RECLANATION Managing Water in the West

Colorado River Basin Operational Model Development

RiverWare User Group Meeting February 11, 2009



U.S. Department of the Interior Bureau of Reclamation

Colorado River Basin Operational Model Development

- Davis Parker Hourly Model
- 24-Month Study Expanded Model
 - Lower Basin
 Enhancements
 - Upper Basin
 Enhancements
- 24-Month Study Probabilistic Model

Colorado River Basin



Lake Mead



Lake Mohave

Davis Dam

Hoover Dam

Lake Havasu

Parker Dam

Lower Basin Colorado River Reservoir Management

- Parker and Davis Dams
 - Set daily releases to meet water demands
 - Set hourly releases within the day to meet peak power demands while still meeting daily water demands

Hoover Dam

 Set monthly release, convert to energy, and provide to Western Area Power Administration

Davis-Parker Hourly Model Aka: The New MSU

- Use RiverWare's new Unit Power Method to replace outdated spreadsheet model
- Better utilize HDB by transferring and storing data with Database DMI
- Provide increased security for Continuity of Operations emergency plan
- Use RPL to verify guidelines for operating units have been met and to move between hourly and daily timeslots within the same model

MSU (Lotus 123)

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1	-1	27	0	0	447.02	366.77	80.25	4.94	7	26	1	CUR		19		
2	-1	15	0	0	447.01	366.27	80.74	3.18	7	15	2	CUR		8		
3	-1	8	0	0	447.10	365.82	81.28	2.05	- 7	7	3	CUR		0		
4	-1	8	0	0	447.12	364.95	82.17	2.05	7	7	4	CUR		. 0		
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12	27	27	0	0	447.12	368.79	78.33	9.80	54	0	12	CUB		0		
13	27	27	0	0	447.12	368.79	78.33	9.80	54	0	13	CUR		0		
14	27	27	0	0	447.12	368.79	78.33	9.80	54	0	14	CUR		0		
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18	27	27	8	0	447.12	369.81	77.31	12.29	62	0	18	CUR		0		
19	27	27	8	0	447.12	369.81	77.31	12.29	62	0	19	CUR		0		
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Davis-Parker Model (RiverWare)

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imestep		Davis Dam Unit 1 Generation MWH	Davis Dam Unit 2 Generation MWH	Davis Dam Unit 3 Generation MWH	Davis Dam Unit 4 Generation MWH	Davis Dam Unit 5 Generation MWH	Davis Dam Total Generation MWH	Lake Mohave Pool Elevation ft	Davis Dam Release cfs
0/18 18:00	Sun	-1.00	-1.00	48.00	-1.00	48.00	93.00	633.67	9707
/18 19:00	Sun	-1.00	-1.00	48.00	-1.00	48.00	93.00	633.67	9707
/18 20:00	Sun	-1.00	-1.00	48.00	-1.00	48.00	93.00	633.67	9707
/18 21:00	Sun	-1.00	-1.00	48.00	-1.00	48.00	93.00	633.67	9707
)/18 22:00	Sun	-1.00	-1.00	48.00	-1.00	-1.00	44.00	633.67	4737
0/18 23:00	Sun	-1.00	-1.00	48.00	-1.00	-1.00	44.00	633.67	4737
0/18 24:00	Sun	-1.00	-1.00	48.00	-1.00	-1.00	44.00	633.67	4737
0/19 1:00	Mon	-1.00	-1.00	48.00	-1.00	-1.00	NaN	633.65	NaN
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0/19 5:00	Mon	-1.00	-1.00	48.00	-1.00	-1.00	NaN	633.65	NaN
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0/19 22:00	Mon	-1.00	-1.00	48.00	-1.00	-1.00	NaN	633.65	NaN
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1	0/18 22:00	Sun		-1.00	-1.00	48.00	-1.00	-1.00	44.00	633.67	4737			
1	0/18 23:00	Sun		-1.00	-1.00	48.00	-1.00	-1.00	44.00	633.67	4737			
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1	0/19 12:00	Mon		-1.00	48.00	48.00	-1.00	48.00	NaN	633.65	NaN			
1	0/19 13:00	Mon	11	-1.00	48.00	48.00	-1.00	48.00	NaN	633.65	NaN			
1	0/19 14:00	Mon		-1.00	48.00	48.00	-1.00	48.00	NaN	633.65	NaN			
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1	0/19 16:00	Mon		-1.00	48.00	48.00	-1.00	48.00	NaN	633.65	NaN			
1	0/19 17:00	Mon	11	-1.00	-1.00	48.00	-1.00	48.00	NaN	633.65	NaN			
1	0/19 18:00	Mon		-1.00	-1.00	48.00	-1.00	48.00	NaN	633.65	NaN			
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1	0/19 22:00	Mon		-1.00	-1.00	48.00	-1.00	-1.00	NaN	633.65	NaN			
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LakeMohaveDavisDam.Outflow [@ 10/17 21:00] -- Volume: 34.931335 [1,000,000 ft3]

1 value: 9703 [cfs]

ClakeMohaveDavisDam.Unit Power Table

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Value: 122

	Unit 1 Head ft	Unit 1 Flow cfs	Unit 1 Power MW	Unit 2 Head ft	Unit 2 Flow cfs	Unit 2 Power MW	Unit 3 Head ft	Unit 3 Flow cfs	Unit 3 Power MW	Unit 4 Head ft	Unit 4 Flow cfs	Unit 4 Power MW	Unit 5 Head ft	Unit 5 Flow cfs	Unit 5 Power MW
D	122.0	0	0	122.0	0	0	122.0	0	0	122.0	0	0	122.0	0	0
1	122.0	828	1	122.0	828	1	122.0	828	1	122.0	828	1	122.0	828	1
2	122.0	865	2	122.0	865	2	122.0	865	2	122.0	865	2	122.0	865	2
3	122.0	924	3	122.0	924	3	122.0	924	3	122.0	924	3	122.0	924	3
4	122.0	997	4	122.0	997	4	122.0	997	4	122.0	997	-4	122.0	997	4
5	122.0	1080	5	122.0	1080	5	122.0	1080	5	122.0	1080	5	122.0	1080	5
5	122.0	1169	6	122.0	1169	6	122.0	1169	6	122.0	1169	6	122.0	1169	6
7	122.0	1262	7	122.0	1262	7	122.0	1262	7	122.0	1262	7	122.0	1262	7
8	122.0	1358	8	122.0	1358	8	122.0	1358	8	122.0	1358	8	122.0	1358	8
9	122.0	1454	9	122.0	1454	9	122.0	1454	9	122.0	1454	9	122.0	1454	9
10	122.0	1551	10	122.0	1551	10	122.0	1551	10	122.0	1551	10	122.0	1551	10
11	122.0	1647	11	122.0	1647	11	122.0	1647	11	122.0	1647	11	122.0	1647	11
12	122.0	1742	12	122.0	1742	12	122.0	1742	12	122.0	1742	12	122.0	1742	12
13	122.0	1837	13	122.0	1837	13	122.0	1837	13	122.0	1837	13	122.0	1837	13
14	122.0	1931	14	122.0	1931	14	122.0	1931	14	122.0	1931	14	122.0	1931	14
15	122.0	2024	15	122.0	2024	15	122.0	2024	15	122.0	2024	15	122.0	2024	15
16	122.0	2116	16	122.0	2116	16	122.0	2116	16	122.0	2116	16	122.0	2116	16
17	122.0	2207	17	122.0	2207	17	122.0	2207	17	122.0	2207	17	122.0	2207	17
18	122.0	2297	18	122.0	2297	18	122.0	2297	18	122.0	2297	18	122.0	2297	18
19	122.0	2387	19	122.0	2387	19	122.0	2387	19	122.0	2387	19	122.0	2387	19
20	122.0	2476	20	122.0	2476	20	122.0	2476	20	122.0	2476	20	122.0	2476	20
21	122.0	2564	21	122.0	2564	21	122.0	2564	21	122.0	2564	21	122.0	2564	21
22	122.0	2653	22	122.0	2653	22	122.0	2653	22	122.0	2653	22	122.0	2653	22
23	122.0	2741	23	122.0	2741	23	122.0	2741	23	122.0	2741	23	122.0	2741	23
24	122.0	2830	24	122.0	2830	24	122.0	2830	24	122.0	2830	24	122.0	2830	24
25	122.0	2918	25	122.0	2918	25	122.0	2918	25	122.0	2918	25	122.0	2918	25
26	122.0	3007	26	122.0	3007	26	122.0	3007	26	122.0	3007	26	122.0	3007	26

	Hailwater Table	
	Outflow cfs	TW Elevation ft
0:0	0	495.90
1:1	11	495.91
2: 2	29	495.92
3: 3	47	495.93
4: 4	66	495.94
5: 5	84	495.95
6: 6	102	495.96
7:7	120	495.97
8:8	139	495.98

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Timestep		Parker Dam Unit 1 Generation MWH	Parker Dam Unit 2 Generation MWH	Parker Dam Unit 3 Generation MWH	Parker Dam Unit 4 Generation MWH	Parker Dam Total Generation MWH	Lake Havasu Pool Elevation ft	Parker Dam Release cfs
2/17 24:00	Thu	-0.78	0.00	7.61	0.00	6.83	447.40	1827
2/18 1:00	Fri	-0.72	0.00	7.61	0.00	6.89	447.33	1827
2/18 2:00	Fri	-0.72	0.00	26.06	0.00	25.33	447.38	4610
2/18 3:00	Fri	-0.78	0.00	22.50	0.00	21.72	447.39	3969
2/18 4:00	Fri	-0.72	0.00	27.56	0.00	26.83	447.40	4743
12/18 5:00	Fri	-0.72	0.00	28.00	0.00	27.28	447.38	4767
12/18 6:00	Fri	-0.72	0.00	27.39	0.00	26.67	447.42	4683
2/18 7:00	Fri	-0.78	0.00	27.50	0.00	26.72	447.42	4683
12/18 8:00	Fri	-0.72	0.00	27.61	0.00	26.89	447.40	4731
12/18 9:00	Fri	-0.72	0.00	27.28	0.00	26.56	447.42	4671
12/18 10:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
12/18 11:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
12/18 12:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
12/18 13:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
12/18 14:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
2/18 15:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
12/18 16:00	Fri	-1.00	0.00	27.00	0.00	26.00	447,42	4652
12/18 17:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
12/18 18:00	Fri	-1.00	0.00	27.00	0.00	26.00	447.42	4652
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Davis-Parker Report Output

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24-Month Study Model

- Monthly timestep model
 - Projects reservoir elevations, releases 24 30 months into the future throughout basin
- Deterministic model
- Coordination between Upper Colorado and Lower Colorado regions
- Run once a month



24-Month Study Expanded Model Goals of LC Enhancements

- Move functions that calculate Parker Dam releases into RiverWare
- Explicitly account for all Lower Basin water users in RiverWare
- Improve HDB data access and storage
- Automate key policies using RPL
- Forecast Lower Basin operations when Shortage is projected in out-years

24-Month Study Expanded Model Benefits of LC Enhancements

- Increased transparency of data and modeling assumptions
- All data easily accessible and stored in HDB – One stop for all data!
- Reduction of potential user error

Parker Release Spreadsheet Model

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Parker Release Spreadsheet Model

Aggregates Monthly Parker Releases

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RECLAMA

24-Month Study Expanded Model LC Enhancements

- Schedules and actual use data for all water users transferred between RiverWare and HDB
- Use RPL to adjust schedules of lower priority users based on water use trends
- Calculate forecasted annual use by water user and compare to approved schedules

RECLAMATION

 Aggregate annual water use by state and compare to adjusted state apportionments

24-Month Study Expanded Model LC Enhancements

- Use RPL to automate schedule changes if Shortage is projected in future years
 - Initial schedules provided by LC Water Accounting Group
 - Reductions based on Interim Guidelines criteria and shortage schedules provided by Arizona

RECLAMATION

 Lake Mohave and Lake Havasu evaporation, diversion, and side inflow modeled separately
 Previous model lumped these into gainloss value

Expanded 24-Month Study Model





Upper Basin Enhancements to 24-Month Study

Powell Evaporation method

 The issue: Evaporation was computed differently in the 24-Month Study model (future) and in Reclamation's Hydrologic Database (HDB) (observed/past)

Past	Future		
Computed in Hydrologic	Projected in 24-Month		
Database (HDB)	Study Model		

Powell Evaporation: the issue

• Evaporation = *f* (reservoir surface area)



- <u>HDB Method</u>: monthly coefficients for each of four different locations in the reservoir
- <u>24-Month Method</u>: single monthly coefficient for entire reservoir
- Resulted in modeled evap not matching observed even if all other inputs were the same RECLAMATION

Powell Evaporation: the solution

- Keep past and future methodologies consistent!
- Periodic net evaporation method in RiverWare
- Model results greatly improved





- 24-Month Study currently a deterministic model
 - Upper Basin driven by most probable inflow forecast
 - Lower Basin driven by scheduled demands
- Jan, Apr, Aug, Oct, inflow scenarios: min(10th), most (50th), max (90th)
 - This provides a range of possible operations, <u>but</u> the max inflow scenario does not translate to the max probable elevation



- Need to better quantify range of possible operations in the Colorado River Basin
 - Better asses risk and uncertainty
 - e.g., probability of Lake Mead being below key elevation on July 4th weekend
 - Stakeholders need this now more than ever
- Currently developing model to produce probabilistic output



- Inflow is greatest source of uncertainty
- Model input is range of probable inflows

 CBRFC's ESP forecasts will drive first and second years of model
 - Ongoing research to develop forecasting techniques for beyond 2 years (CADSWES grad student work)
 - 2-10 year range



RECLAMATIC

- Currently, UC operators manually input operations (releases) into the model
 - Probabilistic nature requires rules to drive the simulation
- CADSWES grad student working w/ UC operators to develop UB rules
 - Fontenelle done
 - Working on Flaming Gorge



RECLAMAT

- Model currently uses "unregulated inflow" forecasts
 - Depletions are implicit in the forecast
- Want to move to "natural inflow"
 - ESP forecast is natural flow
 - Can explicitly model demands



Implementation Timeframes

LC Expanded Water Users

- January 2010
- Provides stakeholders an opportunity to review prior to April 24-Month Study
- Updated Lake Powell Evaporation Method

 February 2010
- Probabilistic Model with RPL of UC Reservoir Operations

 January 2011



Questions?