Estimating Colorado River Storage Project Power Economics with the GTMax Model

Presented by

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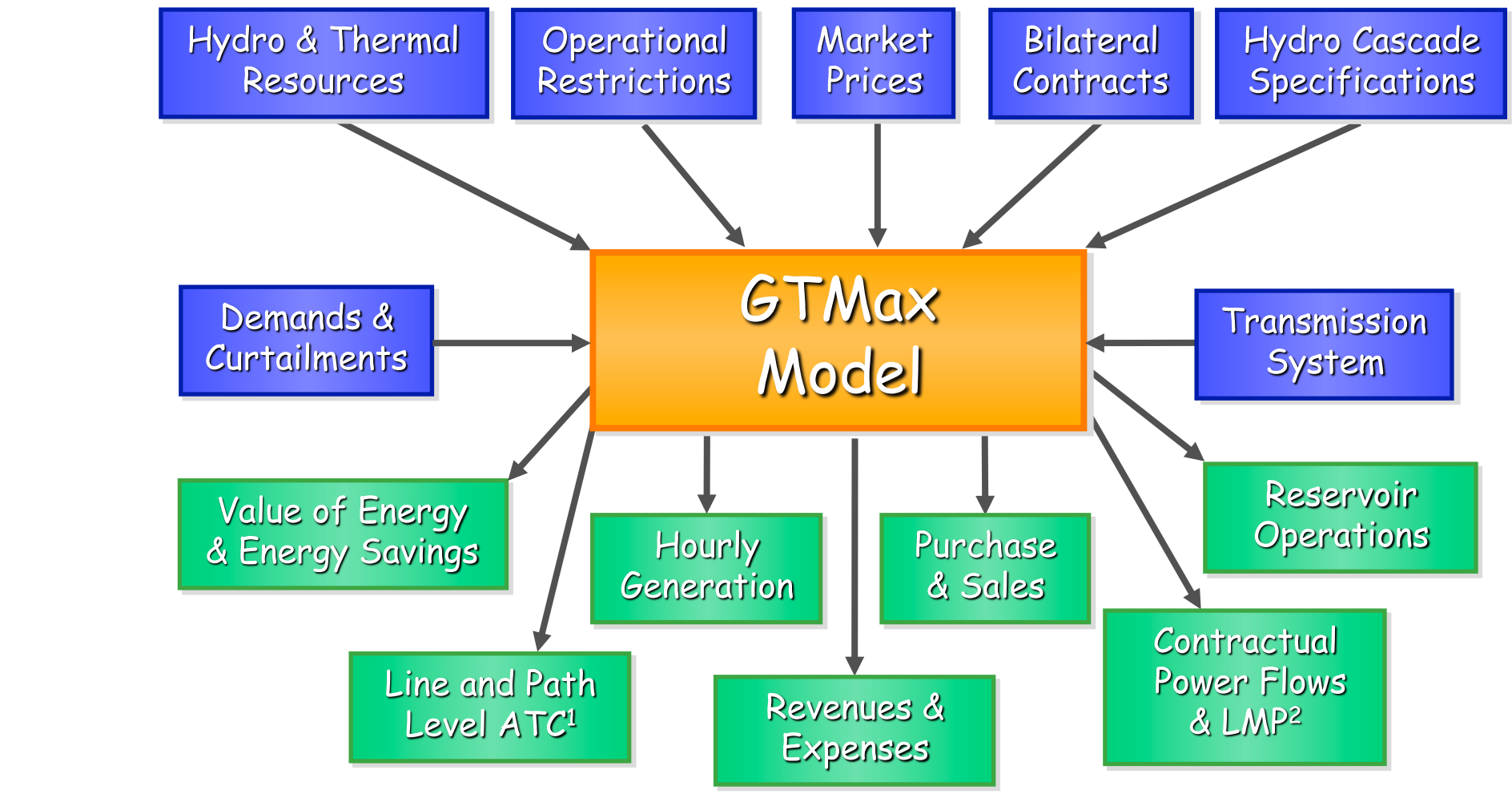
Presentation Topics

- **Introduction to the GTMax model**
  - Methods
  - Approach
  - Features

- **Salt Lake City Area Integrated Project (SLCA/IP) monthly simulations**
  - Flaming Gorge and Jensen Gauge
  - Available Hydropower (AHP)
  - Pre-schedule and future power purchases

- **GTMax knobs and levers**
  - Affects on results

The Generation and Transmission Maximization (*GTMax*) Model Optimizes Power System Operations

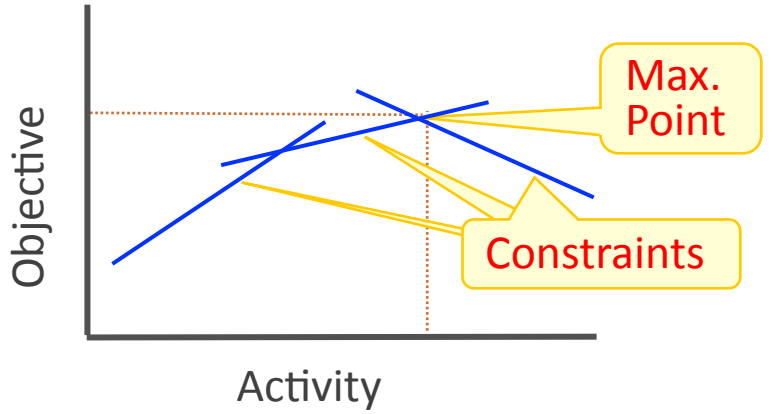


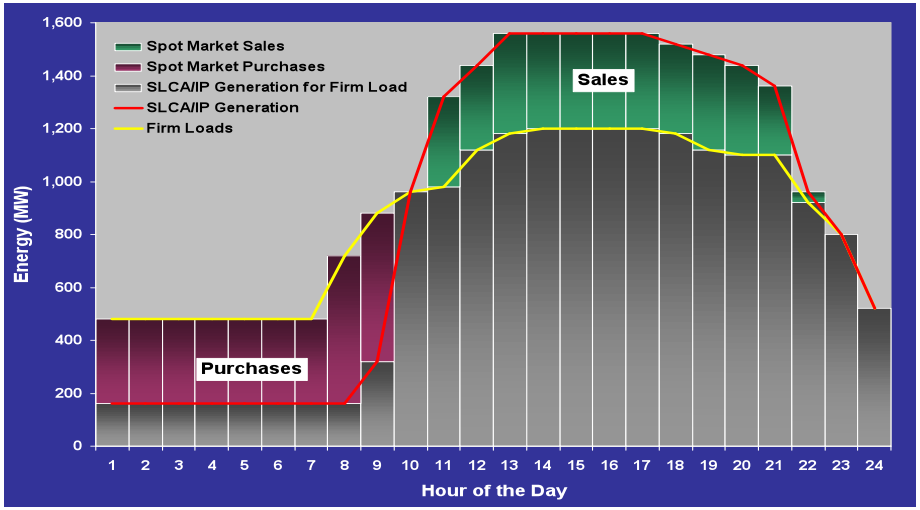
1. Available Transfer Capability (ATC)

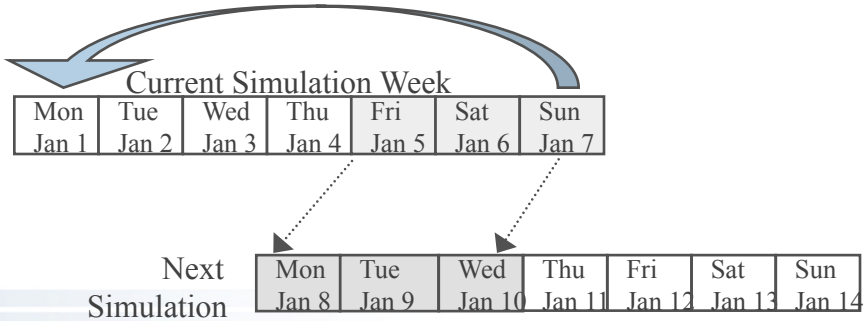
2. Locational Marginal Price (LMP)

GTMax Uses Linear & Mixed Integer Programming to Solve Problems

- **Scope and granularity**
  - One week is solved simultaneously
  - Hourly time step
- **Electric utility system components**
  - Hydro and thermal power plants
  - Intermittent technologies
  - Firm purchase and sales contracts
  - Spot market transactions (block & variable)
  - Customers (electricity demand)
  - Transmission lines and connections
- **Hydro system**
  - Reservoirs
  - Water channels
  - River gauges
- **Physical and institutional constraints**
  - Capacity
  - Technical minimum
  - Ramping limits
  - Reservoir limits
- **Grid services**
  - Spinning reserves
  - Regulation services



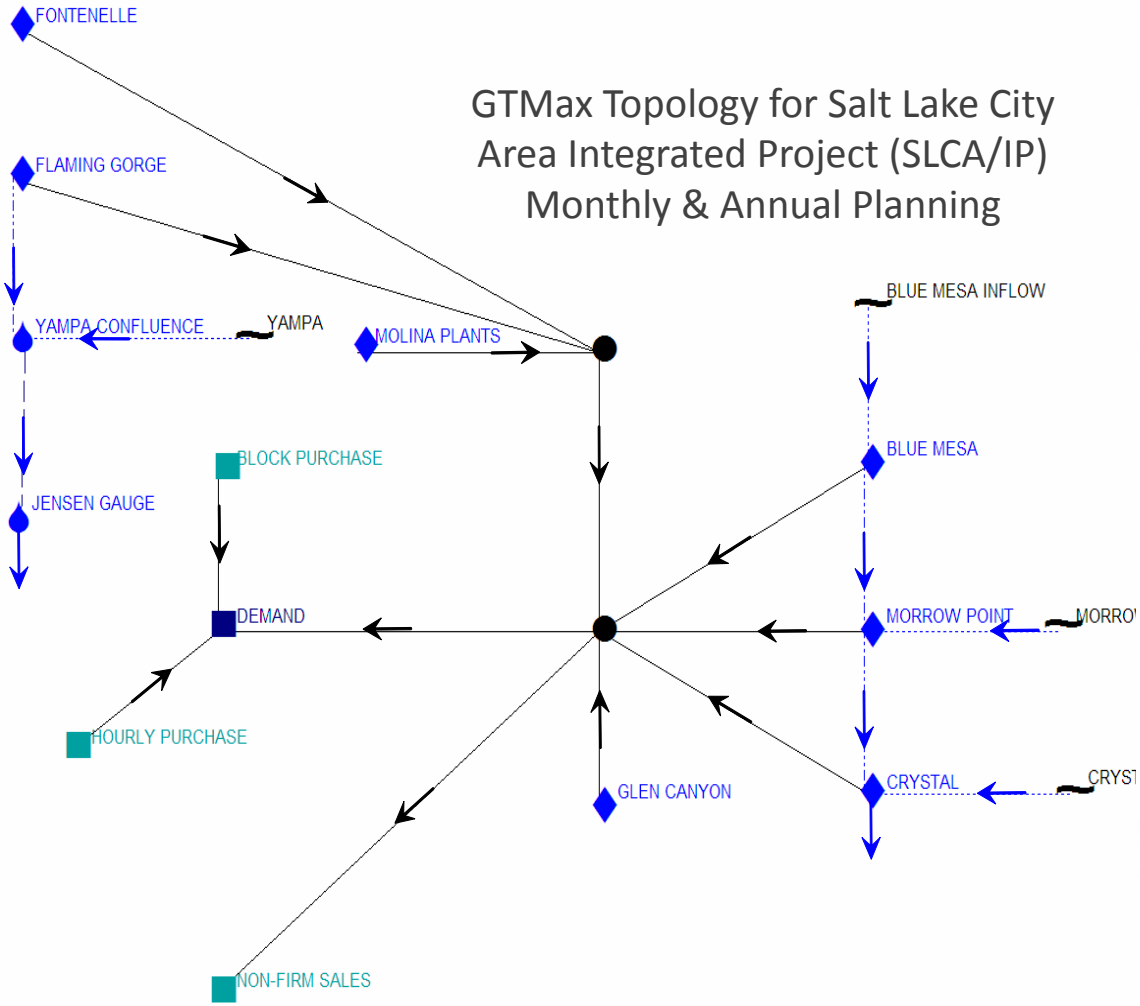




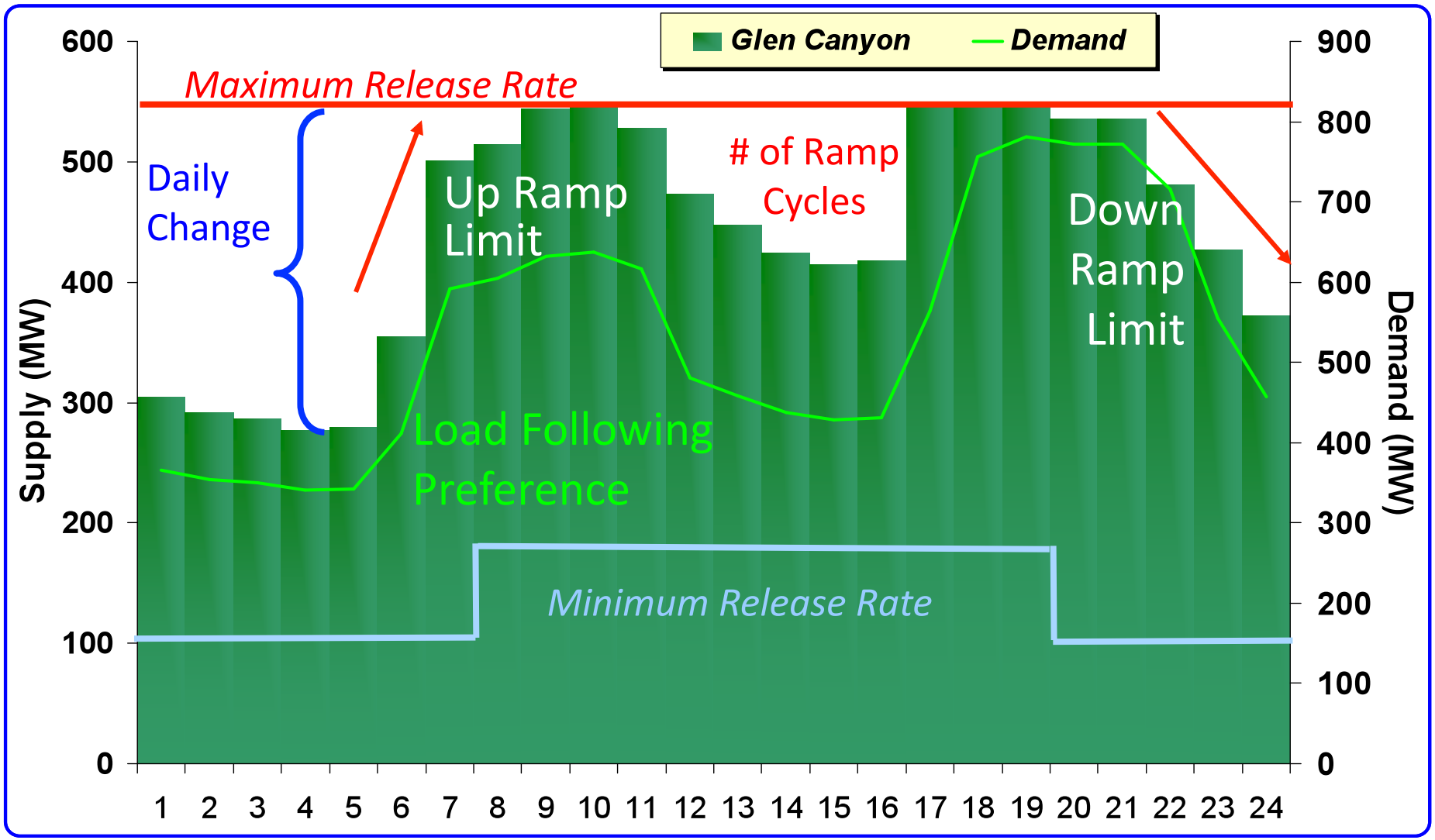
SLCA/IP Components Are Simulated Using a Systems Approach

- *GTMax Uses a Network Representation of a Power System*
- *All Aspects Are Connected in Time & Space*

GTMax Topology for Salt Lake City Area Integrated Project (SLCA/IP) Monthly & Annual Planning

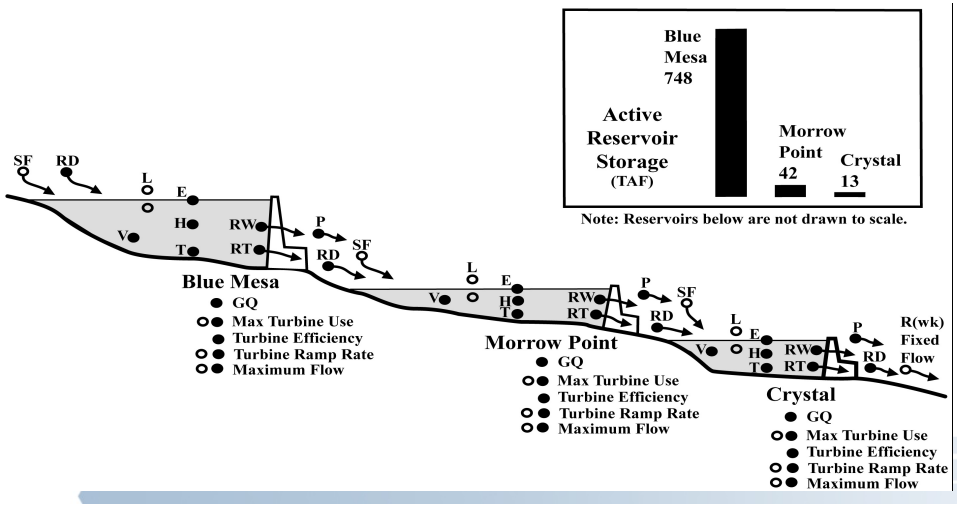


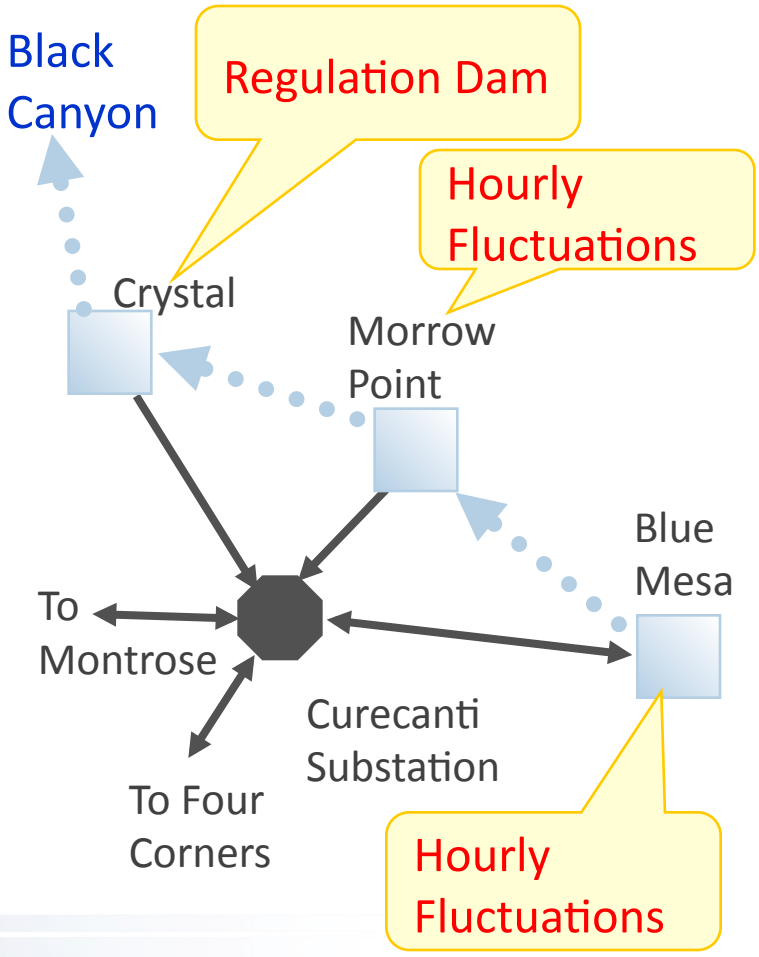
Model Operations Reflect Physical Limitations, Environmental Restrictions, and Institutional Policies



Hydropower Dispatch Is Constrained by Reservoir Limitations

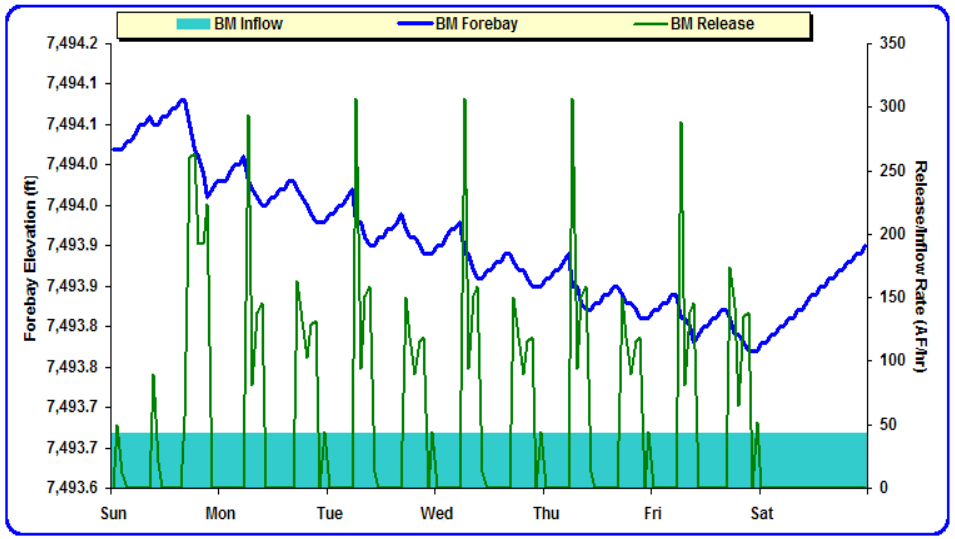
- **Maximum reservoir elevation level**
- **Minimum reservoir elevation level**
- **Daily reservoir elevation change**
- **Change over a 3-day period**
- **Elevation levels are functions of:**
  - Initial reservoir conditions
  - Hourly up-stream reservoir releases
  - Side flows
  - Hourly reservoir releases
  - Elevation/volume function





Recent GTMax Model Result

Aspinall Cascade



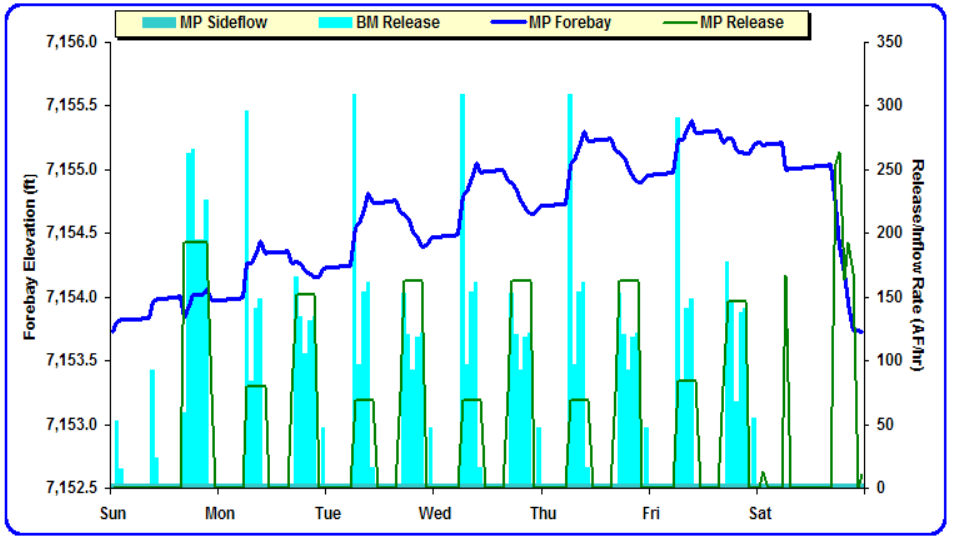
7,233

Blue Mesa	
In (AF)	7,233
Out (AF)	8,167
Elev Diff (ft)	-0.1200

Month
Nov

8,167

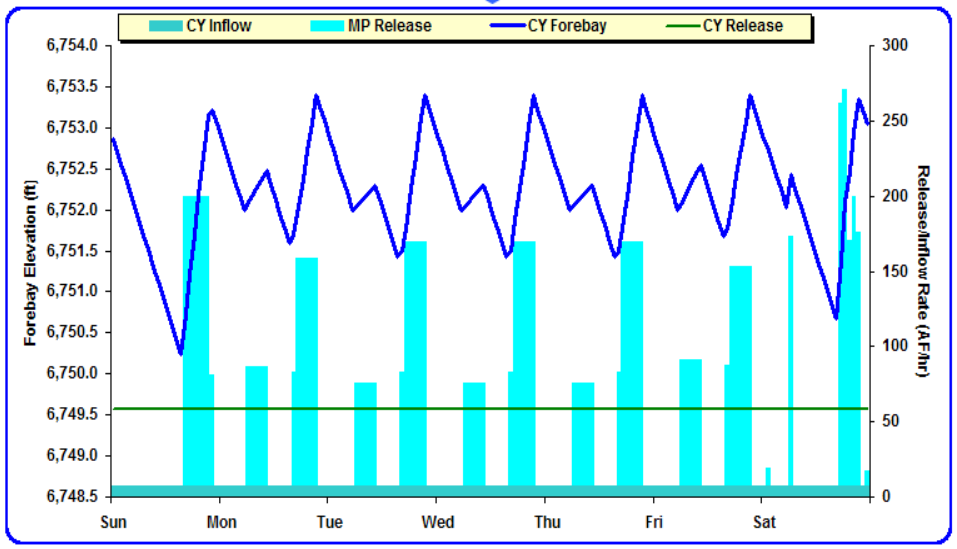
467



1,167

Morrow Point	
In (AF)	8,633
Out (AF)	8,633
Elev Diff (ft)	0.0000

8,633



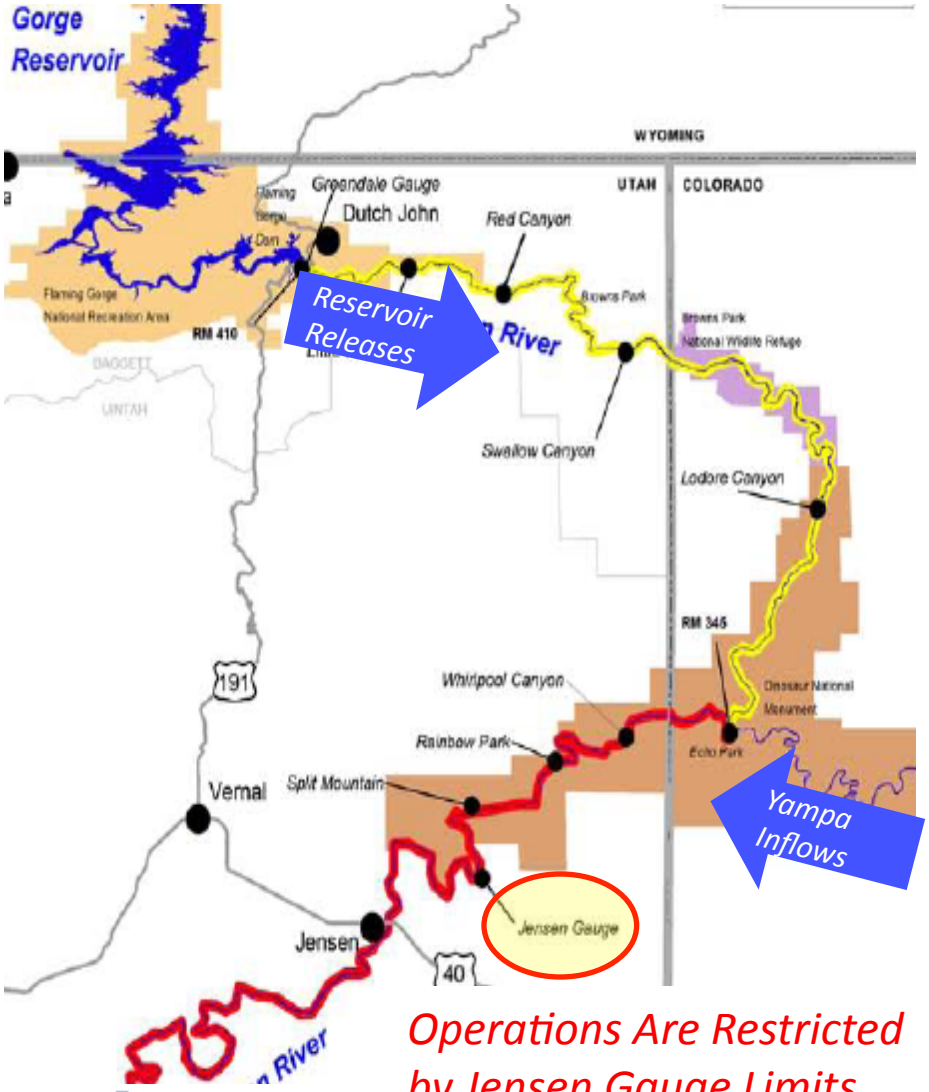
Crystal	
In (AF)	9,800
Out (AF)	9,800
Elev Diff (ft)	0.1800

9,800

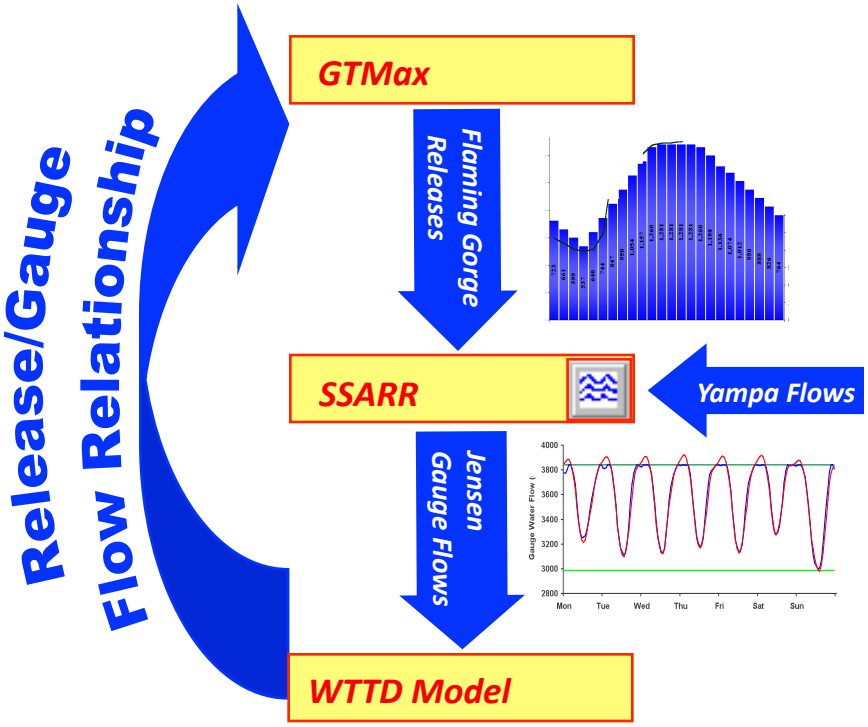
Crystal	Max Elevation (ft)	Min Elevation (ft)	Daily Elevation Change (ft)	3-Day Change (ft)	
Sun	6,753.2	6,750.2	3.0		1
Mon	6,753.4	6,751.6	1.8		2
Tue	6,753.4	6,751.4	2.0	3.2	3
Wed	6,753.4	6,751.4	2.0	2.0	4
Thu	6,753.4	6,751.4	2.0	2.0	5
Fri	6,753.4	6,751.7	1.7	2.0	6
Sat	6,753.4	6,750.7	2.7	2.7	7
Week	6,753.4	6,750.2	3.0	3.15	
Change	3.2		Max Daily	Max 3-Day	

Hourly Powerplant Operations Can also Be Constrained by Gauge Limitations

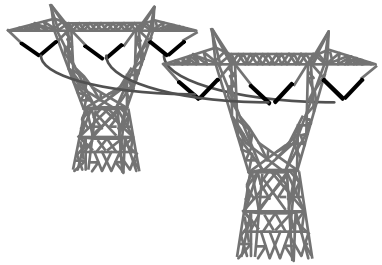
Capacity: 152 MW
Generation: 767 GWh/yr

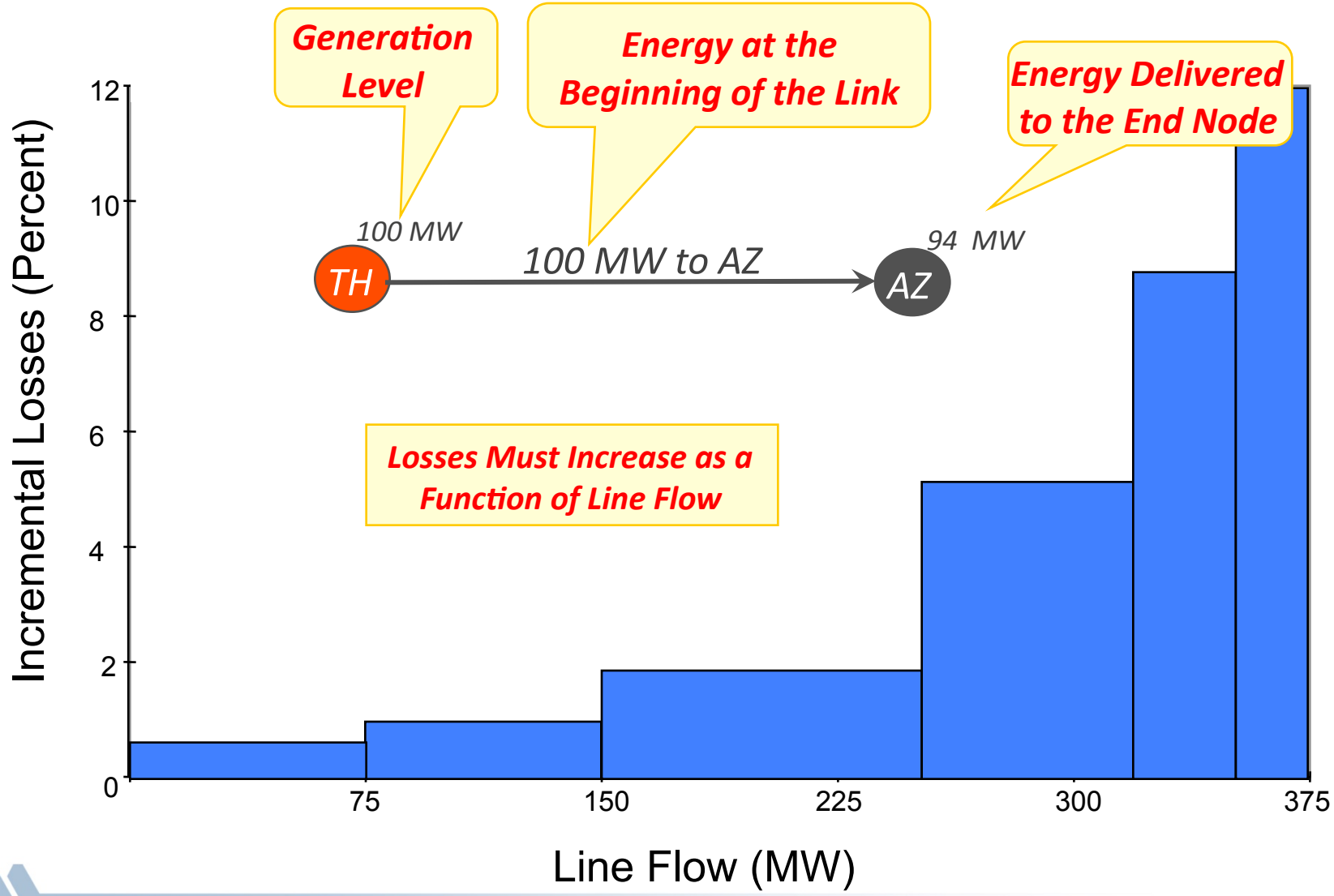


Operations Are Restricted by Jensen Gauge Limits



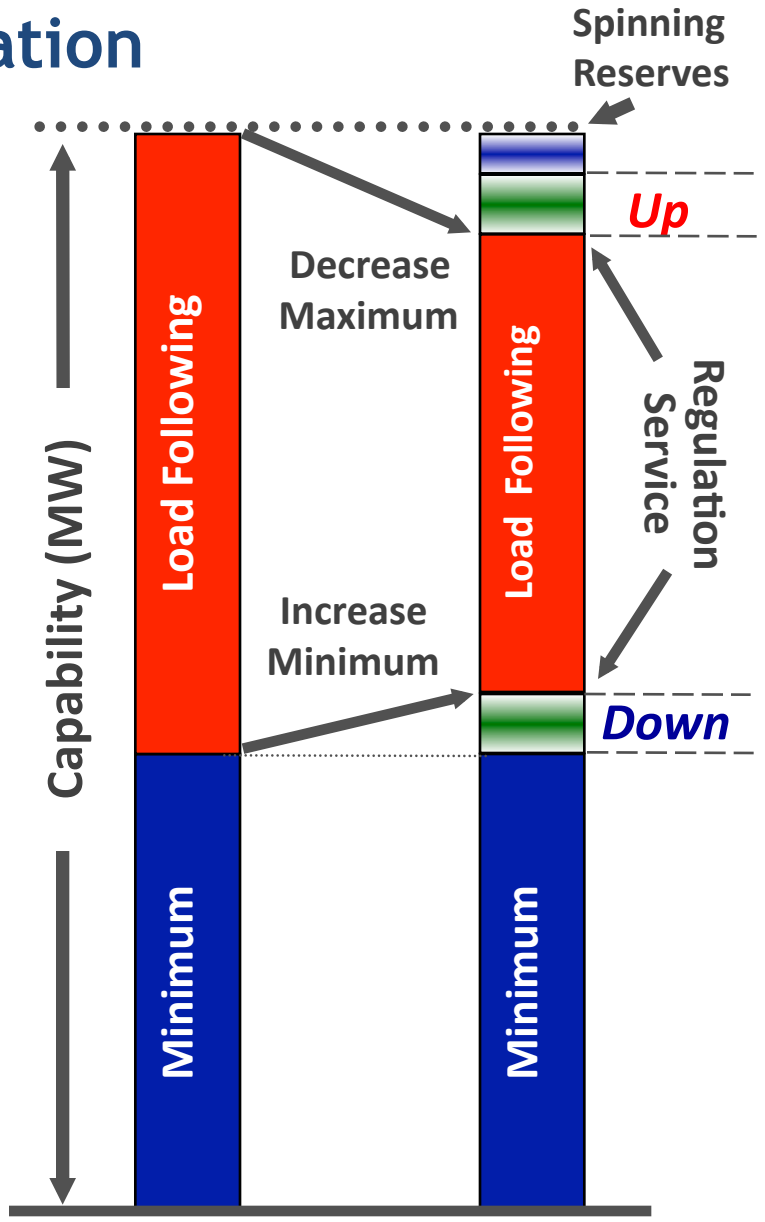
Transmission Line Losses Are Specified as a Step Function





Units that Provide Ancillary Service Have a Reduced Range of Scheduled Operation

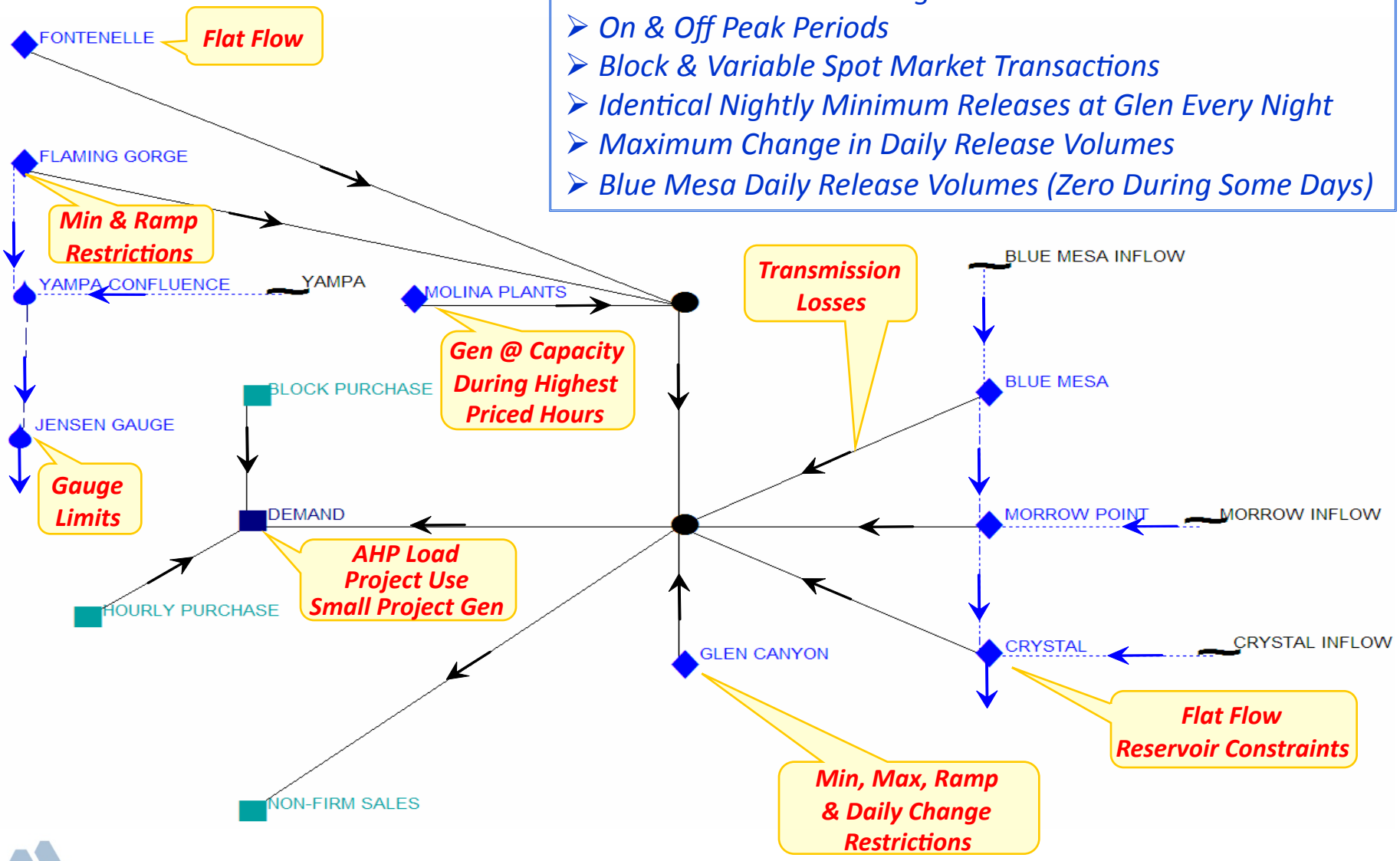
- Spinning reserves (SR)
  - Affects maximum generation
- Regulation services (RS)
  - Affects both the minimum & maximum generation
- Minimum generation
  - When generation is off-line the unit cannot provide regulation services
- Glen Canyon Dam exception criteria



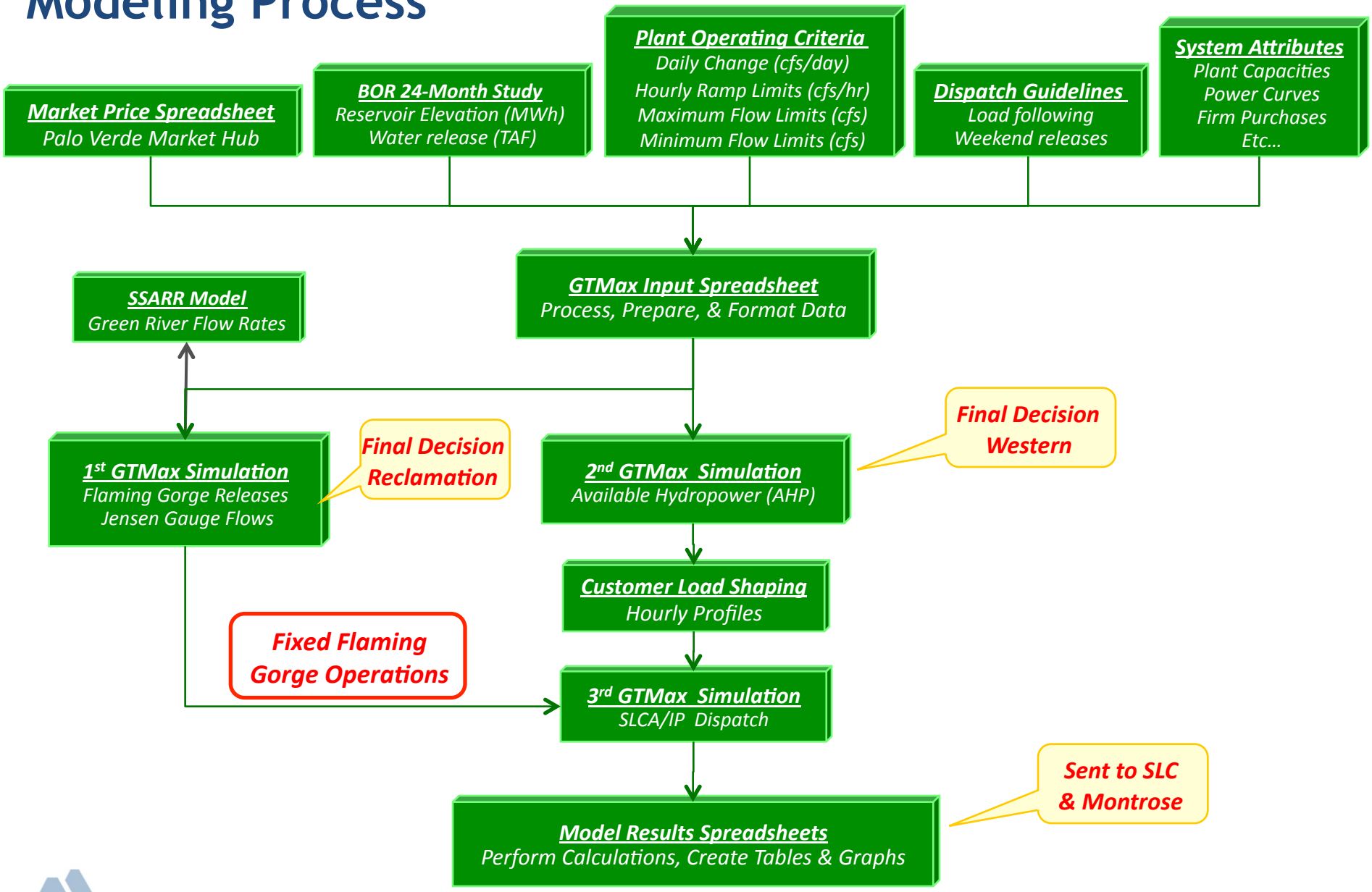
SLCA/IP Monthly Simulation Topology

Montrose Operating Guidelines

- *Customer Load Following or Maximize Economic Value*
- *On & Off Peak Periods*
- *Block & Variable Spot Market Transactions*
- *Identical Nightly Minimum Releases at Glen Every Night*
- *Maximum Change in Daily Release Volumes*
- *Blue Mesa Daily Release Volumes (Zero During Some Days)*



Monthly and Annual Planning Modeling Process



Recent GTMax Model Result

Flaming Gorge and the Jensen Gauge

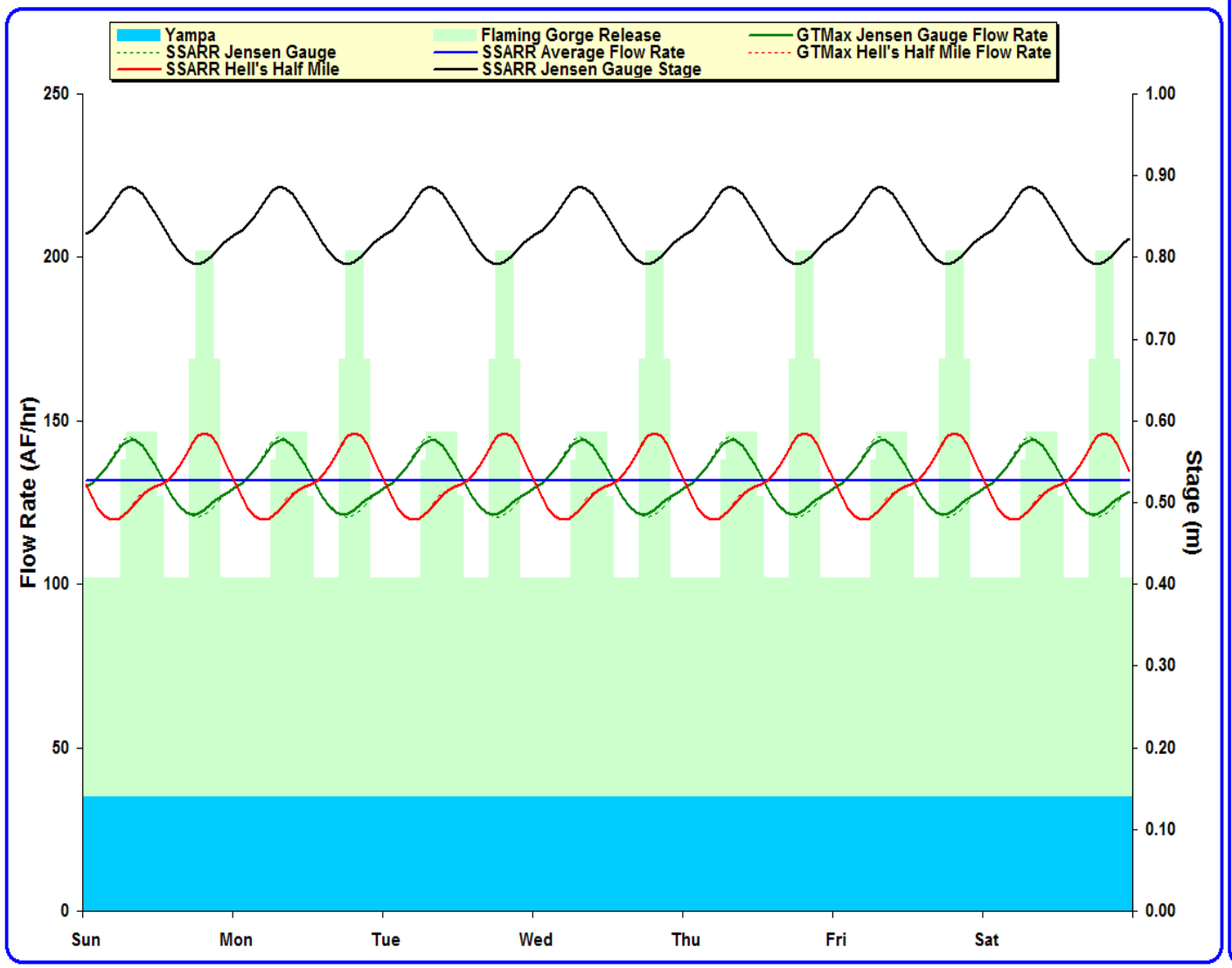
1st GTMax Simulation
Flaming Gorge Releases
Jensen Gauge Flows

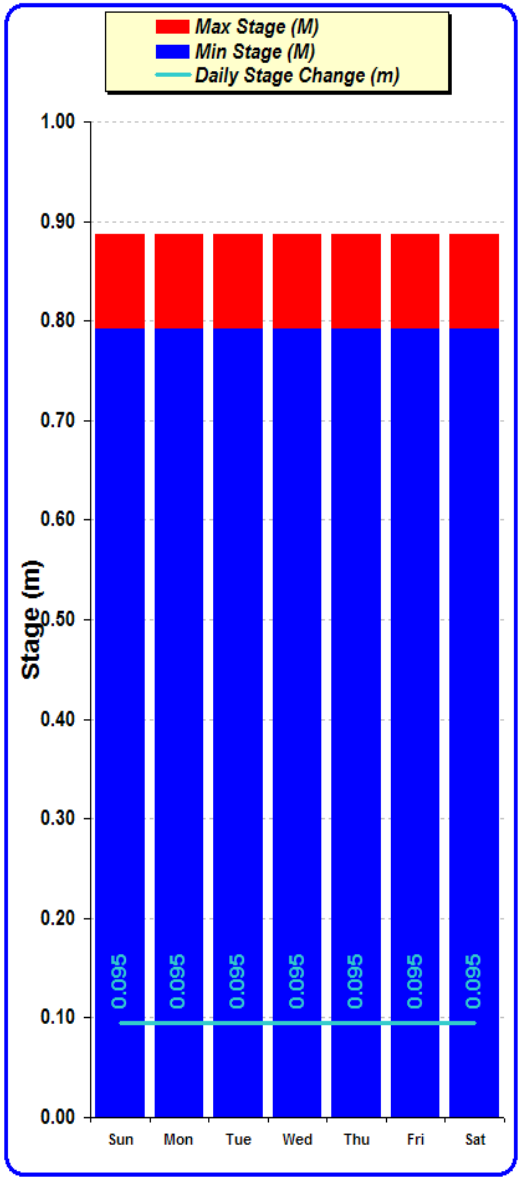
FG Release (AF/week) 16,248.34

Month	SSARR (Jensen Gauge)	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Nov	Slowest Allowed	127.9	127.9	127.9	127.9	127.9	127.9	127.9
cfs	Average Flow Rate	131.8	131.8	131.8	131.8	131.8	131.8	131.8
Min FG Rel 808	Fastest Allowed	135.8	135.8	135.8	135.8	135.8	135.8	135.8
Max FG Rel 2,021	% Volume Change	0.00	0.00	0.00	0.00	0.00	0.00	0.00

FG Max Ramp (cfs/hr)
808.2 Up
808 Down
Change from previous day

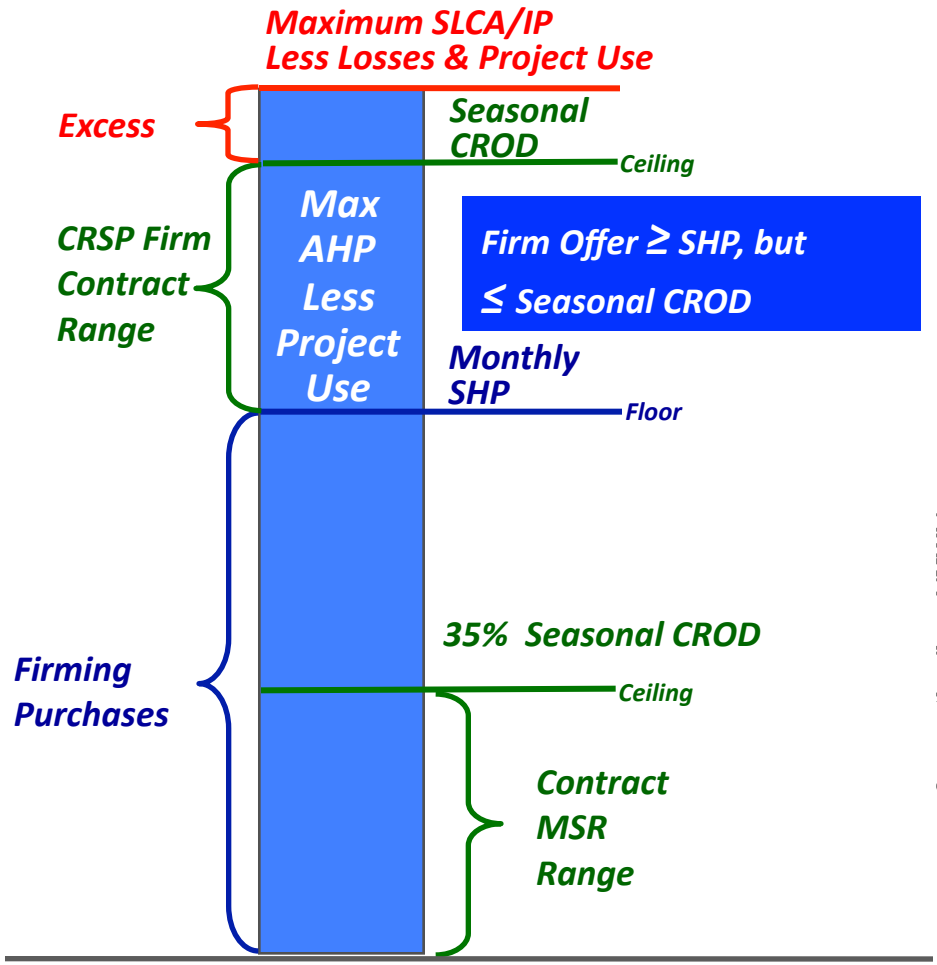
Max Daily Stage Change = 0.1 meters/day
Max Daily Flow Change at the Gauge = 3%

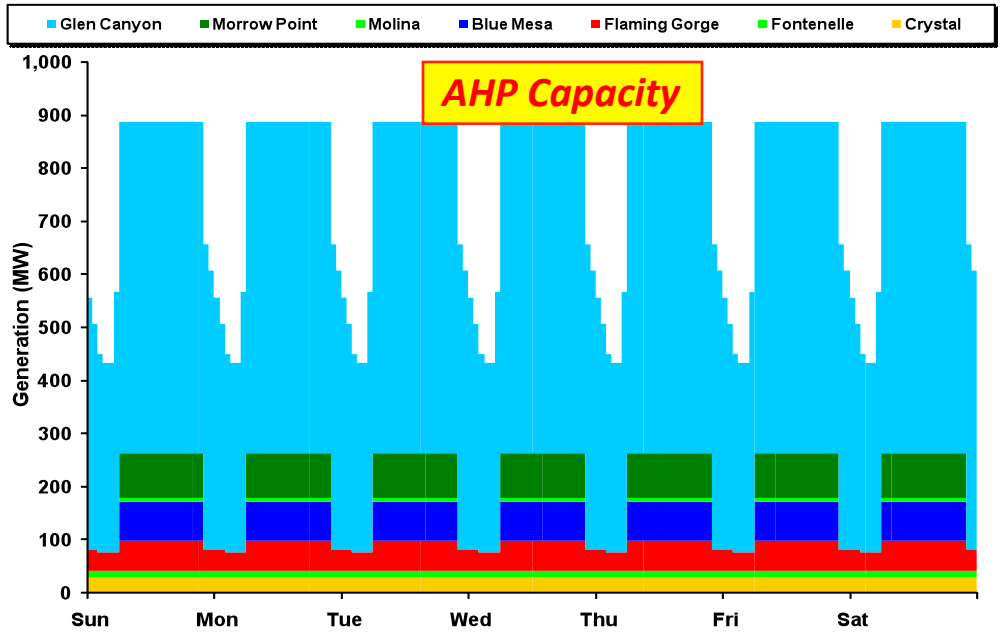


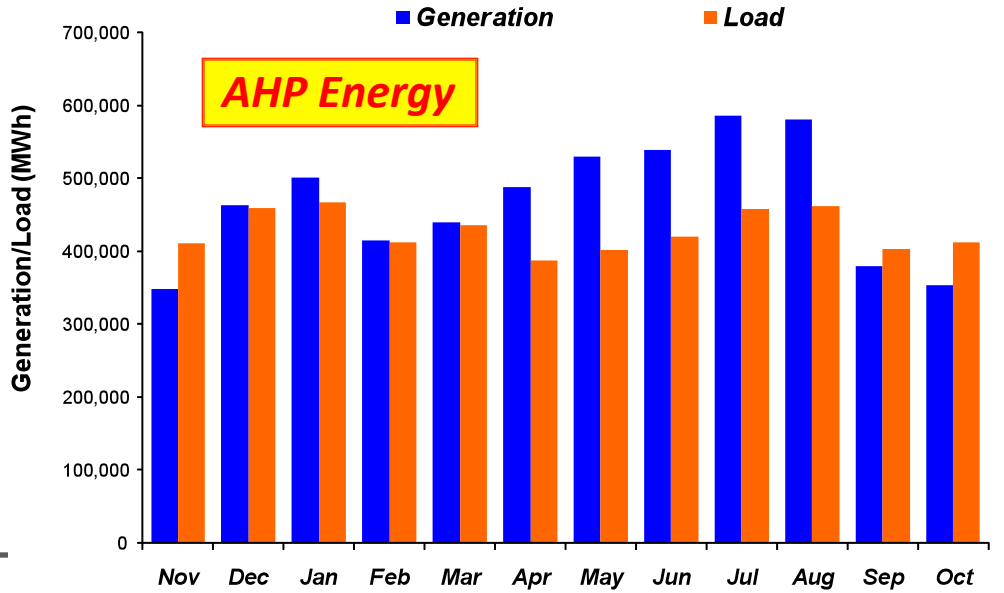


Minimum Schedule Requirement (MSR) Sustainable Hydropower (SHP), & Available Hydropower (AHP)

2nd GTMax Simulation
Available Hydropower (AHP)

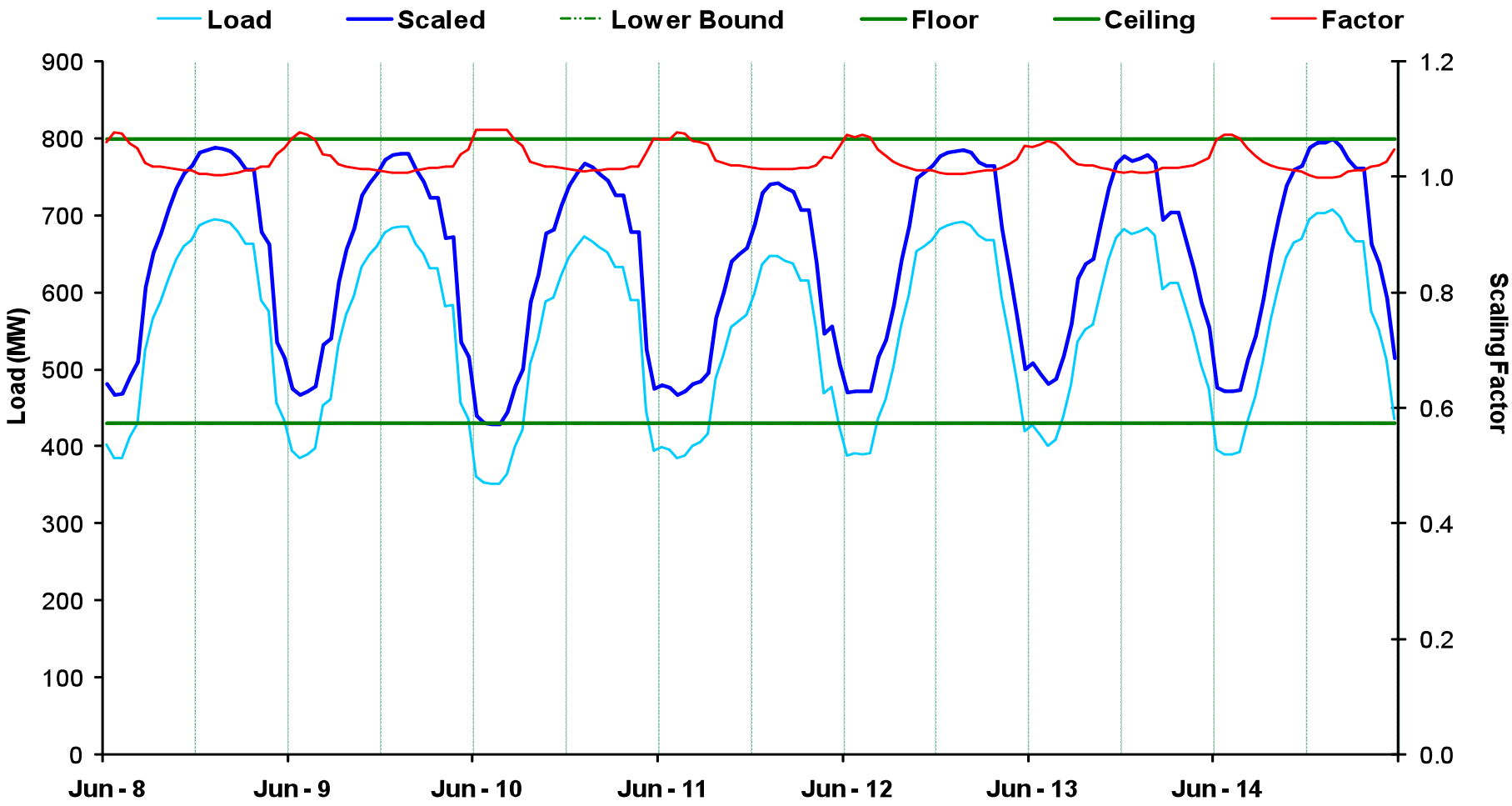






Based on AHP Offers and the MSR Customer Hourly Loads Are Approximated

Customer Load Shaping
Hourly Profiles



Recent GTMax Model Result

Pre-schedules Results

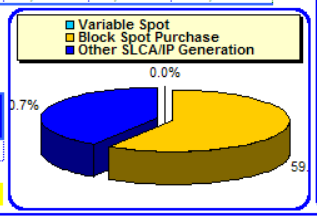
3rd GTMax Simulation
SLCA/IP Dispatch

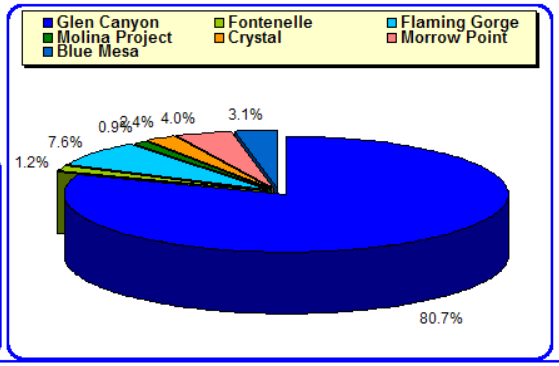
SLCA/IP Weekly Hydro Generation (MWh)							Total Generation (MWh)
Glen Canyon	Fontenelle	Flaming Gorge	Molina Project	Crystal	Morrow Point	Blue Mesa	
61,450.3	939.0	5,815.8	712.5	1,797.0	3,051.4	2,396.2	76,162.2
% 417.69	6.38	39.53	4.84	12.21	20.74	16.29	
w/Loss 56,042.7	887.4	5,495.9	673.3	1,698.1	2,883.5	2,264.4	69,945.4

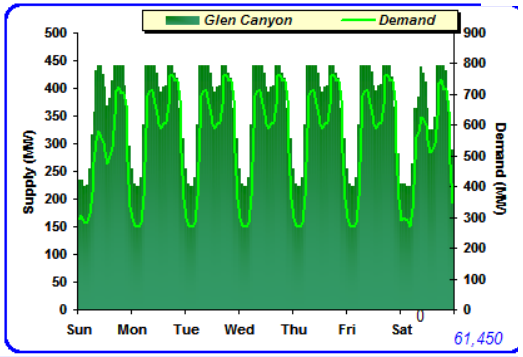
Variable Spot	Block Spot Purchase	Other SLCA/IP Generation	Total Supply
0.0	21,436.0	14,711.8	97,598
	w/Loss 13,902.7		

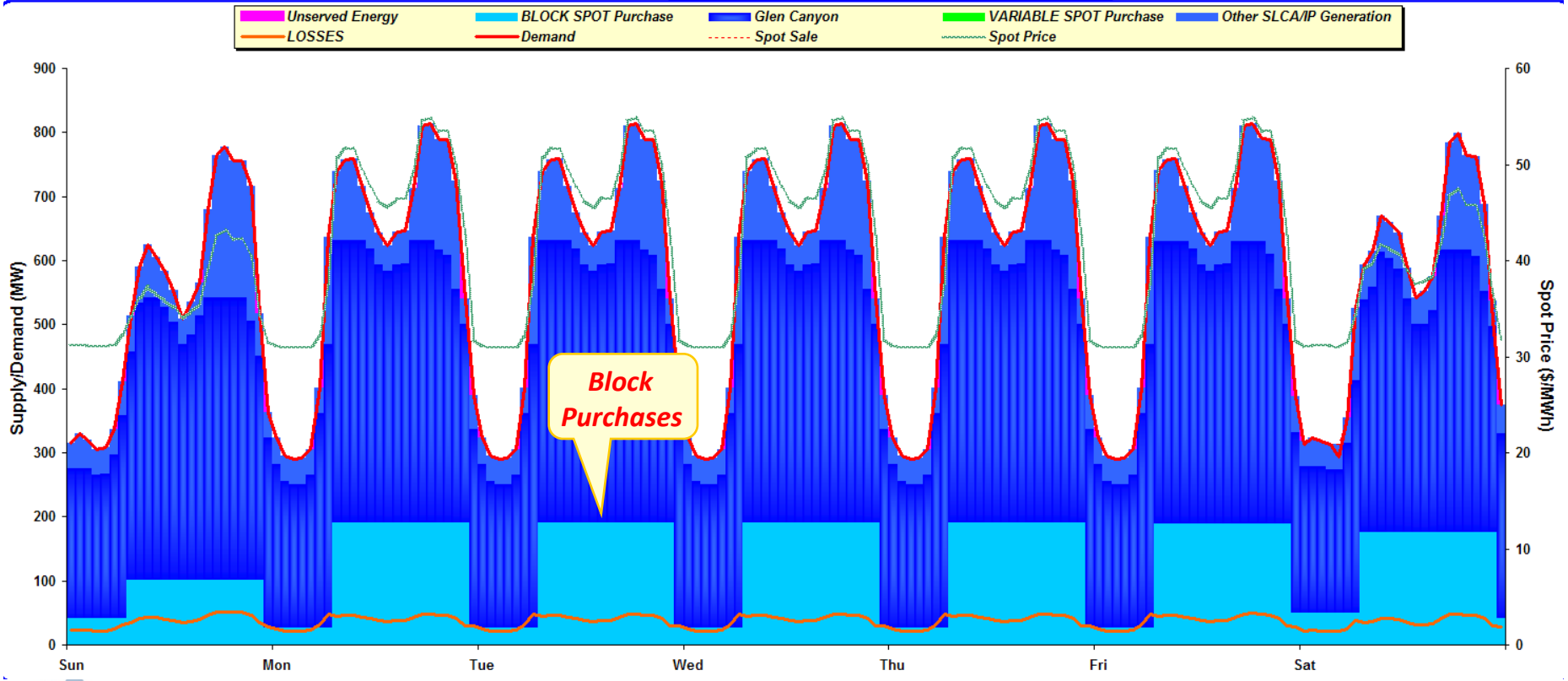
Total Load	Spot Sales	Losses	Unserved Load	Total Demand
91,321	60.5	6,216.8	0.0	97,598
Check	-21,375.4	6,216.8		

Week: Nov Plant: Glen Canyon



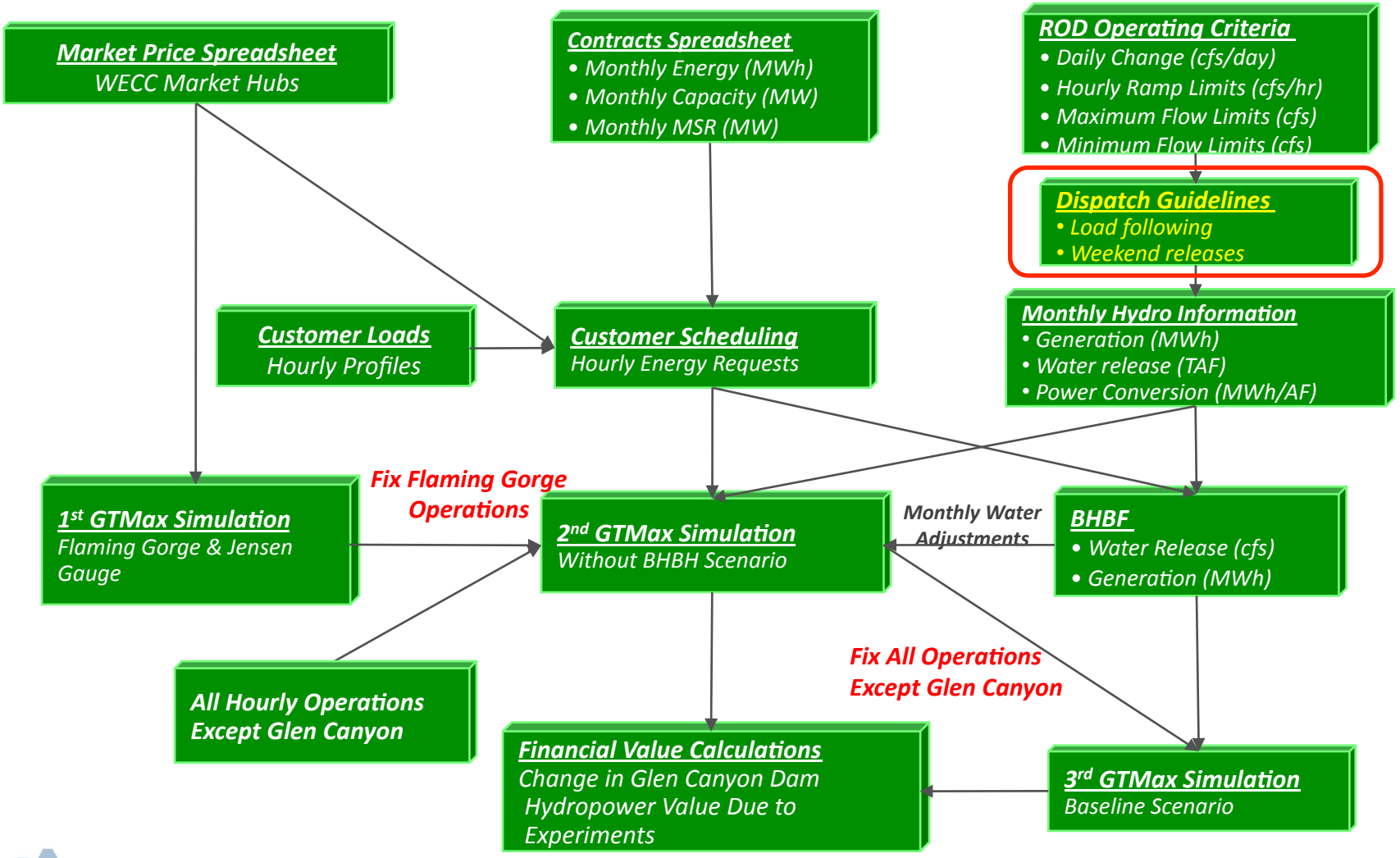






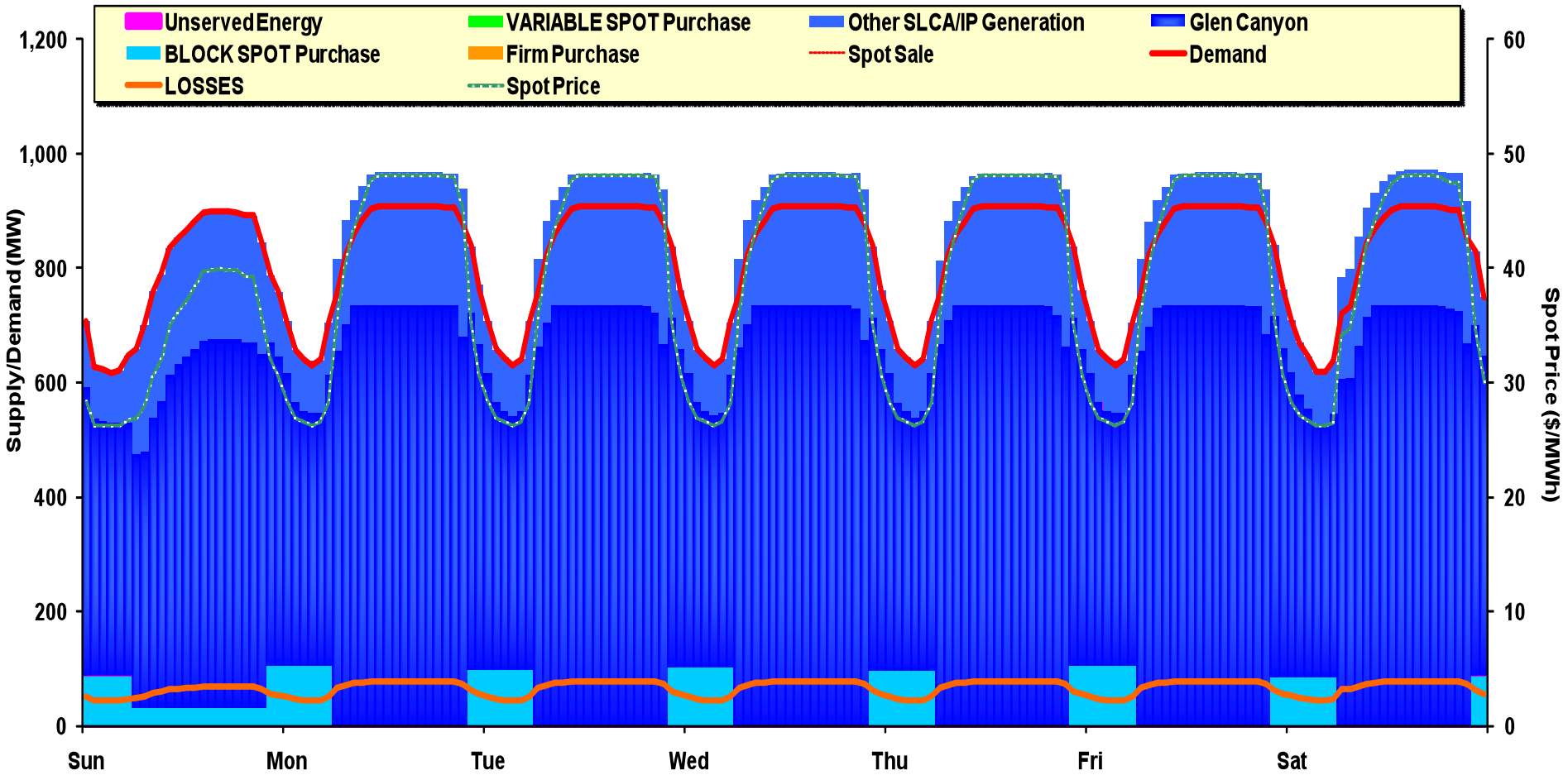
Model Assumptions Matter

Alternatives: Freezing All but Glen Results
Optimize Economics or Realistic Operations



GTMax Model Result

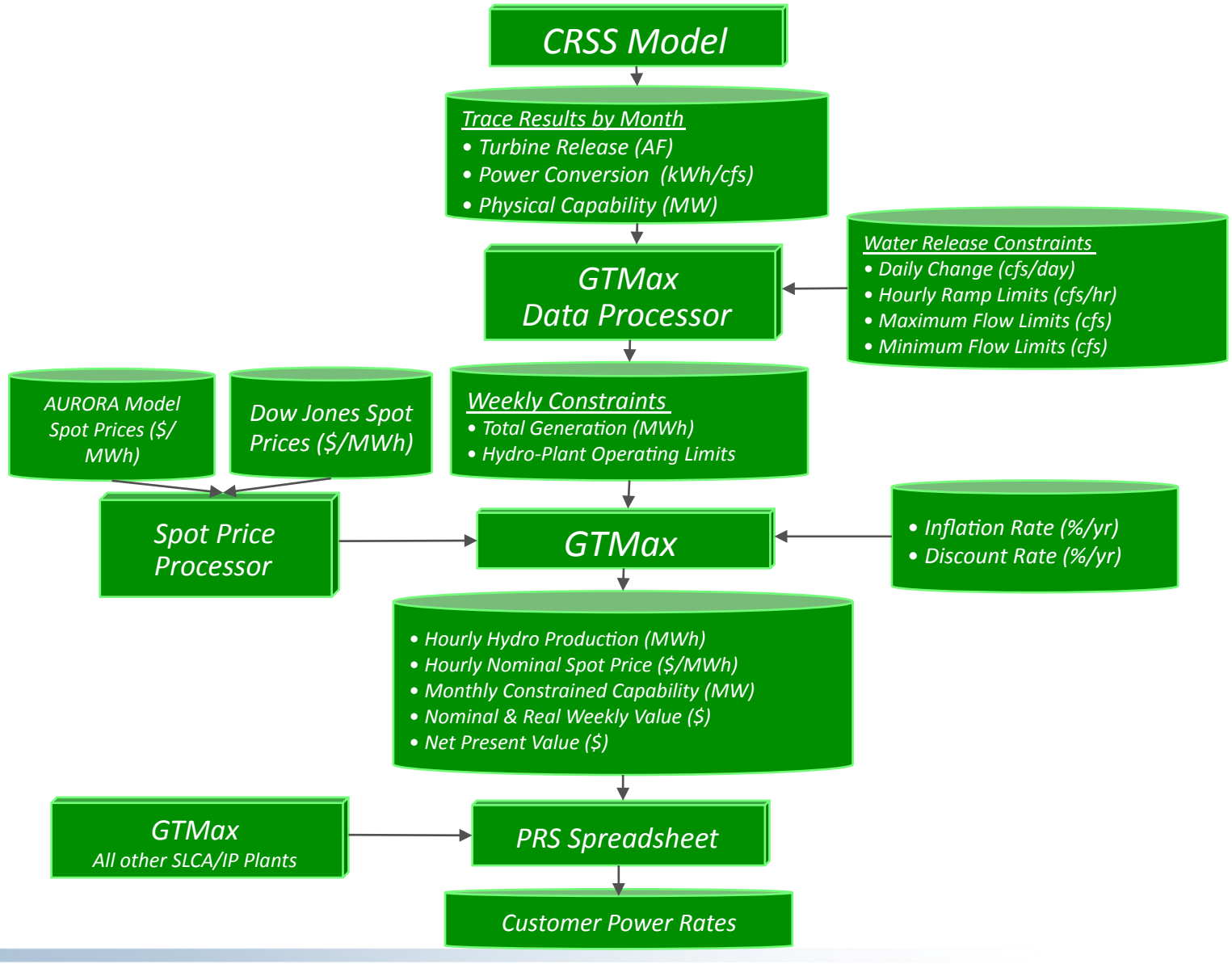
Allow Off-Peak Block Purchases for On-Peak Sales



These Results Are Very Different from Ones that Require Strict Load Following

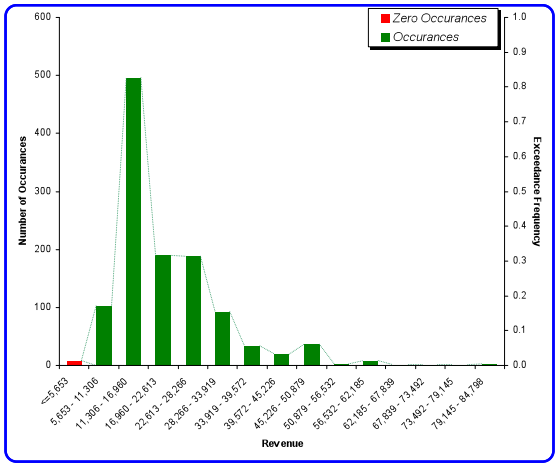
No One Modeling Process Solves Every Problem

Future Projections - Shortage Criteria Power Economics Modeling Process

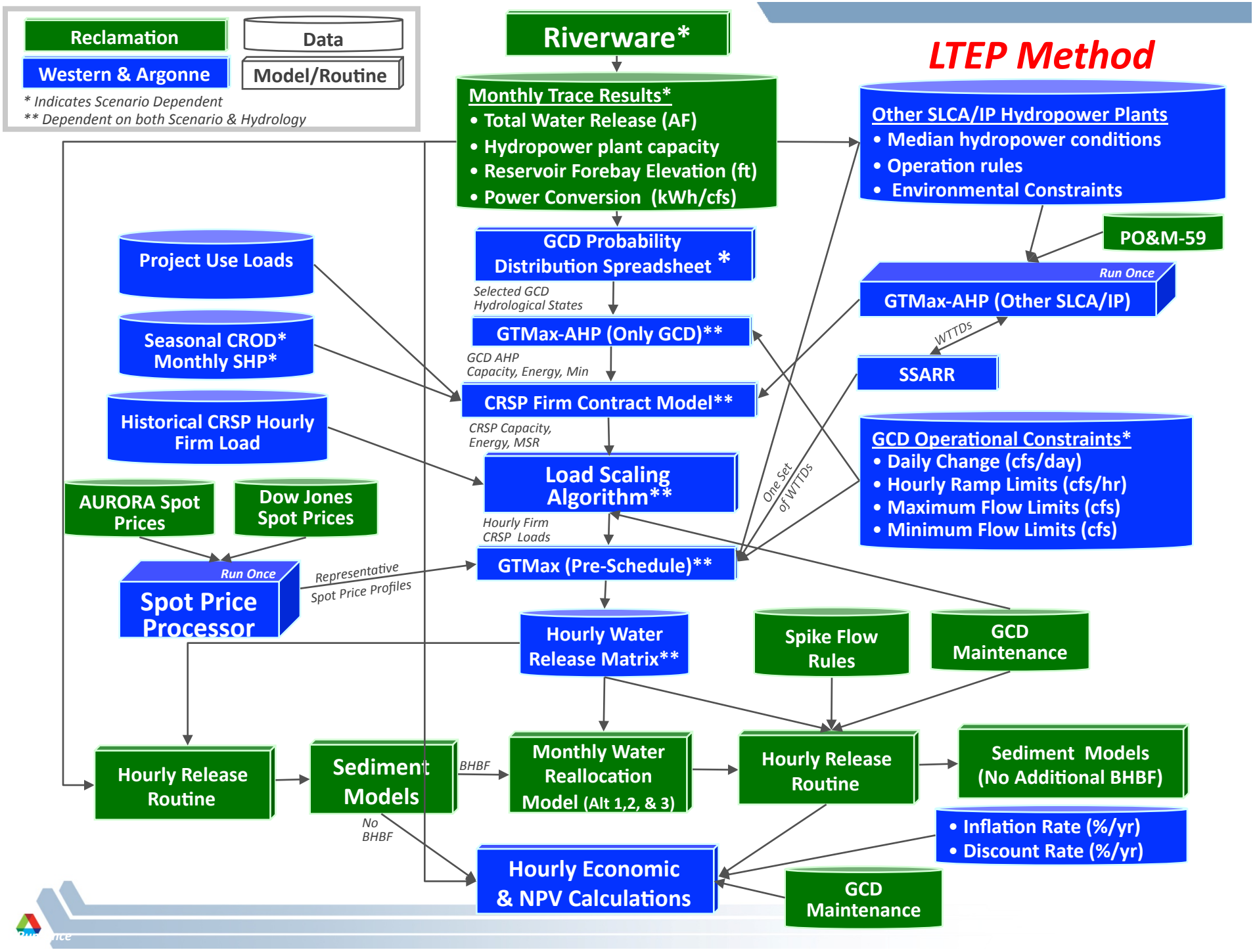


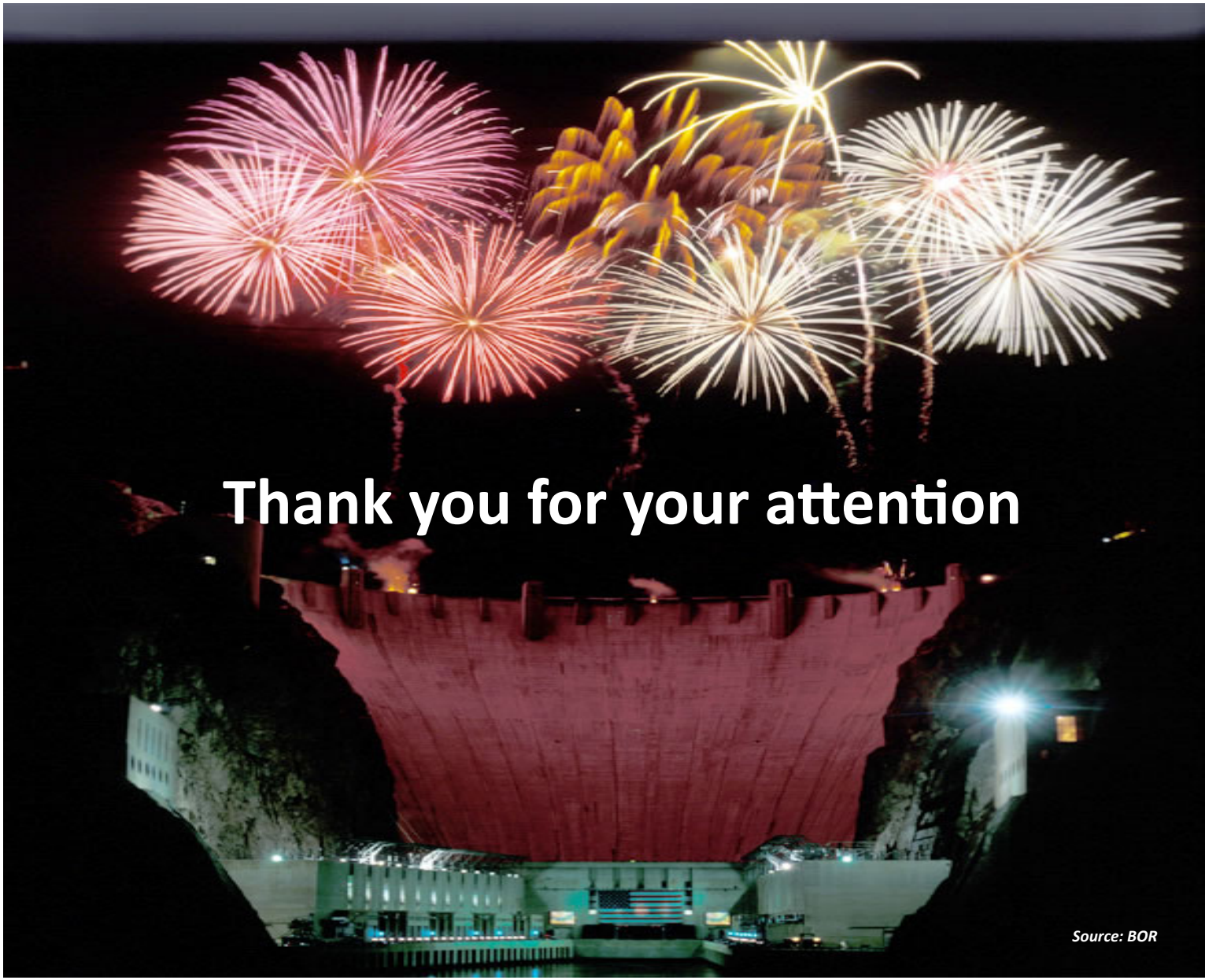
GTMax-Lite Revenue Risk Assessment

No Action Alternative in 2020



Monthly Revenue (1000's $)			
Month	Average of All Traces	CRSS Average Hydropower	Over Estimate
Jan	20,121.4	20,128.8	7.4
Feb	16,984.3	17,032.1	47.8
Mar	14,511.9	14,514.3	2.4
Apr	15,979.1	15,986.5	7.4
May	17,077.7	17,085.5	7.7
Jun	19,472.2	19,487.2	15.0
Jul	39,543.1	39,675.7	132.6
Aug	32,308.5	32,480.4	171.8
Sep	15,109.4	15,213.5	104.1
Oct	13,864.0	13,859.0	-5.0
Nov	16,632.7	16,628.8	-3.9
Dec	24,843.3	24,774.6	-68.8
Annual	246,447.6	246,866.3	34.9


Reclamation
Western & Argonne
Data
Model/Routine
* Indicates Scenario Dependent
** Dependent on both Scenario & Hydrology
LTEP Method
Riverware*
Monthly Trace Results*
• Total Water Release (AF)
• Hydropower plant capacity
• Reservoir Forebay Elevation (ft)
• Power Conversion (kWh/cfs)
Other SLCA/IP Hydropower Plants
• Median hydropower conditions
• Operation rules
• Environmental Constraints
PO&M-59
Project Use Loads
GCD Probability Distribution Spreadsheet *
Selected GCD Hydrological States
Run Once
GTMax-AHP (Other SLCA/IP)
WTTDs
Seasonal CROD*
Monthly SHP*
GTMax-AHP (Only GCD)**
GCD AHP Capacity, Energy, Min
SSARR
Historical CRSP Hourly Firm Load
CRSP Firm Contract Model**
CRSP Capacity, Energy, MSR
GCD Operational Constraints*
• Daily Change (cfs/day)
• Hourly Ramp Limits (cfs/hr)
• Maximum Flow Limits (cfs)
• Minimum Flow Limits (cfs)
Load Scaling Algorithm**
One Set of WTTDs
AURORA Spot Prices
Dow Jones Spot Prices
Hourly Firm CRSP Loads
GTMax (Pre-Schedule)**
Run Once
Spot Price Processor
Representative Spot Price Profiles
Hourly Water Release Matrix**
Spike Flow Rules
GCD Maintenance
Hourly Release Routine
Sediment Models
BHBF
Monthly Water Reallocation Model (Alt 1,2, & 3)
Hourly Release Routine
Sediment Models (No Additional BHBF)
No BHBF
• Inflation Rate (%/yr)
• Discount Rate (%/yr)
Hourly Economic & NPV Calculations
GCD Maintenance


Thank you for your attention
Source: BOR