
  - Seasonal differences in electrical demand
- Reclamation CRSS → Western GTMax
- Western uses GTMax optimization program
  - Utilizes water availability (CRSS), historic electrical demand, environmental and operational constraints

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Analyses

Modeling Approach

CRSS
-Overview
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Analyses

- What hydrologic traces make sense to analyze for the HFE Protocol?
  - Impractical to analyze every CRSS trace at hourly timestep in sediment model
- Want good sampling of hydrologic data to run sediment/other analysis and adequately frame the range potential responses to various “HFE protocol alternatives”

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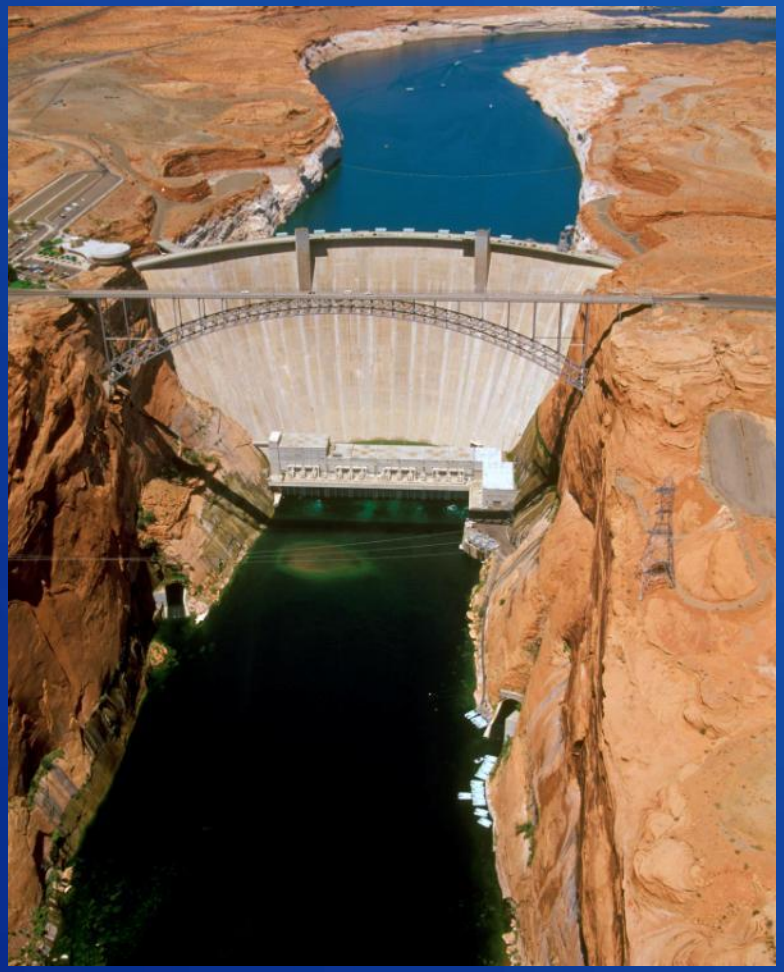
Modeling Questions

- Which inflow hydrology? - How long will action/protocol last?
- How many years of data? Do we need to consider sequences of annual hydrology? (Or does sediment “reset” each year?)
- How many traces should be analyzed? (various annual release patterns – 8.23, equalization, balancing, etc. at several elevations…?)
- ???

Questions / Discussion



Modeling Approach

CRSS
- -Overview
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Analyses

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Extra Slides Follow

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CRSS Background

Modeling Approach

CRSS
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Analyses

- Developed by Reclamation in the early 1970s
  - Comprehensive model of the Colorado River Basin
  - Primary tool for studying river operations and projected development
  - Used in a number of environmental compliance studies (e.g., ISG and MSCP)
- Implemented in RiverWare™ in 1996
  - RiverWare™ is a generalized river and reservoir modeling tool developed and supported by the University of Colorado
- Updated and maintained continually by Reclamation's Upper and Lower Colorado Regions
- Provided hydrologic data for resource analysis in the Shortage EIS

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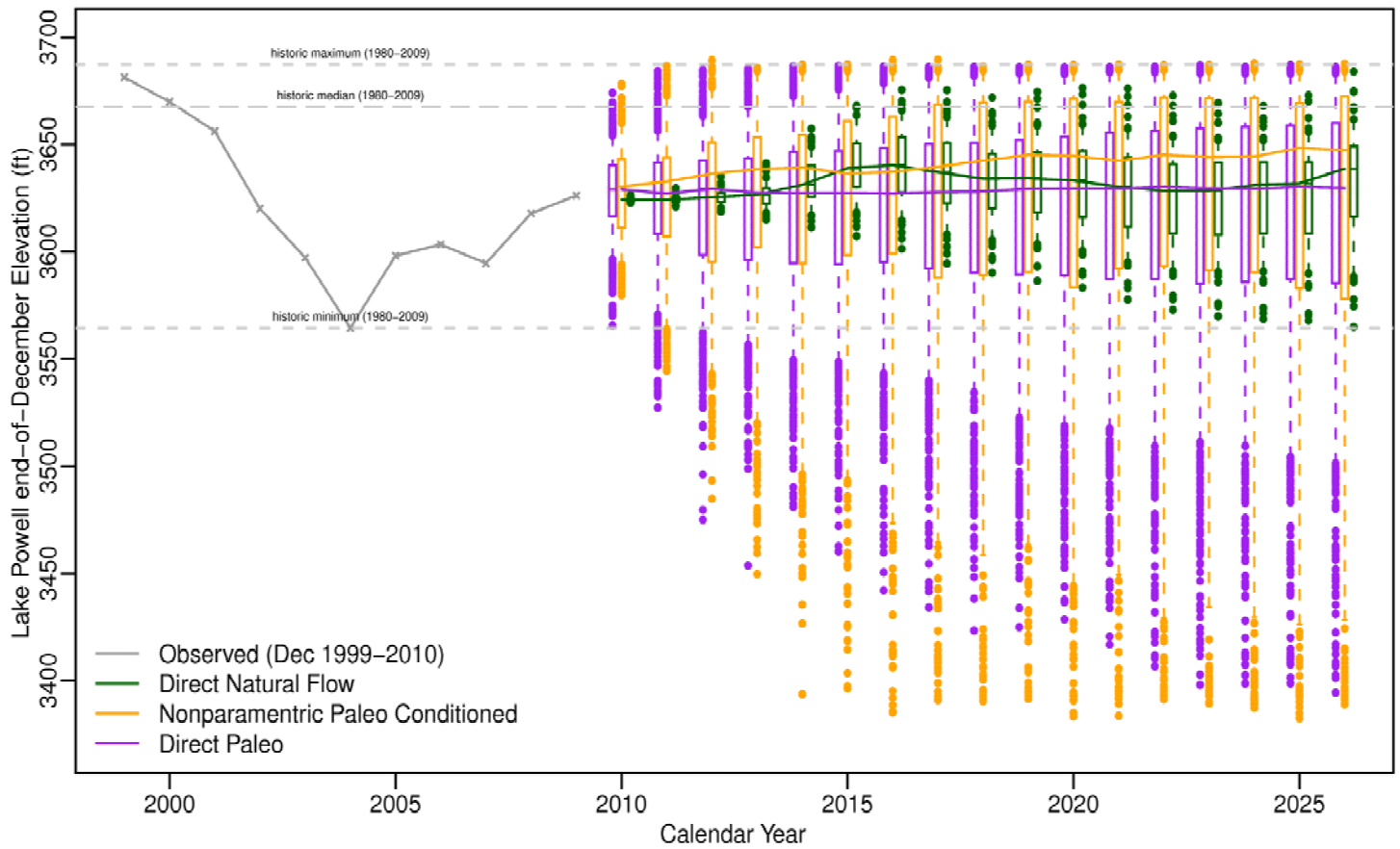
Powell Elevation Evolution

Modeling Approach

CRSS
- -Overview
- -Inflows
- -Demands
- -Results

Analyses



Note: Solid lines through boxes connect the median. Bottom, middle and top of boxes represent the 25th, 50th and 75th percentiles, respectively. At whisker ends are 5th and 95th percentiles. Outliers are beyond the whiskers.

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Mead Elevation Evolution

Modeling Approach

CRSS
- -Overview
- -Inflows
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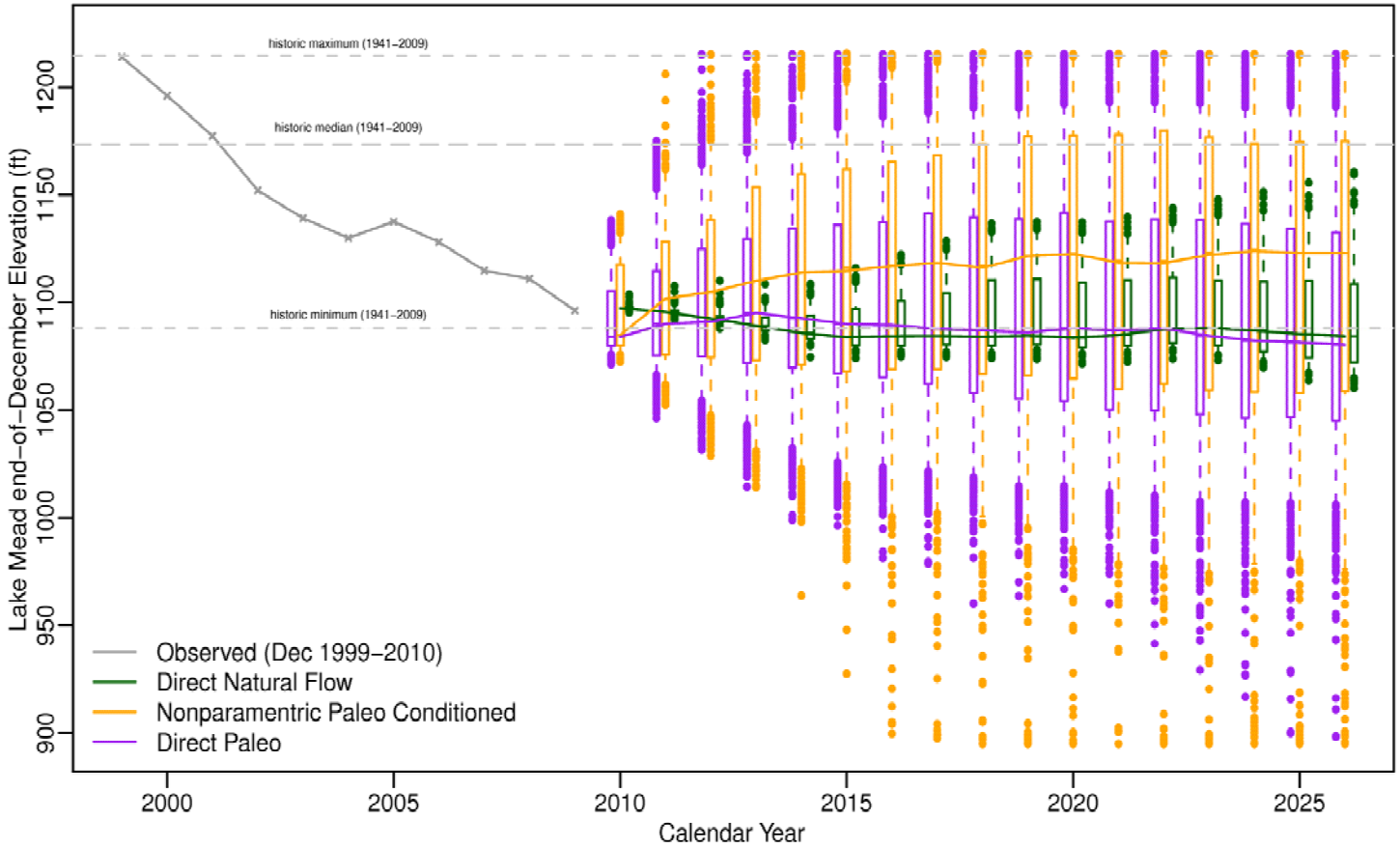
Analyses



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Mead Elevation

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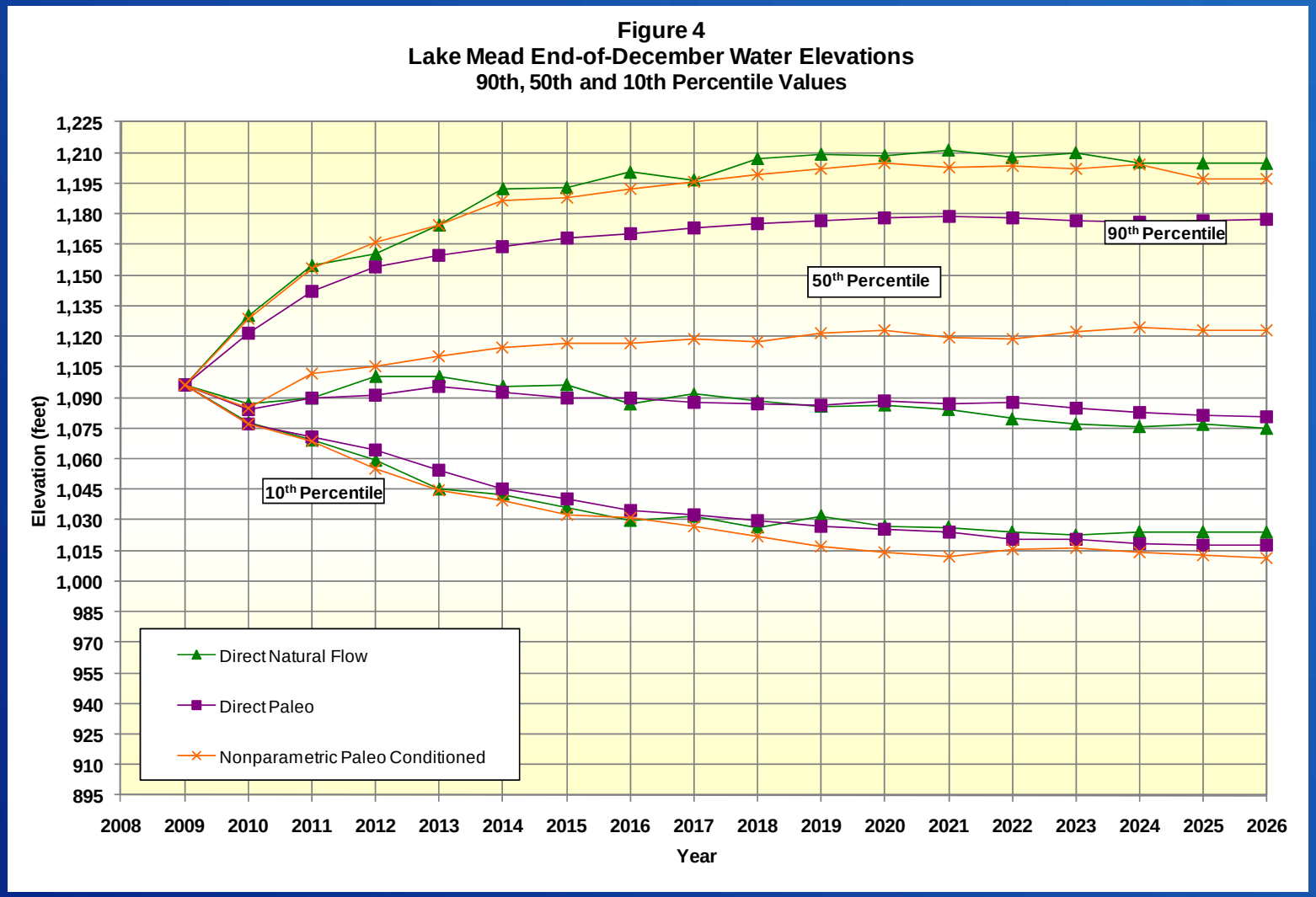

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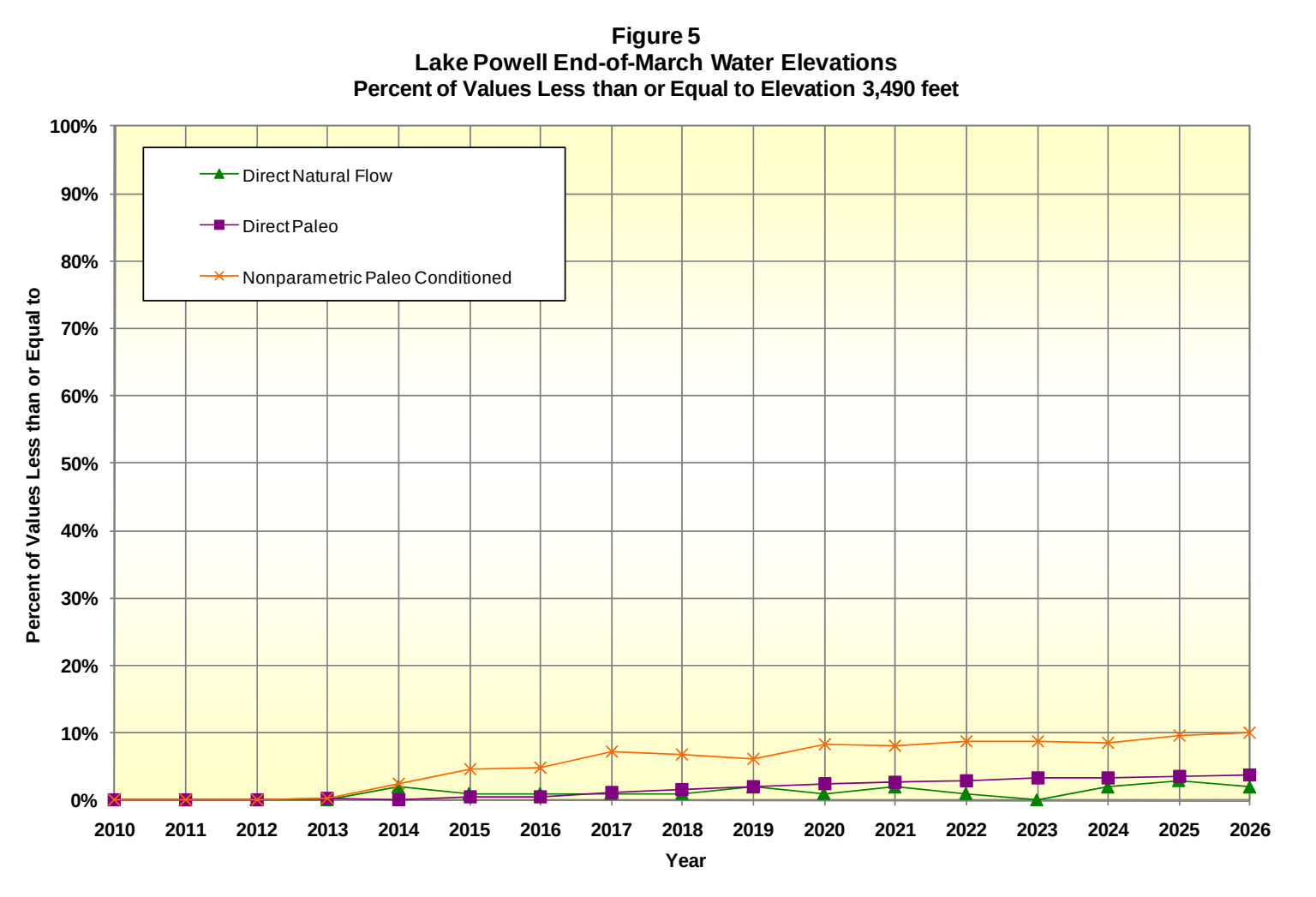
Powell Minimum Power Pool

Modeling Approach

CRSS
- -Overview
- -Inflows
- -Demands
- -Results

Analyses



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Mead 1050' (Shortage)

Modeling Approach

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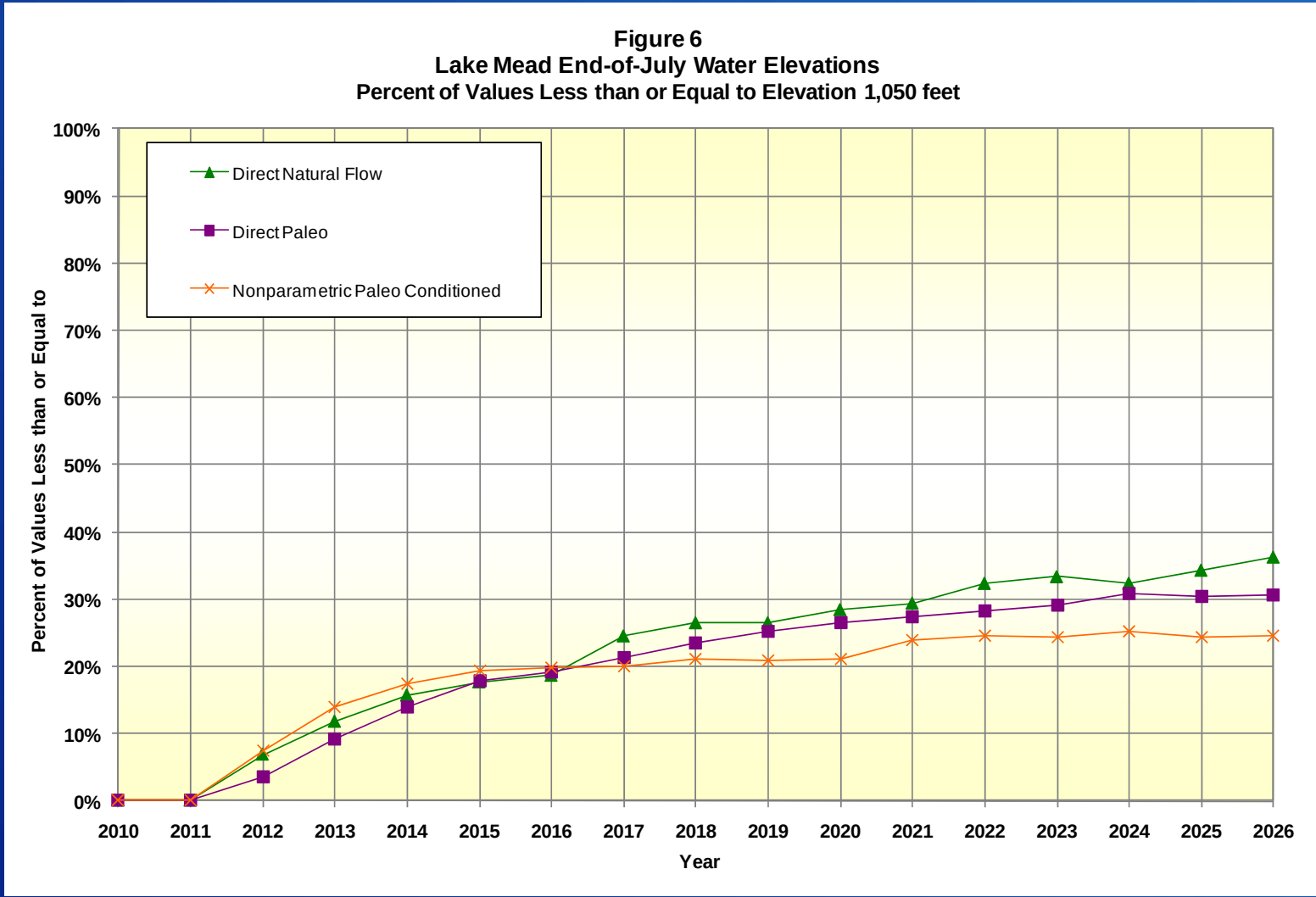

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Climate Change Scenarios

Modeling Approach

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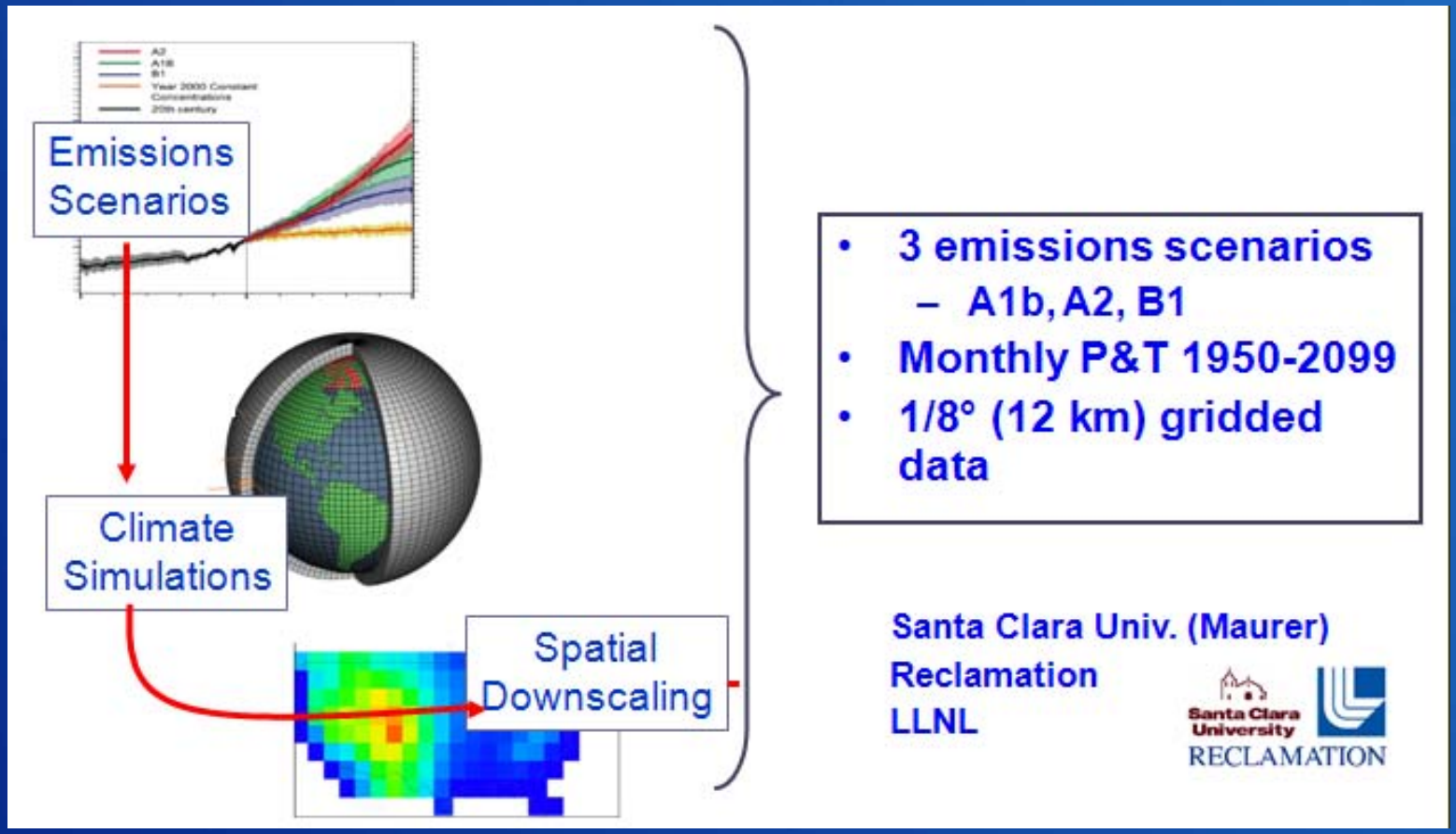

Climate Change Scenarios

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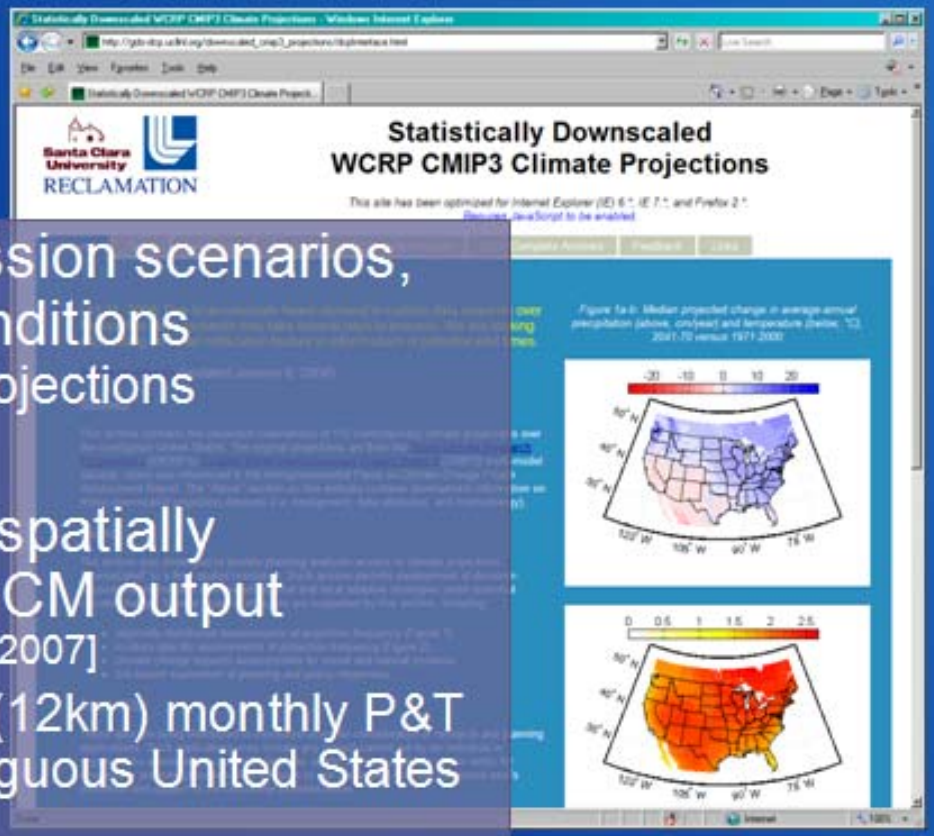

- 16 GCMs, 3 emission scenarios, multiple initial conditions
  - Resulted in 112 projections
- Bias-correct and spatially downscale raw GCM output
  [Wood et al. 2004, Maurer 2007]
  – Resulted in 1/8° (12km) monthly P&T 1950-2099, contiguous United States

Climate Change Scenarios

Modeling Approach

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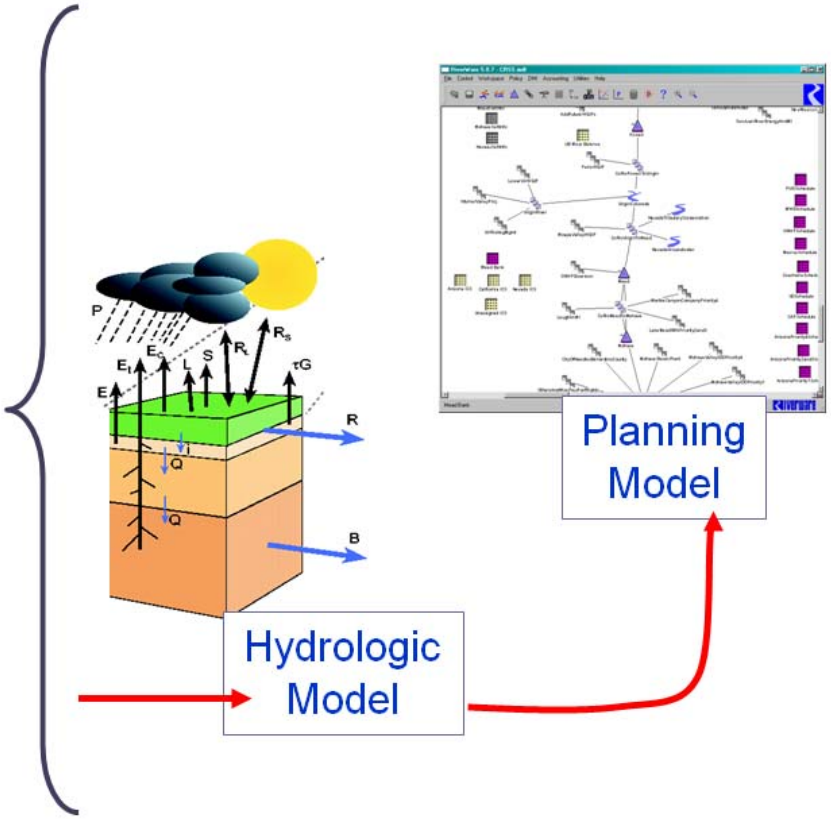
Analyses

Move 112 climate projections through VIC to simulate runoff

Move runoff through Reclamation's long term planning model (CRSS)



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