Colorado River Water Availability Study

Study Overview for

Colorado River Basin Roundtable

February 23, 2009

Consulting Team

Boyle - AECOM Water
AMEC Earth & Environmental
Canyon Water Resources
Leonard Rice Engineers
Stratus Consulting

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Agenda

- Introductions
- Study Purpose and BRT Involvement
- Approach
  - Two-Phase Study
  - Three-Step Hydrologic Analysis
- Study Limitations
- Status
- CRDSS Overview
- StateCU Model
- StateMod Model
- Comments, Questions, Model Enhancements?

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Study Team – Management

CWCB Board of Directors

Ray Alvarado
Ross Bethel
Eric Hecox
Veva Deheza
CWCB & DWR Staff

Department of Natural Resources

Attorney General's Office

IBCC - Basin Roundtables

Boyle Management

Blaine Dwyer, P.E.
Project Manager

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Assistant P.M.

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Study Team – Technical

Blaine Dwyer	Project Manager
Matt Brown	Assistant Project Manager
Ben Harding	Paleo, Stochastic, and Big River hydrology / operations
Erin Wilson	CDSS applications
Meg Frantz	StateMod refinements / execution
Jim Pearce	Review - Water Management issues
Joel Smith	Guidance - Climate Change approaches

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Study Purpose – State-Wide Sponsorship

Interstate Issues

Information for the entire state to use in relation to current and future water management

Intrastate Issues

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Basin Roundtable Involvement

- BRT Workshops on Model Briefs for each Basin
  - Colorado – February 23
  - Gunnison – March 2
  - White/Yampa – March 4
  - Southwest – March 11
- BRT input on CDSS Model Refinements
- BRT input on other Study products as developed

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Two-Phase Study

- Phase I – Water Availability under current water supply infrastructure, currently perfected water rights, and current levels of consumptive and non-consumptive water demands
- Phase II – Water Availability under projected demands from existing, conditional, and new water rights and for additional consumptive and non-consumptive water demands

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Study Approach – Three Step Hydrologic Analysis

1) Historical Hydrology

- To be used for comparative analysis
- 1950's forward (most reliable data)

2) Alternate Historical Hydrology | Extend Records with Tree-Rings & Stochastic Methods

3) Climate Change and Forest Change

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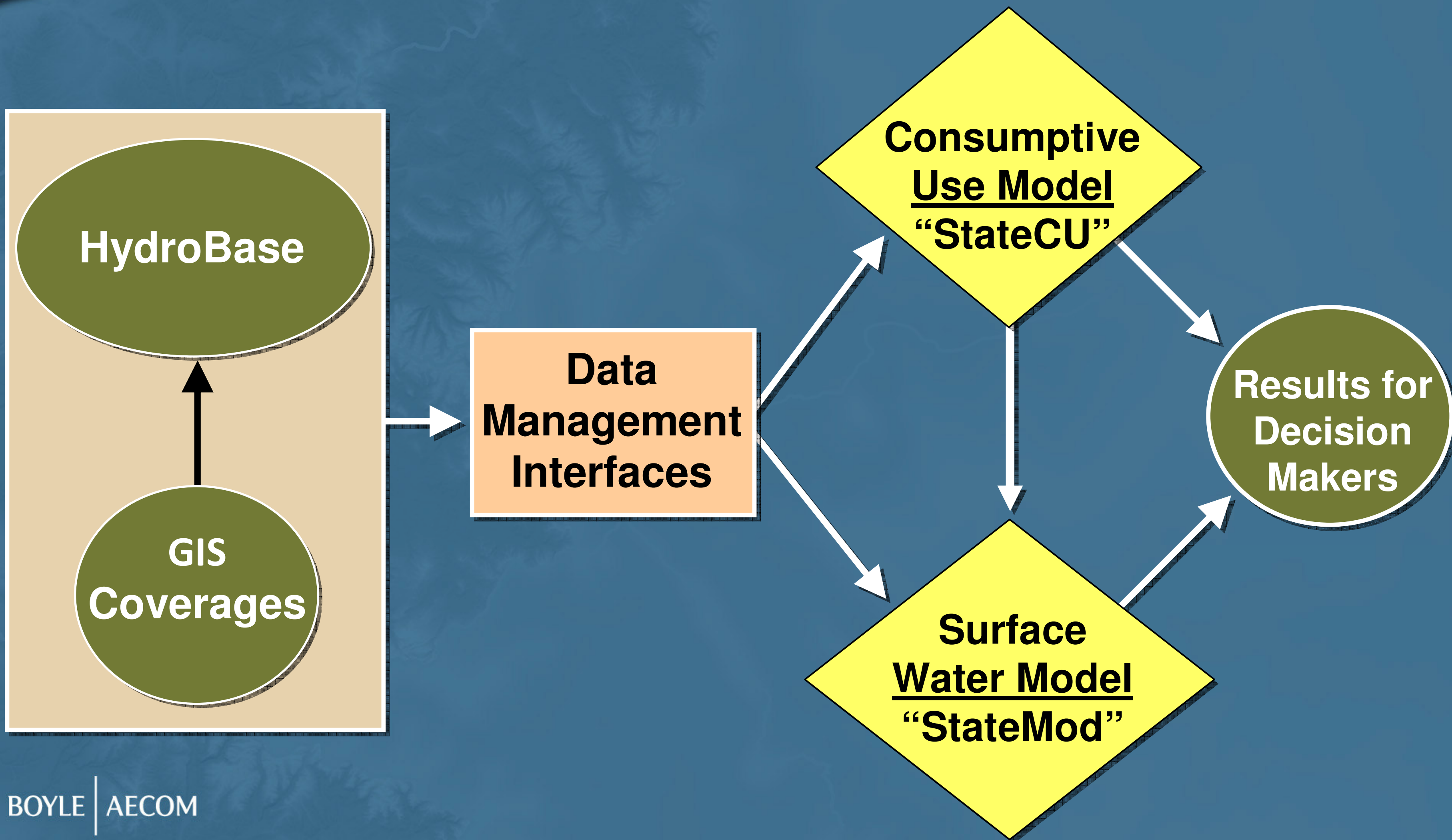
1) Historical Hydrology – Data-Centered CDSS



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1) Historical Hydrology → Water Availability

→

Surface Water
<u>Model</u>
"StateMod"/CRSS

→

Results for Decision Makers

<u>Historical</u>
Water Availability
Reservoir Conditions
Instream Flows
Reliability

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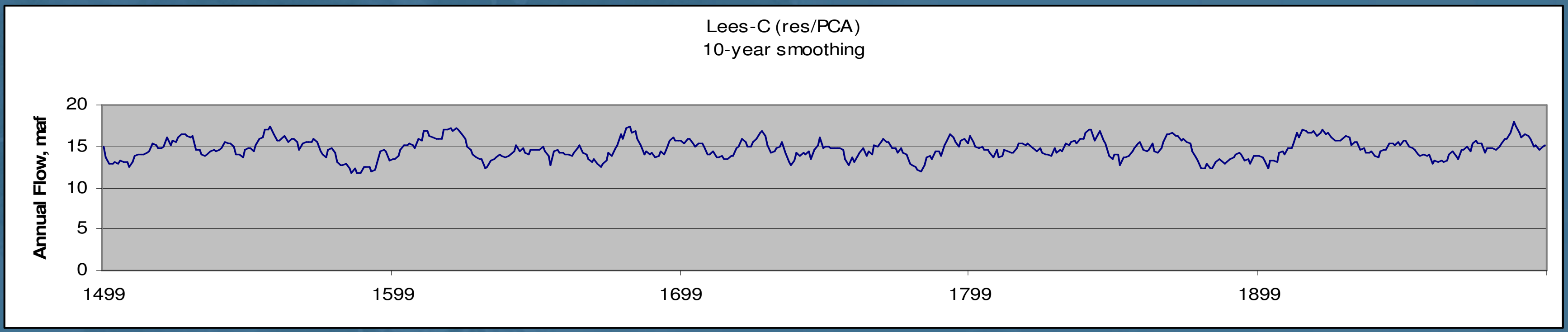
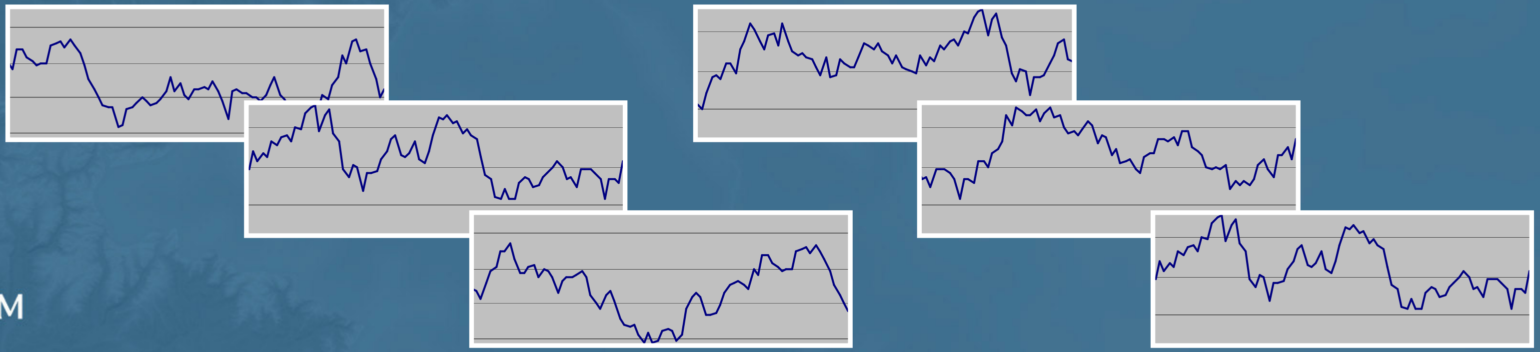
2) Alternate Historical Hydrology (Paleohydrology)

Reconstructed Flows



"Ensemble" of "Traces"



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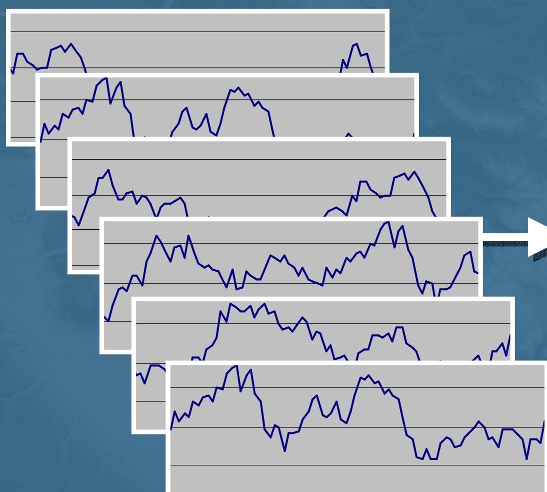
2) Alternate Historical Hydrology → Water Availability

"Ensemble" of "Traces"



Surface Water
Model
"StateMod"/CRSS

→ **Results for Decision Makers**

Alternate Historical
Water Availability
Reservoir Conditions
Instream Flows

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3) Climate Change & Down - Scaling

Earth

- Emissions Scenarios
- Global Climate Models

Result: *Altered Temperature and Precipitation*

Colorado River Basin

- "Down-Scaled" Projections
- Revised Basin-Wide Hydrology

Result: *Altered Stream Flows*

State of Colorado

- CDSS Modeling

Result: *Water Availability*

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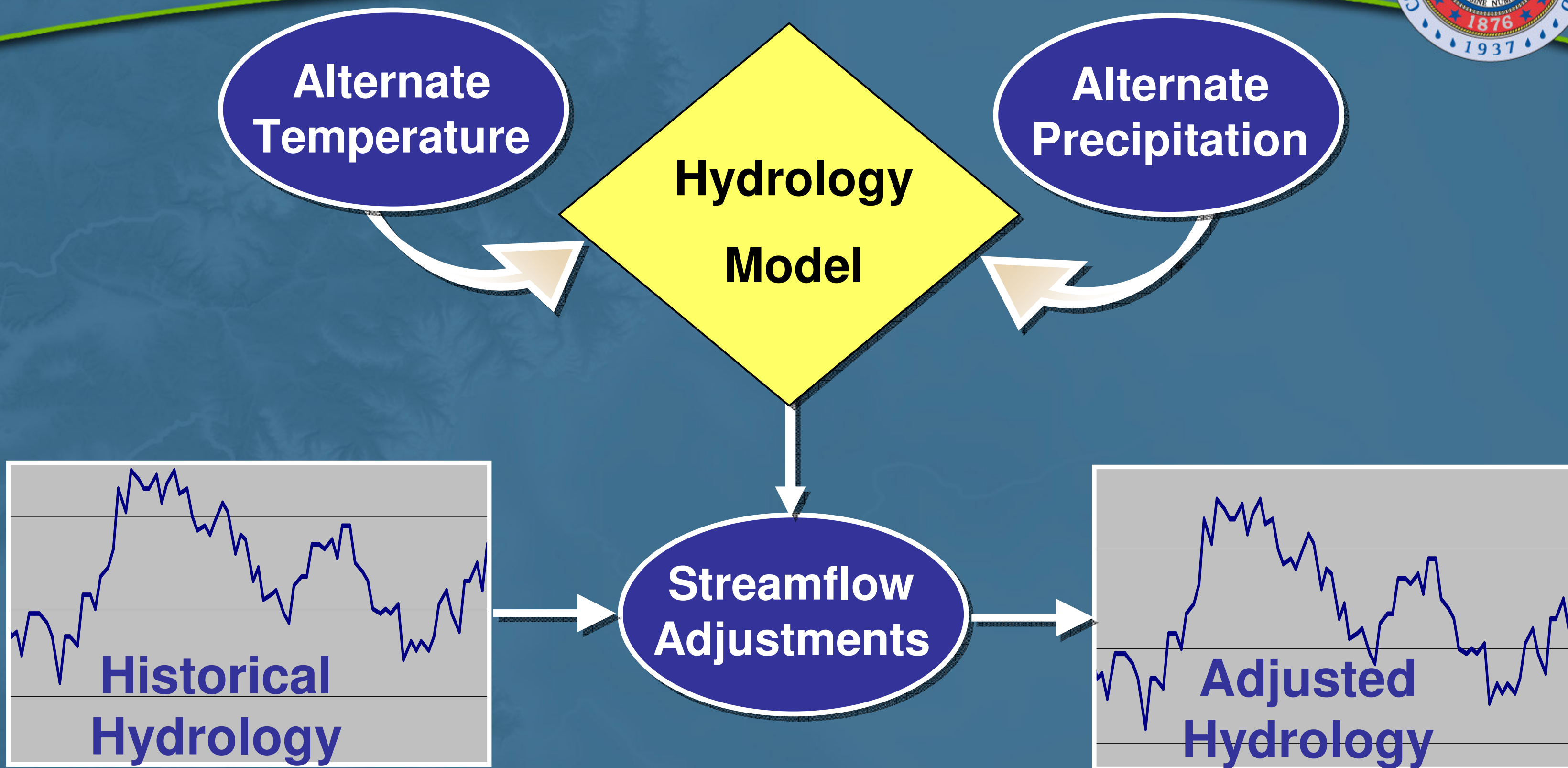
3) Alternate Hydrology of Climate Change



CRDSS Natural Flows
CRSS Natural Flows

CRDSS Adjusted Flows
CRSS Adjusted Flows

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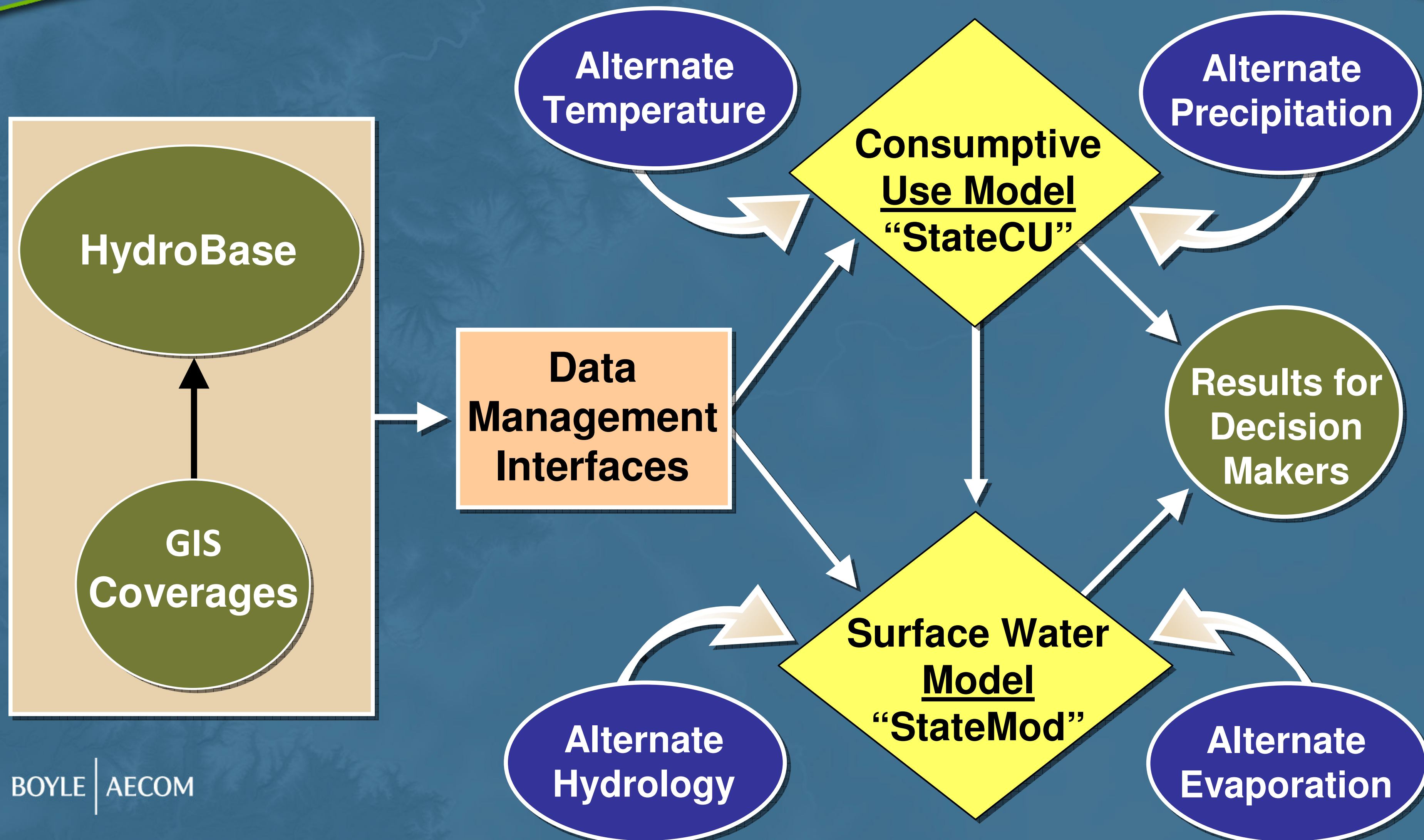
3) Alternate Historical Hydrology



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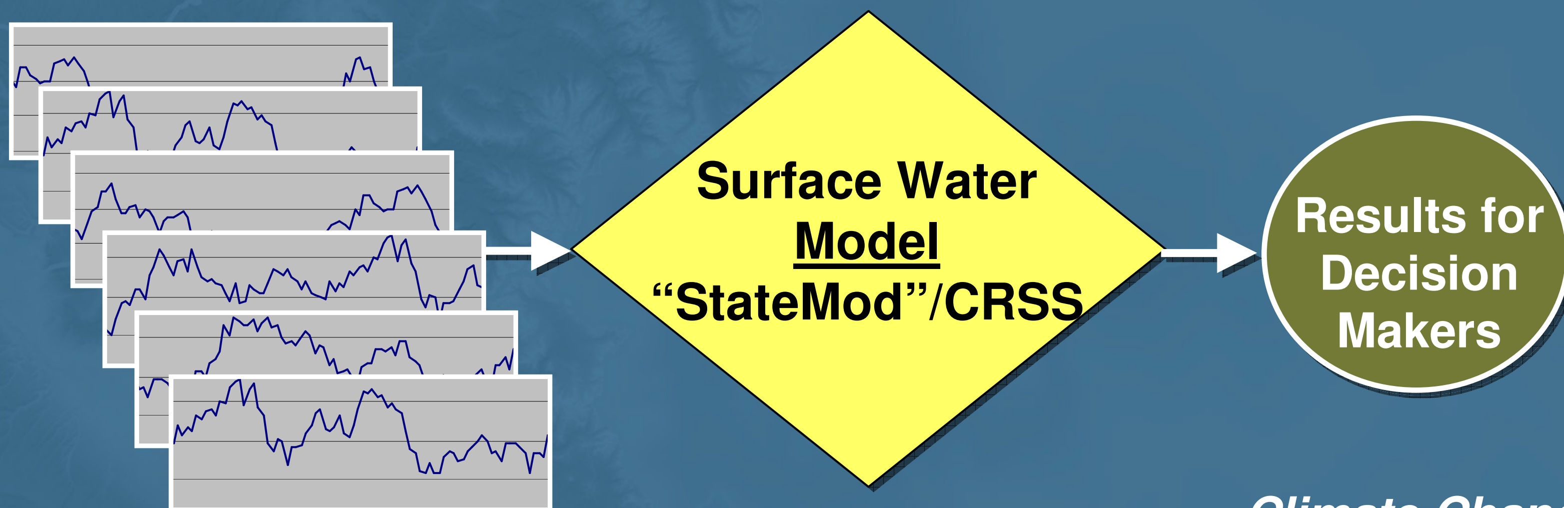
3) Alt. Hydrology / Climate Change → Water Availability

Ensemble of Traces
Adjusted Streamflows



Climate Change

Water Availability
Reservoir Conditions
Instream Flows

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Study Limitations – Scope

- No assessment of compact call administration or potential for curtailments!
- Phase I only considers current levels of water demands and current infrastructure
  (Phase II considers potential future water demands)

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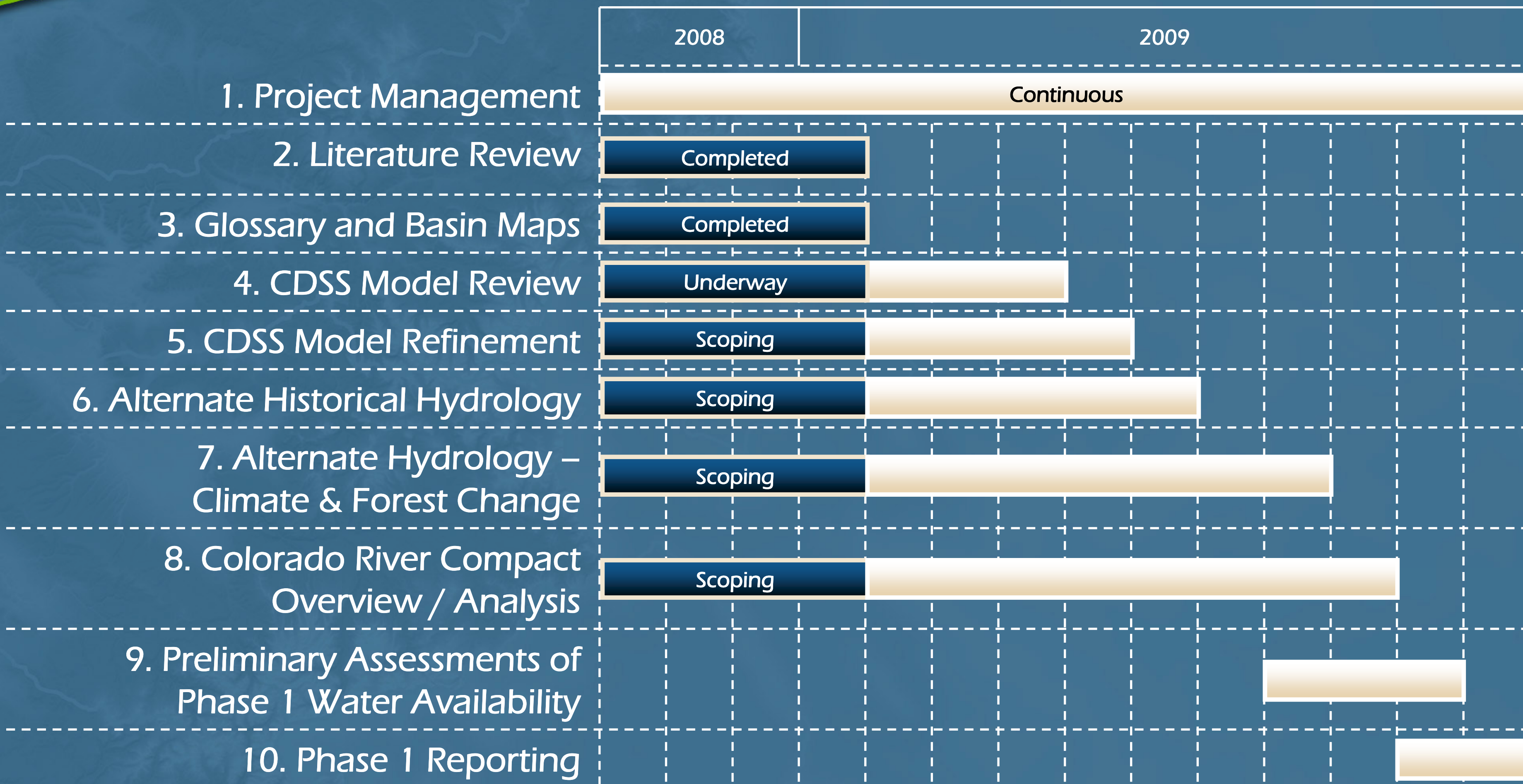
Study Status – Phase I



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CDSS Overview - Goals

"Provide the capability to develop credible information on which to base informed decisions concerning water resource management issues."

Benefits to the State:

- Interstate Compact Analysis
- Resources Planning (response to population growth, drought, environmental issues, etc.)
- Water Rights Administration by DWR

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CDSS Overview - Goals

COLORADO WATER CONSERVATION BOARD · STATE OF COLORADO · NIL SINE NUMINE · 1876 · 1937

Benefits to Water Users:

- Quality Controlled Data
- Data Accessibility
- GIS Coverages
- Base Data Sets and Models for Planning

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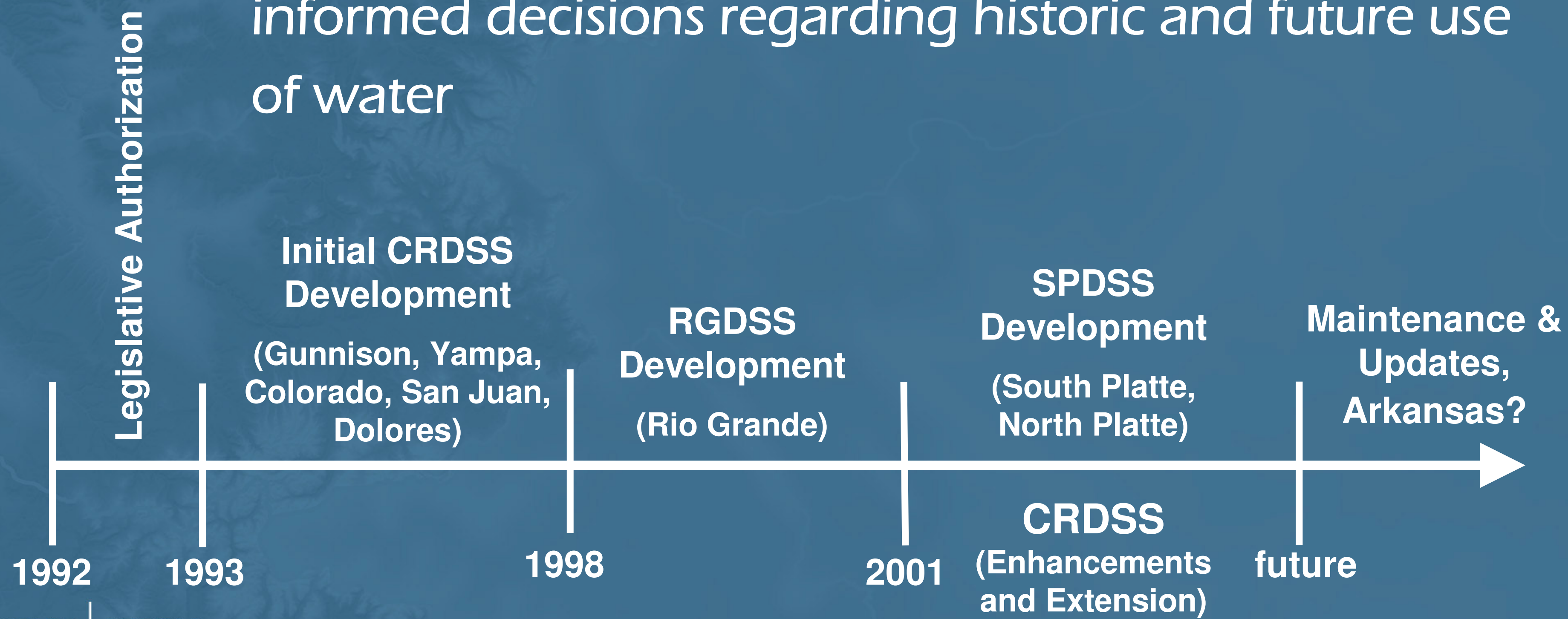
CDSS Overview

- Water Management System
- Developed by CWCB and Division of Water Resources
- Goal is to provide data/tools to assist in making informed decisions regarding historic and future use of water



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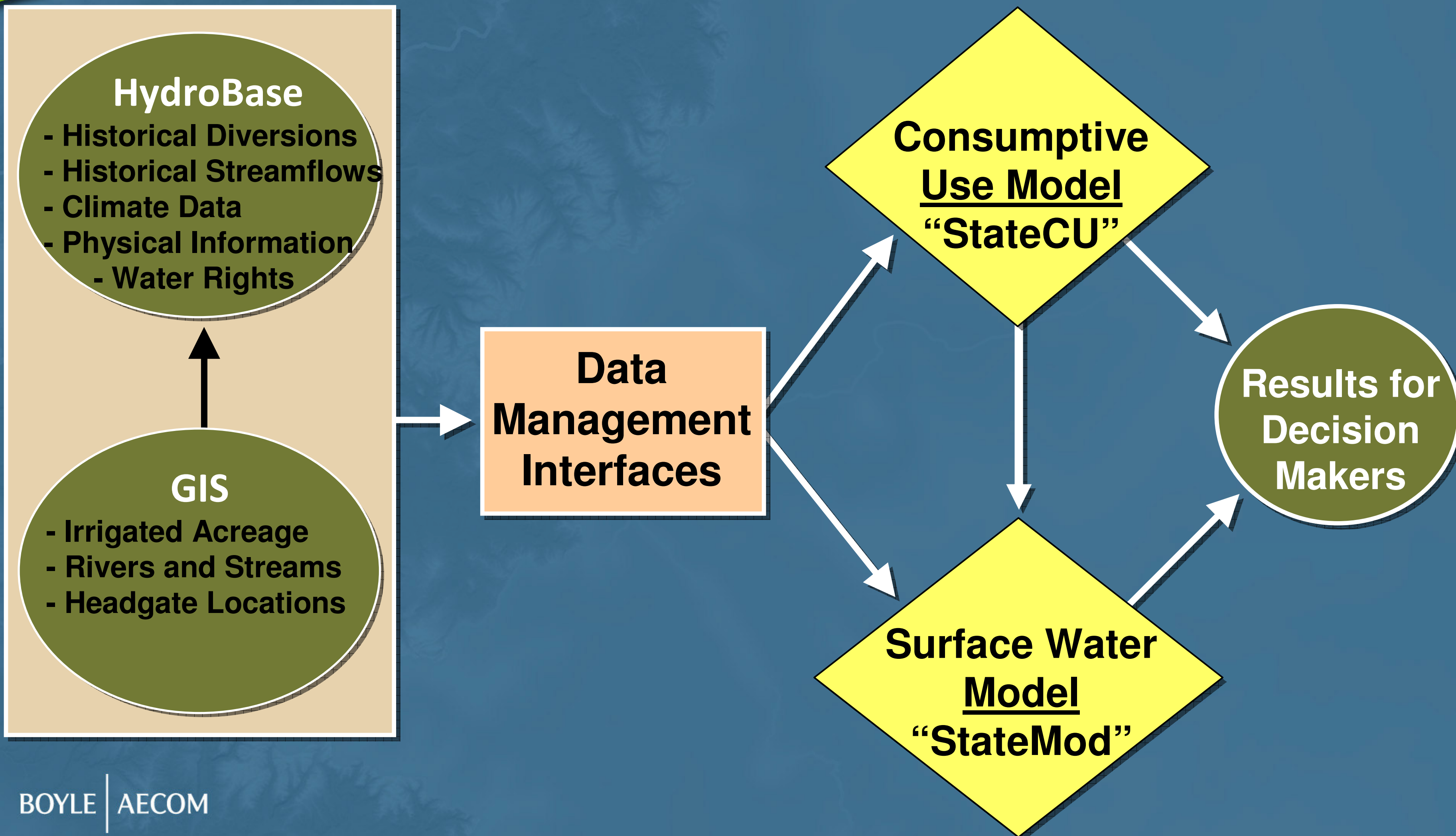
CDSS Overview - Data-Centered Approach



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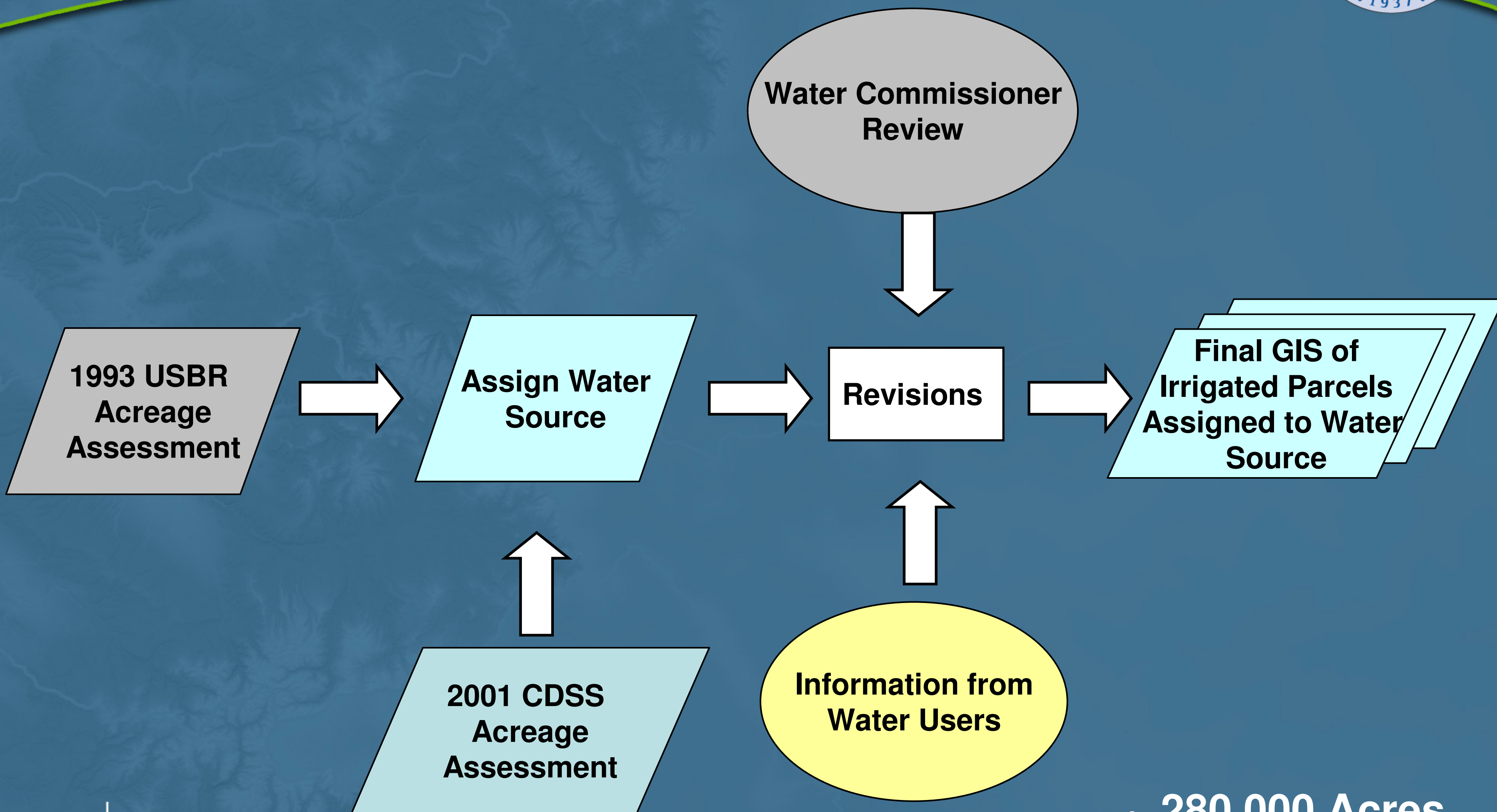
CDSS Overview – Data Collection



~ 280,000 Acres

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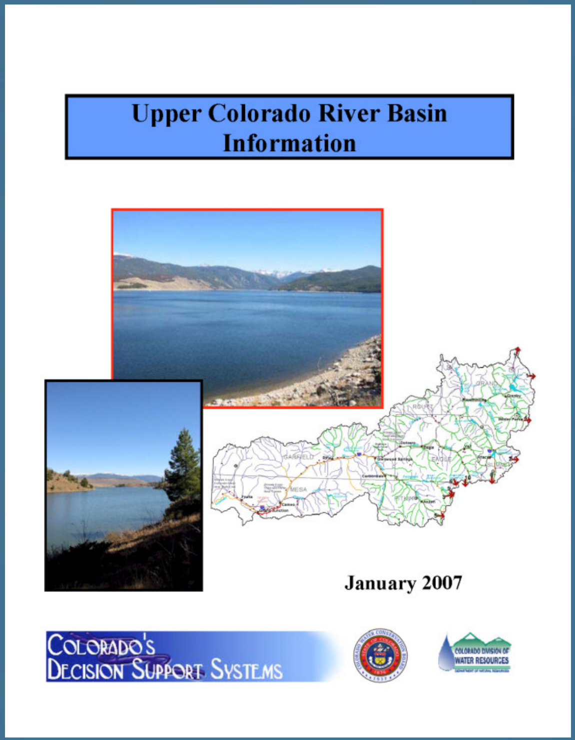
CDSS Overview – Data Collection

- Interviewed water administrators and project operators
- Reviewed and summarized published data on basin water use and project operations
- Identified Irrigation Practices and supplemental sources
- Documented for both technical and non-technical audiences



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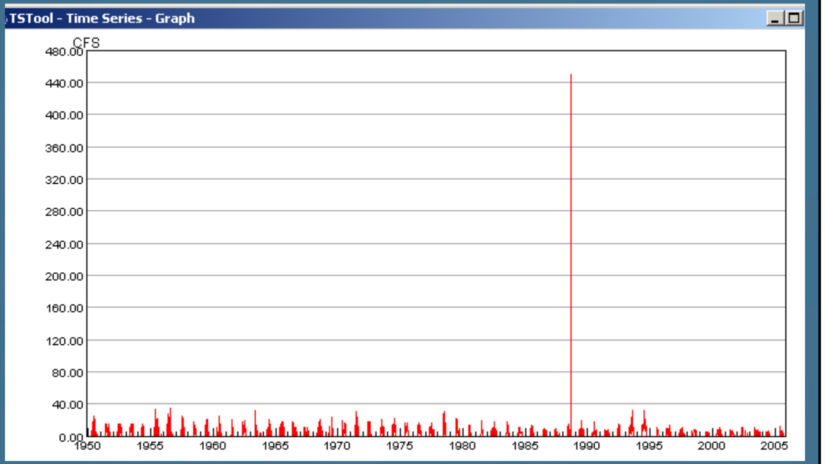
CDSS Overview – Data Collection

- Worked with Reservoir Operators to provide Historical Storage Data
- Reviewed Data from other Sources to "Approve" including in HydroBase
- Digitized Water Commissioner Diversion Records to include in HydroBase
- Reviewed WISP Data and Water Rights Information to Identify and Correct "typos"



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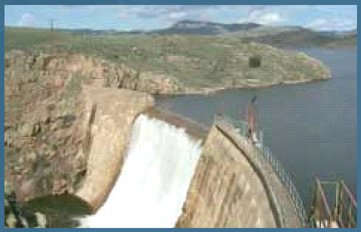
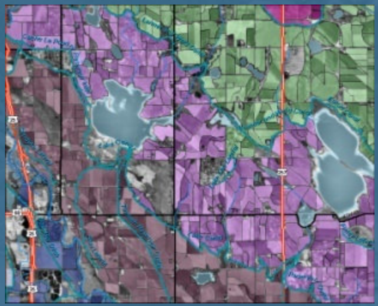
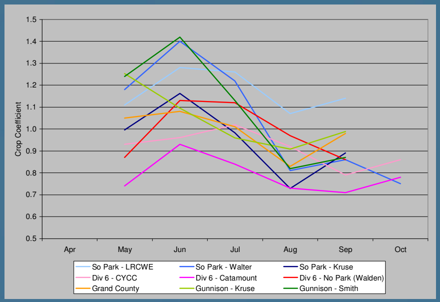
Consumptive Use Analysis

Supplemental Sources User Info



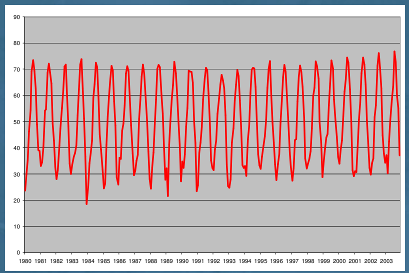
Irrigated Acreage, Crop Type, Irrigation Method



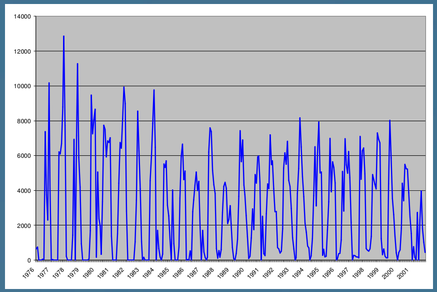


CU Method Review and Selection

Climate Data



Water Supply Data



Irrigation Efficiencies

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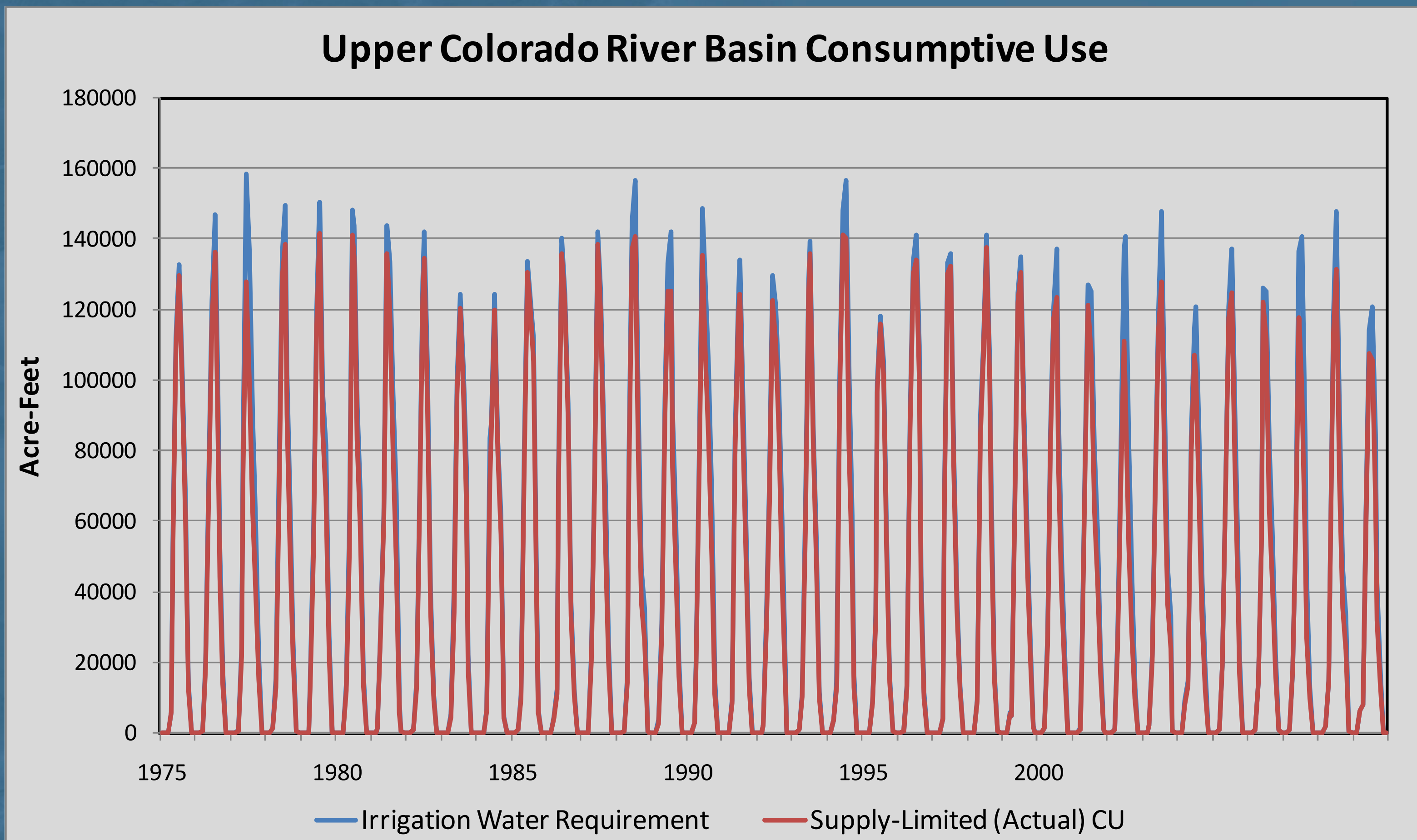
Consumptive Use Analysis



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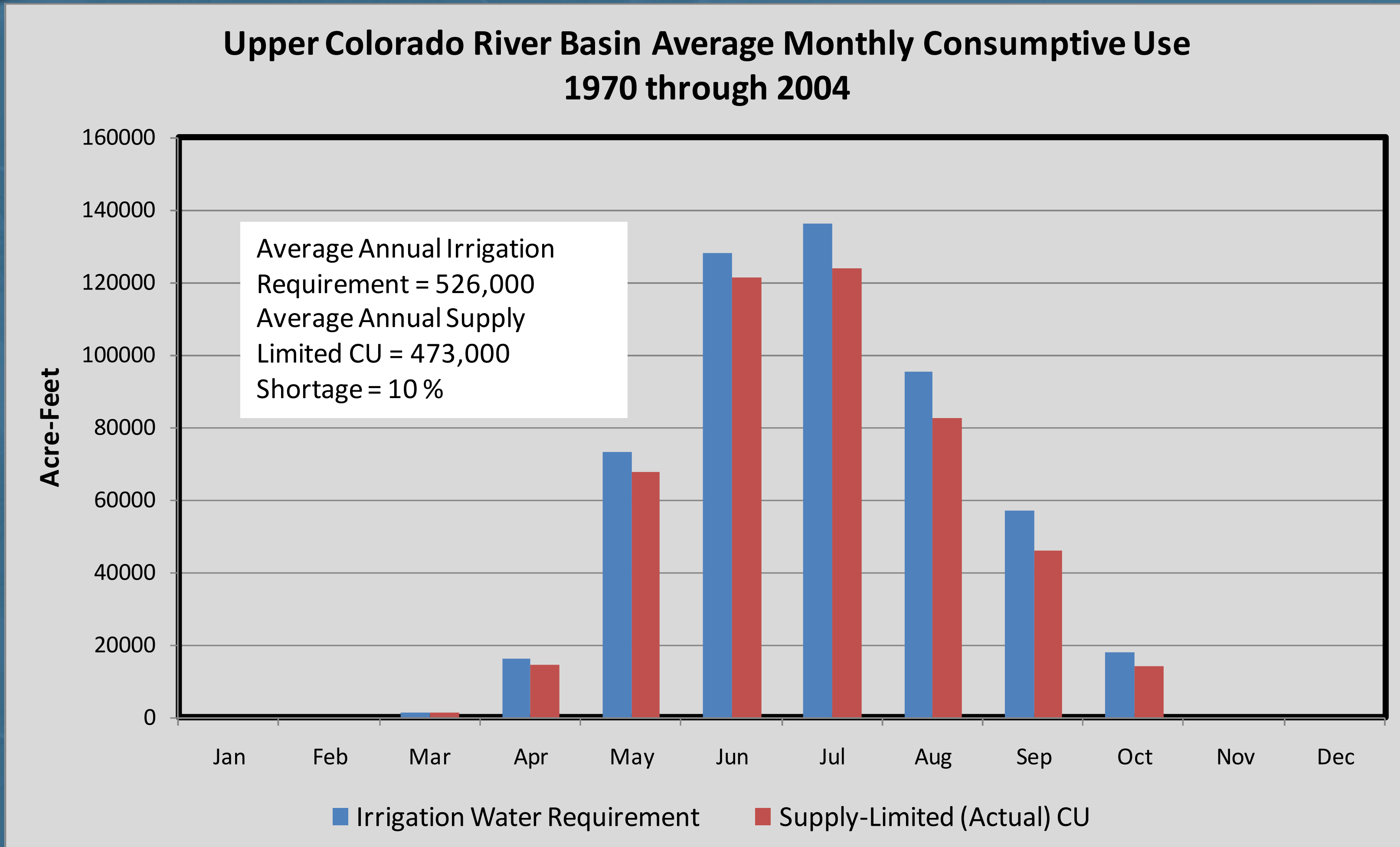
Consumptive Use Analysis



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Consumptive Use Analysis

- CDSS Method Compared to USBR Method for Upper Basin Compact Consumptive Uses and Losses Reporting

	USBR Method	CDSS Method
Irrigated Acreage	1993 USBR GIS	1993 USBR GIS
Potential Crop CU Method	Blaney-Criddle, Coefficients Developed at Lower Elevations	Blaney-Criddle, High-Altitude Coefficients
Shortage Methods	Reduce CU Based on Indicator Gages	Supply-Limited CU Based on Actual Diversions

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Consumptive Use Analysis

- Crop Requirements Used in StateMod to Determine Irrigation Return Flow Amounts
- Crop Requirements Used in StateMod to Determine Baseline Demands
- Consumptive Use Analysis Identifies Shortages. StateMod Identifies "Why"
  - Physical water limitation
  - Legal limitation (downstream senior right)
  - Irrigation practices

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StateCU and Alternate Hydrology

- Extending Historical Hydrology
  - Re-Sequencing of Historical Irrigation Water Requirements for StateMod
  - No StateCU Input File Revisions or Simulation Required
- Climate Change
  - Revisions to Temperature and Precipitation Data Files
  - Temperature File Defines Growing Season
  - No Changes to Acreage, Crop Type
  - StateCU Simulation to Provide Irrigation Water Requirements to StateMod

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StateMod Overview

- General-Purpose Water Allocation Model
- Can be Adapted to Any River Basin through Unique Data Sets
- Data Sets Define Basin
- StateMod Operates Based on Colorado's Water Right System

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StateMod Overview

- Linked-Node Model
- Nodes are Locations Where you Have or Need Information
  - Stream Gages
  - Diversion Locations
  - Reservoirs
  - Beginning/End of Instream Flow Segments
  - Return Flow/Discharge Locations

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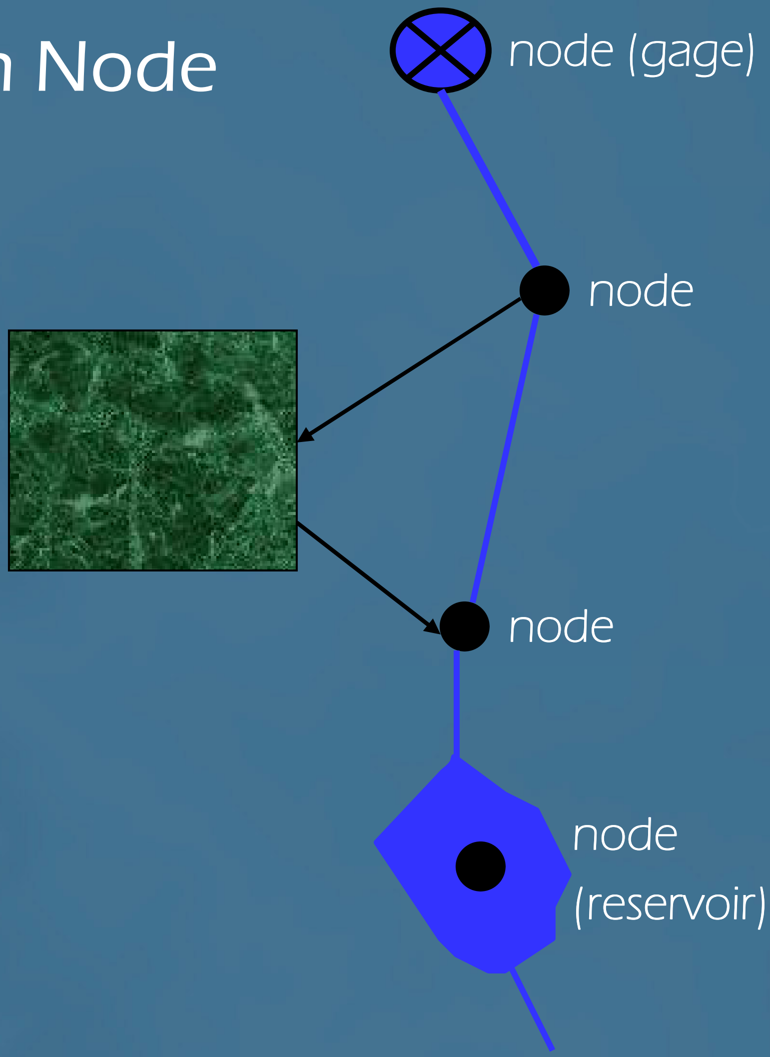
StateMod Overview

- Water is Carried from Node to Node via
  - Rivers
  - Canals
  - Pipelines



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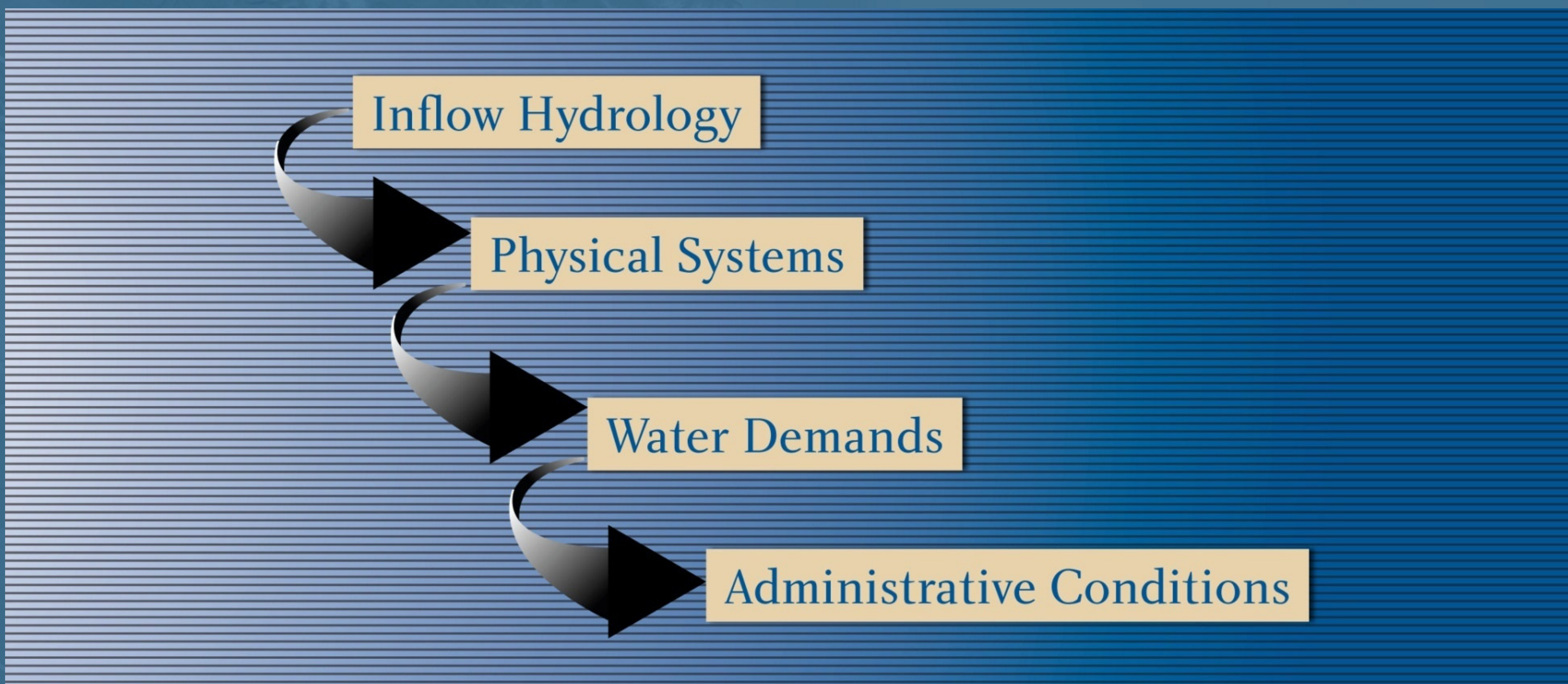
StateMod Model Components



Inflow Hydrology

- CRWAS Model Period - 1950 through 2005
  - Represents Wet/Dry/Average Periods
  - Minimized Data Filling
  - Sufficiently Long to look at Water Availability over time
- Model Represents more than 100 Upper Colorado Tributaries

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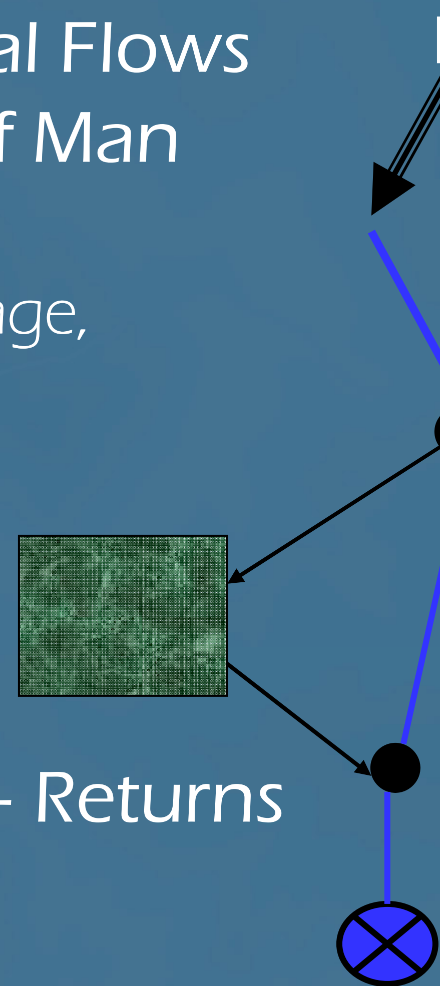
Inflow Hydrology

Inflow Hydrology – Natural Flow Development

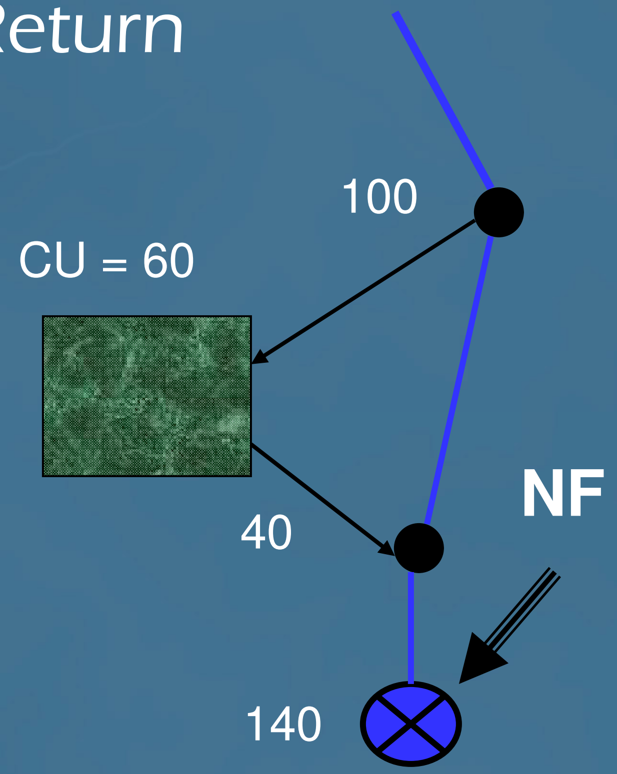
- StateMod estimates Natural Flows by Removing the Effects of Man
  - Diversions, Return Flows, Changes in Reservoir Storage, Evaporation

- NF = Gaged + Diversions – Returns +/- change in storage



Inflow Hydrology – Natural Flow Development

- Develop NF at Gaged Locations
- NF = Gaged + Divert – Return



NF = 140 + 100 – 40

NF = 200

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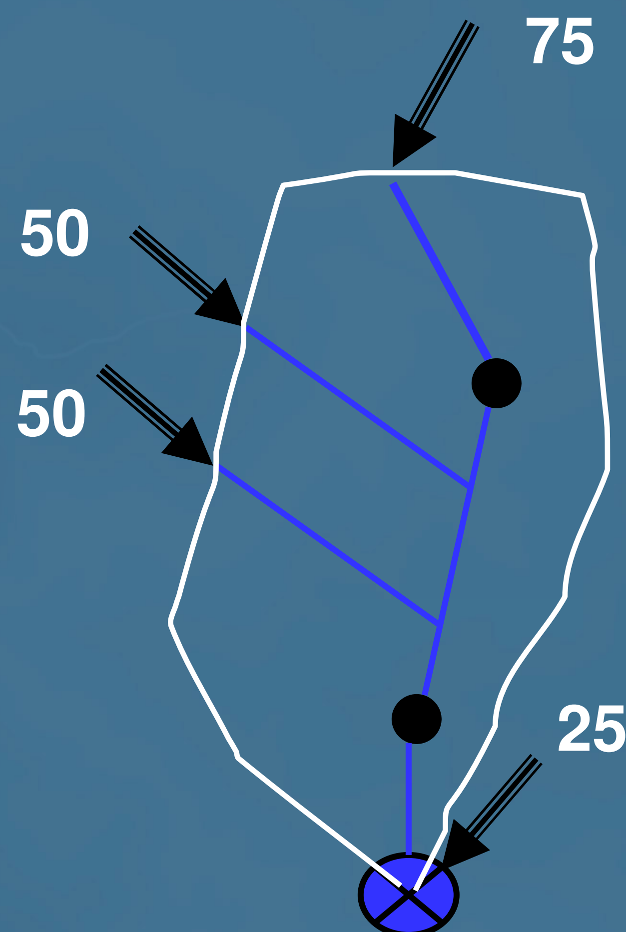
Inflow Hydrology – Natural Flow Development

- Distribute Natural Flow Gains to ungaged tributaries



Overall Gain = 200

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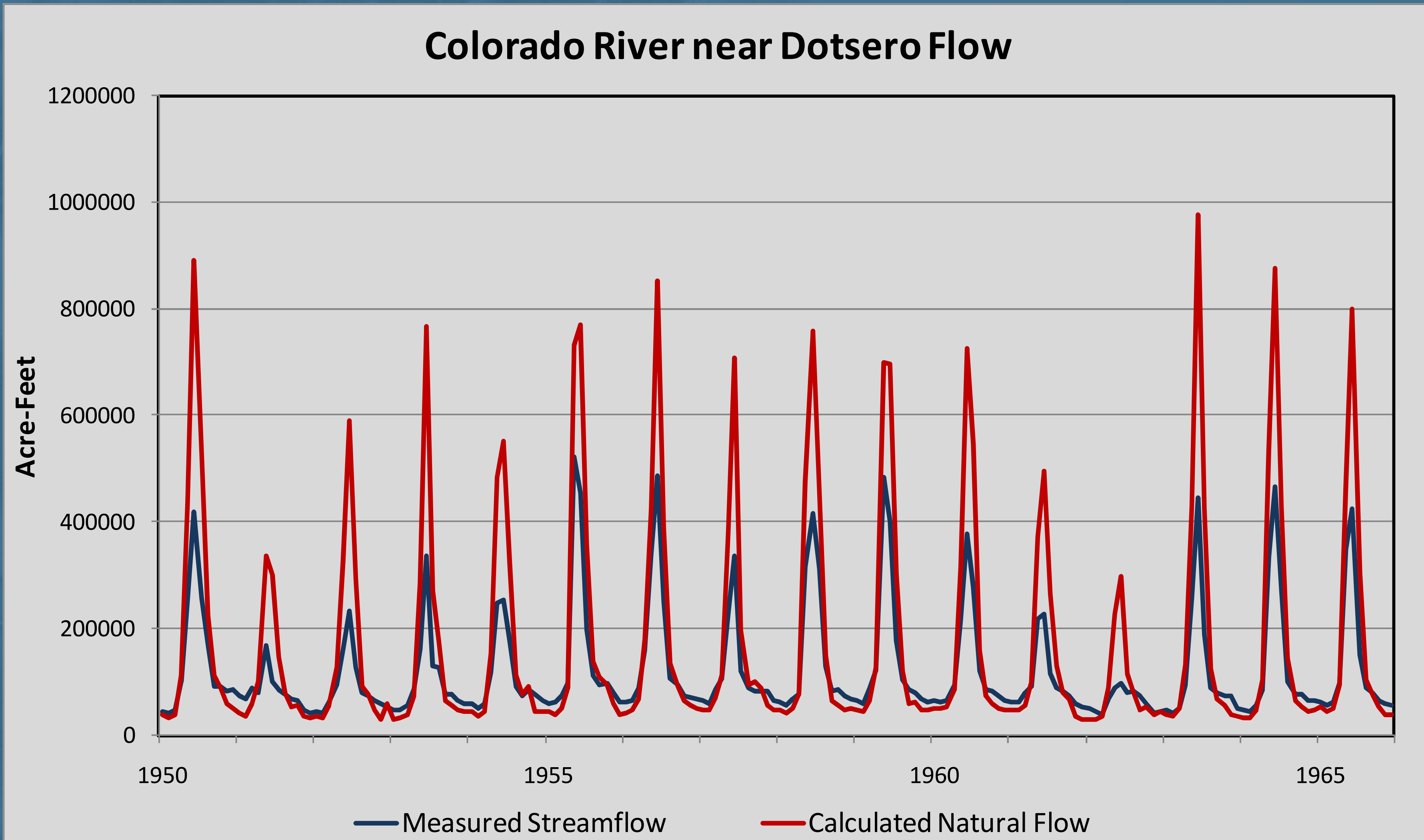
Inflow Hydrology



Inflow Hydrology – Data Sources

- Gaged Data recorded by USGS and DWR, stored in HydroBase
- Diversions Recorded by DWR, Stored in HydroBase
- Reservoir Contents Provided by Reservoir Owners/Operators , Stored in HydroBase
- Return Flows Are the Portion of Diverted Water not Required by the Crops, as Determined by StateCU

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Physical Systems

- Diversion Structures
  - Location on the River
  - Headgate and Canal Capacities
  - Return Flow Locations
- Reservoirs
  - Location on River or Off-Channel
  - Location of Carrier Ditches
  - Storage Volume, Outlet Capacities, Account Size, Area/Capacity Tables
- Instream Flow Reaches
  - Beginning/Ending of Reach

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Physical Systems

- Over 400 Diversion Structures Explicitly Represented
  - 178,000 Irrigated Acres
  - Larger Structures; Structures that are Important in Administration (Per Water Commissioner); Structures Receiving Reservoir Water
  - 17 Transbasin Diversions
  - 23 Municipal and Industrial Diversions

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Physical Systems

- Remaining Structures are Represented in 65 Aggregates
  - 92,000 acres
  - Grouped by Location
  - Structures on Smaller Tributaries not Represented in the Model; Structures without Diversion Records

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Physical Systems

- 18 Key Reservoirs
  - 1.37 Million Acre-feet Combined Storage

Meadow Creek	Shadow Mtn/Grand Lake	Granby
Willow Creek	Williams Fork	Wolford Mountain
Con-Hoosier Blue	Clinton Gulch	Dillon
Green Mountain	Homestake	Reudi
Grass Valley	Rifle Gap	Vega
Cottonwood Creek Reservoirs	Leon Creek Reservoirs	Bonham Reservoirs

- 66 Instream Flow Segments

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Physical Systems – Data Sources

- Physical Structure Location Based on GIS, Available Straight-line Diagrams, and Water Commissioner Input
- Return Flow Locations Based on GIS
- Ditch and Reservoir Capacity Information is Stored in HydroBase (If Available)
- Additional Reservoir Capacities, Account Information, and Area Capacity Curves Obtained from Reservoir Owners/Operations

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Water Demands

- Irrigation Demands
  - Full Irrigation Water Requirements from StateCU
- Municipal Demands
  - 1998 to 2005 Average Monthly Diversions
- Transbasin Demands
  - 1998 to 2005 Average Monthly Diversions
- Reservoir "Demands"
  - Reservoir Capacities or Operational Targets

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Water Demands – Sources

- Reservoir "Demands"
  - Reservoir Capacities or Operational Targets
  - Operational Targets for Ruedi, Green Mountain, and Willow Creek Provided by USBR
  - Operational Targets for Williams Fork Provided by DW

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Administrative Conditions

- Water Rights (Direct, Storage, Instream Flow)
- Reservoir and Carrier Operations
- Policies and Agreements (Such as Minimum Bypasses, Fish Flows, etc)

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Administrative Conditions

- Model "Operating Rules" for the Upper Colorado Model Define:
  - How Water is "Carried" to Off-Channel Reservoirs
  - How Demands are Satisfied From Reservoirs and in What "Priority"
  - How Water is "Carried" to Collection Systems and Common Demands and in What "Priority"

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Administrative Conditions – Sources

- Water Rights Directly From HydroBase
- Reservoir and Carrier Operations Based on Information from Reservoir Owners and Water Administrators
- Priorities for Operations Assigned to Represent "Order" with Other Rights
  - Ex: Reservoir Release to a Ditch would be Assigned a Priority Junior to the Ditch's Direct Flow Right

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Model Operations

1. Based on Natural Inflow and Return Flows from Previous Time Steps
2. Identifies Most Senior Water Right
3. Estimates Diversion =min (Demand, Water Right, Headgate Capacity, Available Flow)
4. Adjusts Downstream Flows to Reflect Senior Diversions and Immediate Return Flows
5. Future Returns are Calculated
6. Repeated for Next Junior Water Right

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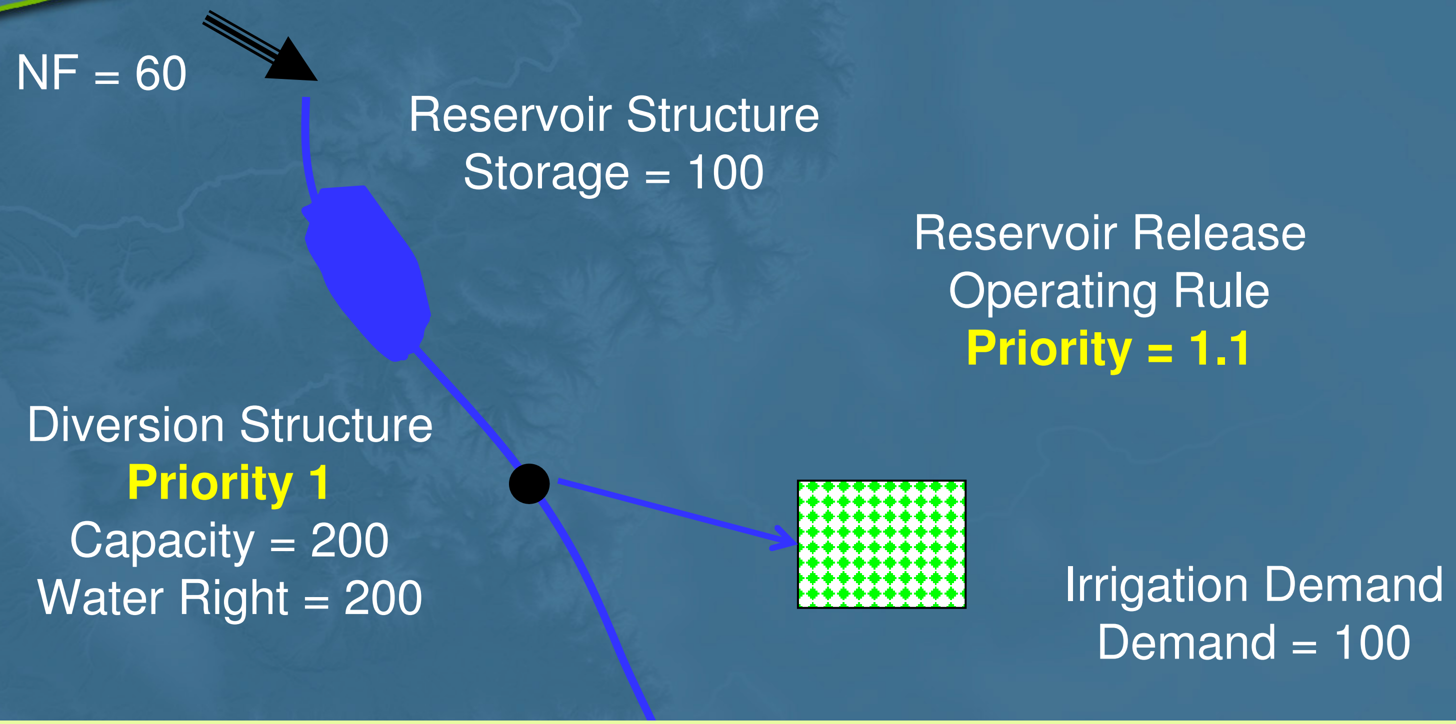
Model Operations - Example Reservoir Release Operation



1) Priority 1: Direct diversion to irrigation = min (demand, water right, capacity, physical flow) = min(100, 200, 200, 60) = 60
2) Demand is decreased to 100 – 60 = 40
3) Diversion structure capacity is decreased to 200 – 60 = 140
4) Priority 2: Reservoir release operating rule, Reservoir Release = min (demand, carrier capacities, reservoir storage) =min(40, 140, 100) = 40

Model Calibration

- Step 1 Calibration - Simulate with Calibration Data Set
  - Demands = Historical Diversions; Including Carriers to Reservoirs or other Demands
  - Reservoir "Targets" = Historical Contents; Reservoirs Store and Release Based on Historical
  - Objective to Refine Natural Flow Hydrology and Return Flow Locations

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Model Calibration

- Do Simulated Results = Historical Measurements? Compare:
  - Diversions
  - Streamflows
  - Reservoir Contents

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Model Calibration

- Calibration "Knobs"
  - Return Flow Locations (Ex. More Return Flows above Shorted Diversions, Around Gage)
  - Natural Flow Distribution to Ungaged Tributaries; Need Enough Physical Flow to Meet Historical Diversions

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Model Calibration

- Step 2 Calibration - Simulate with Calibration Data Set and Operational Data
  - Direct Demands = Historical Diversions
  - Carrier Diversions Driven by Destination Demand via Operating Rules
  - Reservoir "Targets" = Capacity or Operational Targets
  - Objective to Refine Operational Parameters

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Model Calibration

- Calibration "Knobs"
  - Revise "Priorities" Assigned to Operating Rules
  - Change Operating Rule Types
  - Continued Coordination with Reservoir Operators and Water Administrators
  - "Explain" Unresolved Issues with Calibration
    - Ex. Model Simulates Full Reservoir, However Historical Contents were Low due to Maintenance

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Model Calibration

- Streamflow Average Annual Calibration Within 3 Percent with Exceptions
  - Ranch Creek near Fraser ~6% Likely Due to Moffat Collection System Measurement Issues
  - Plateau Creek near Collbran ~32% Due to Lack of Historical Data and Understanding of Southside Canal Diversions and "Releases" to Plateau Creek Tributaries
  - Downstream Plateau Creek near Cameo Simulates within 1%

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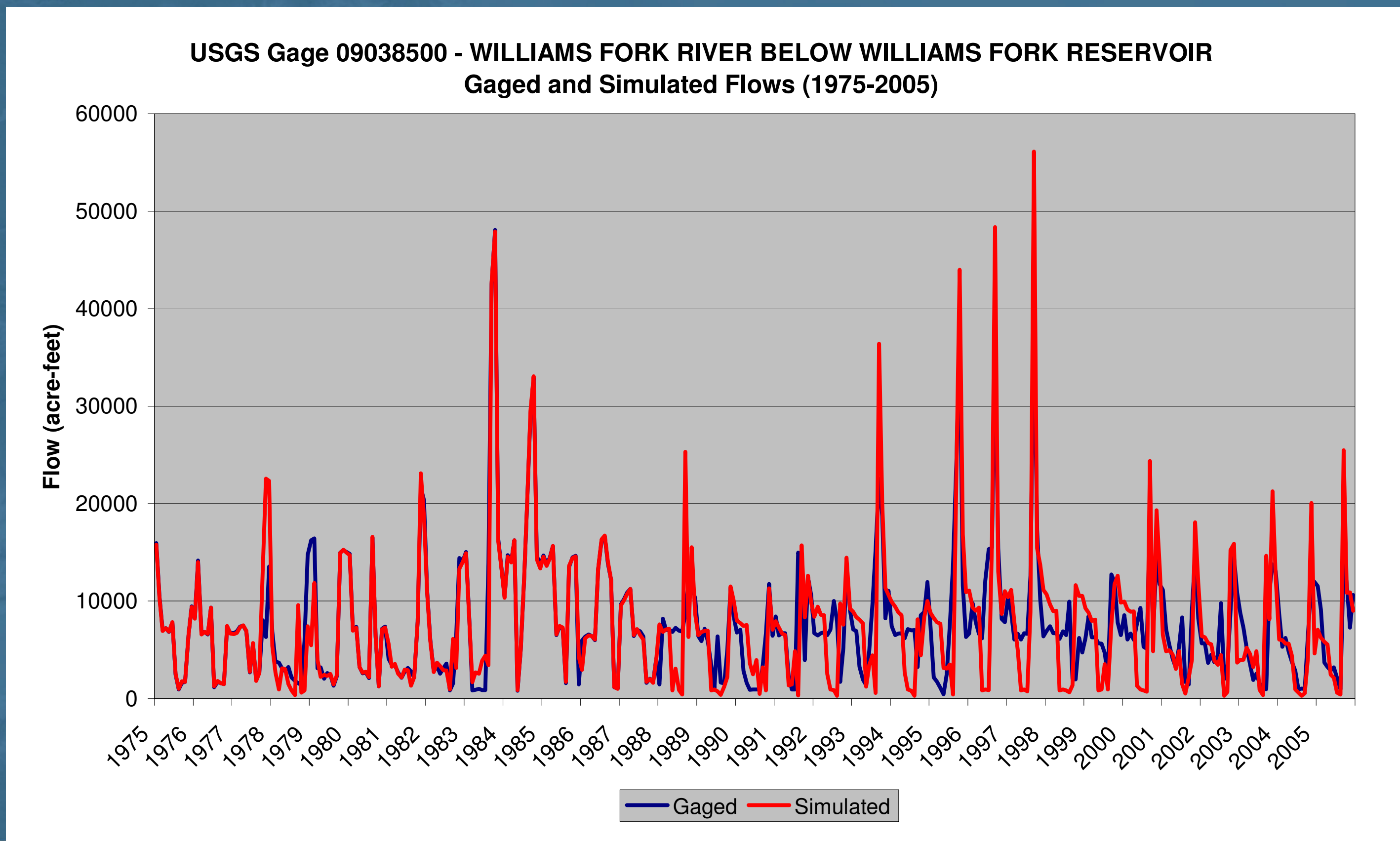
Model Calibration

- Streamflow Calibration below Reservoirs with Operational Targets Reflect that Operational Targets are "Guidelines"



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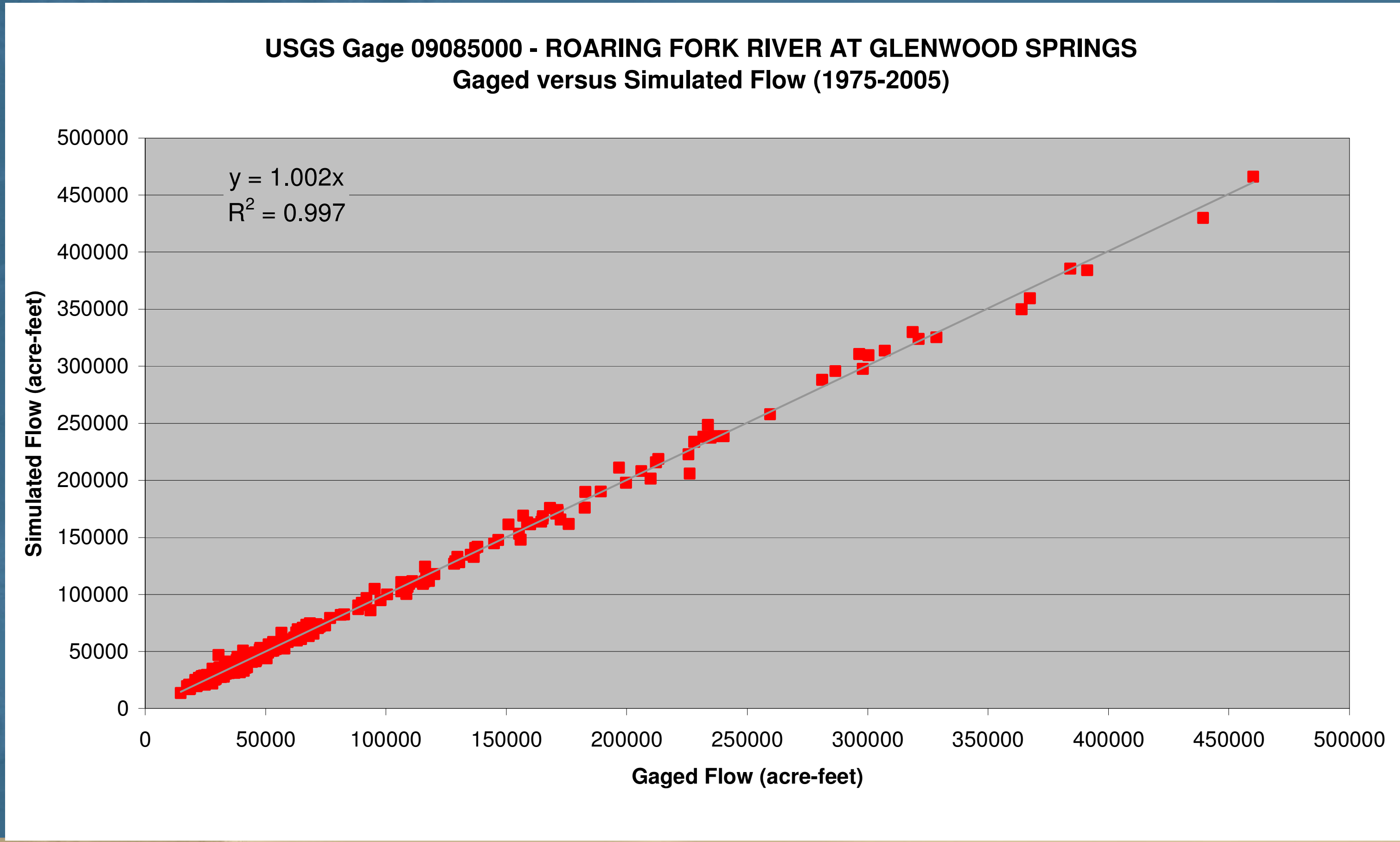
Model Calibration

- Calibration on Larger Tributaries Generally Very Good



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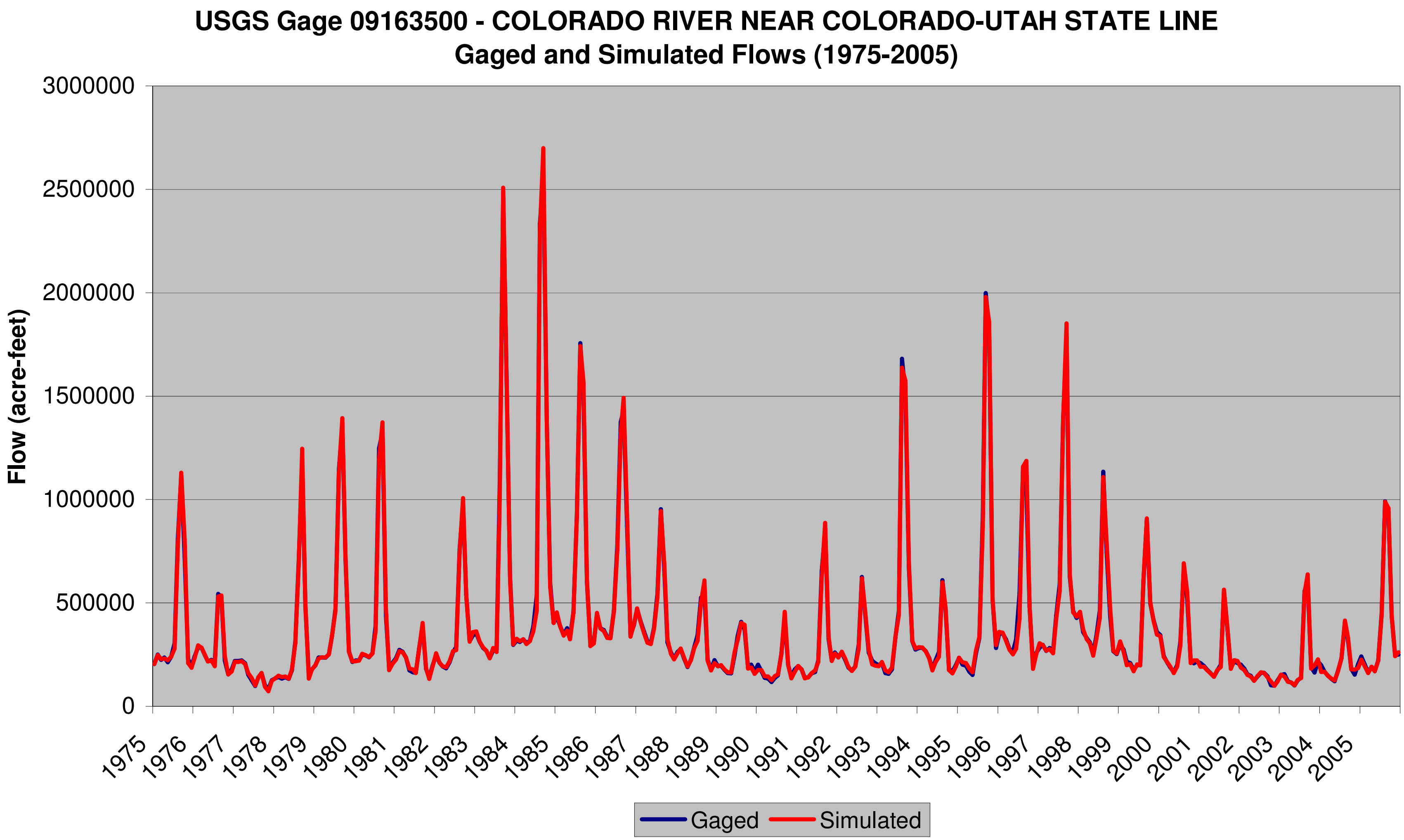
Model Calibration



Model Calibration

- Basin Wide Total Simulated Diversions are within 1 percent of Total Historical Diversions
  - Exceptions Include :Bonham Branch Pipeline , Coon Creek Pipeline, and Cottonwood Branch Pipeline in Plateau Basin
  - Transbasin Diversions Calibrate, but in some cases the individual diversions under collection systems over or under divert
  - Some Aggregated Diversions are Shorted Likely Because they Historically Re-Divert each other's Return Flows

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Model Calibration

Historical and Simulated Average Annual Diversions by Sub-basin (1975-2005) Calibration Run (acre-feet/year)

Tributary or Sub-basin	Historical	Simulated	Historical minus Simulated	
			Volume	Percent
Colorado Main Stem	3,090,881	3,064,110	26,771	1%
Fraser River	83,553	82,351	1,202	1%
Williams Fork River	41,297	41,235	62	0%
Blue River	157,539	154,238	3,301	2%
Eagle River	121,772	120,627	1,145	1%
Roaring Fork River	454,984	446,031	8,954	2%
Plateau Creek	132,689	129,999	2,690	2%
Basin Total	**4,082,716**	**4,038,590**	**44,125**	**1%**

Model Calibration

- Reservoir Calibration Results
  - Reservoir Calibration Good with Some Exceptions
  - Dillon Reservoir Calibration Good Except 1983 through 1986 (Reservoir kept low for Maintenance)
  - Grass Valley and Rifle Gap Simulation Does not Match Historical Due to Lack of Project Demand Information
  - Vega Reservoir Affected by Lack of Information and Understanding of Southside Canal Diversions
  - Green Mountain, Ruedi, Williams Fork, and Willow Creek Simulated Using Operational Storage Targets – Appear to be a General Guidelines

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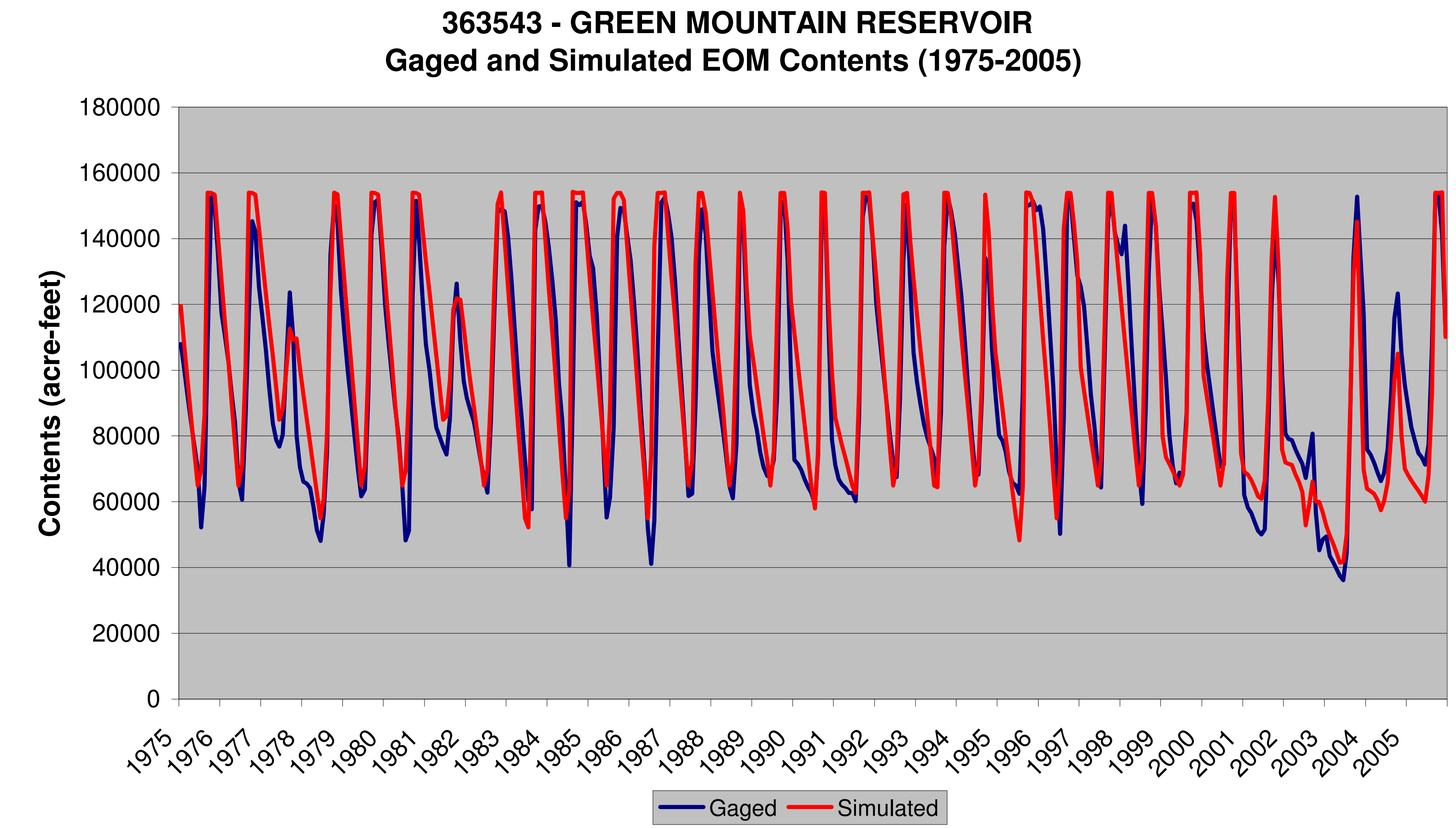
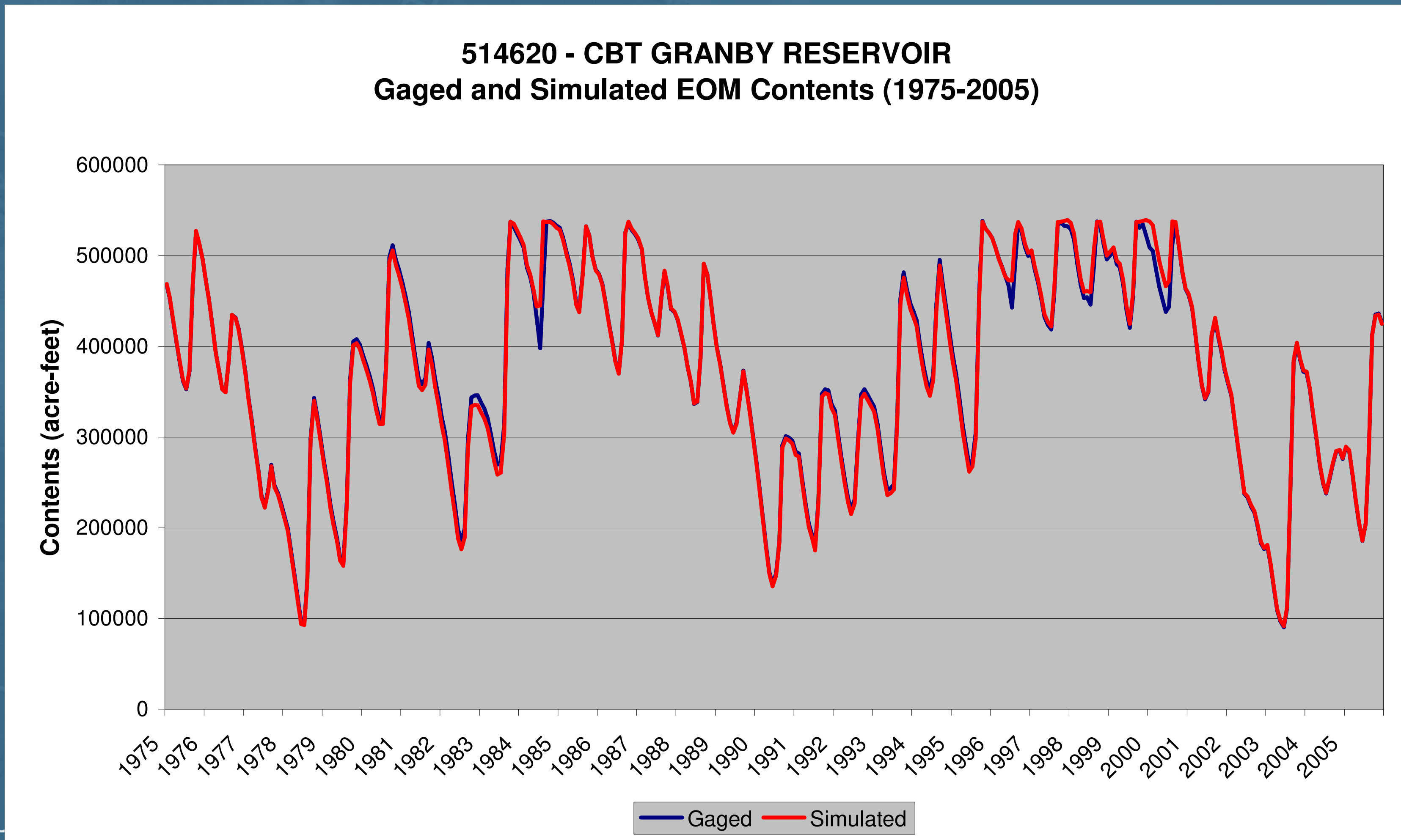
Model Calibration



Model Calibration



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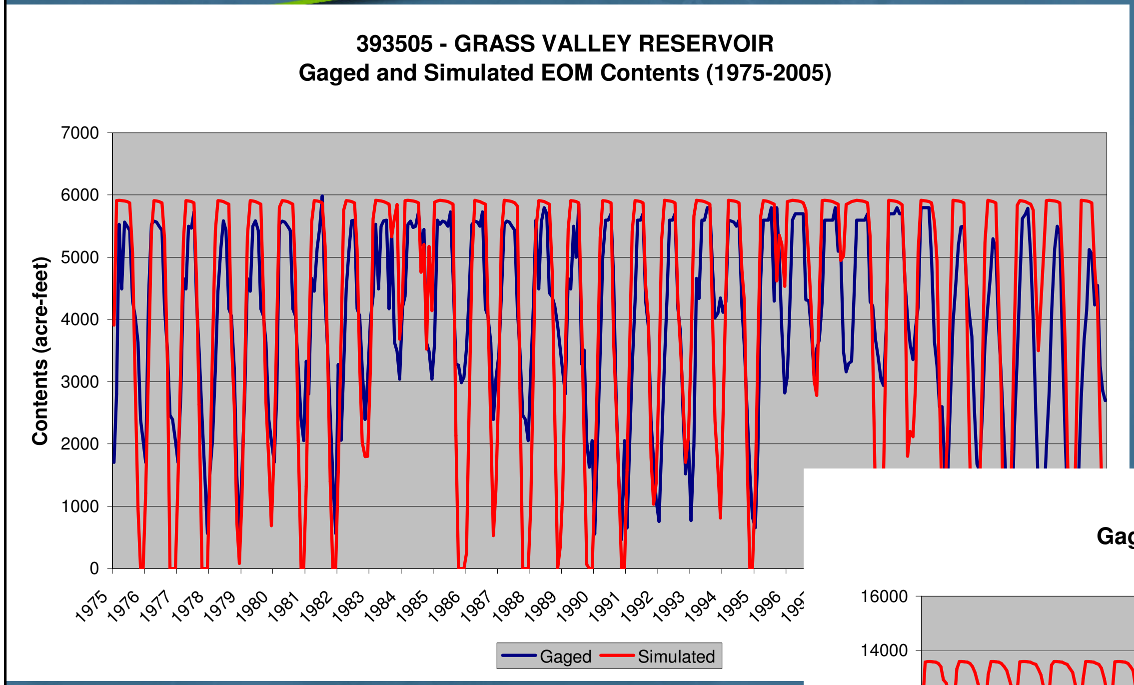
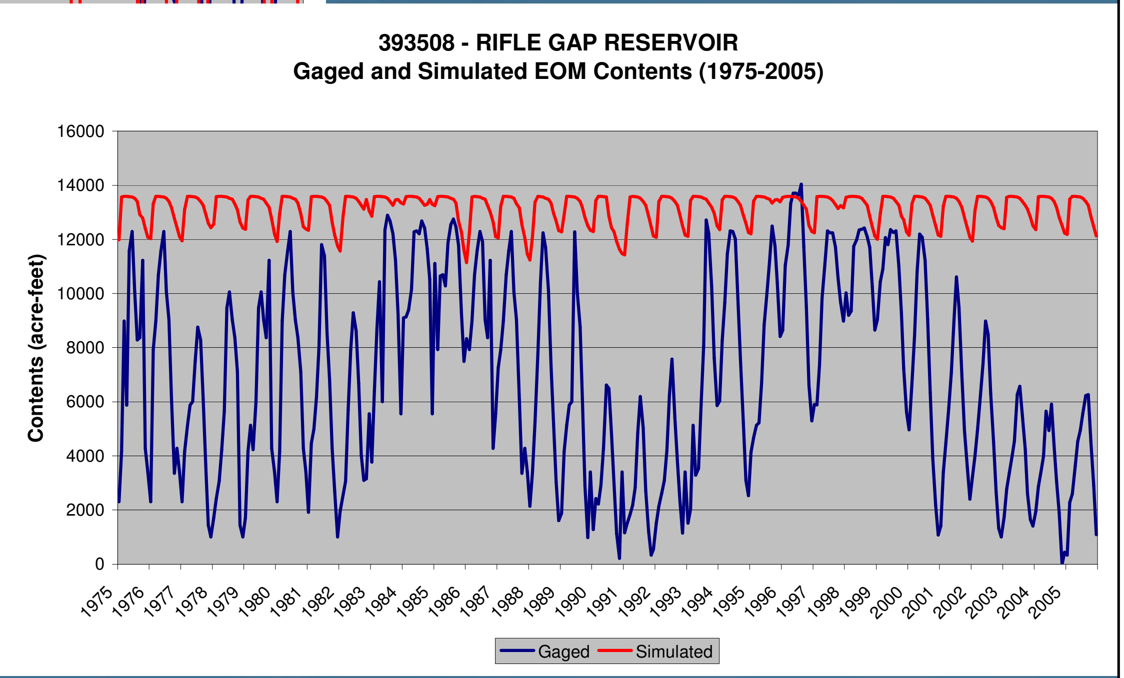
Model Calibration





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Model Calibration

- Basin-wide Calibration Results are Good
- Understanding and Representation of Basin Operations is Good
- Upper Colorado StateMod Model is Appropriate Prediction Tool to Consider Effects of Basin Climate Variability

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StateMod and Alternate Hydrology

- Extending Historical Hydrology
  - Re-Sequenced Irrigation Water Requirements (IWR)
  - Re-Sequenced IWR-Based Demands
  - Re-Sequenced Natural Flows
  - StateMod Simulation to Provide Available Flow
- Climate Change
  - Revised Natural Flows
  - Revised Irrigation Water Requirements (from StateCU)
  - Revised IWR-Based Demands
  - StateMod Simulation to Provide Available Flow

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Questions, Comments, Suggested Model Enhancements?

Website:

http://cwcb.state.co.us/WaterInfo/CRWAS

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