THDC India Ltd.

International Conference on
HYDROPOWER AND DAMS DEVELOPMENT FOR WATER AND ENERGY SECURITY – UNDER CHANGING CLIMATE

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Two ways to benefit from the use of Mathematical Optimization for Revising Reservoir Operating Rules - A Case Study of the Bargi and Tawa Reservoirs

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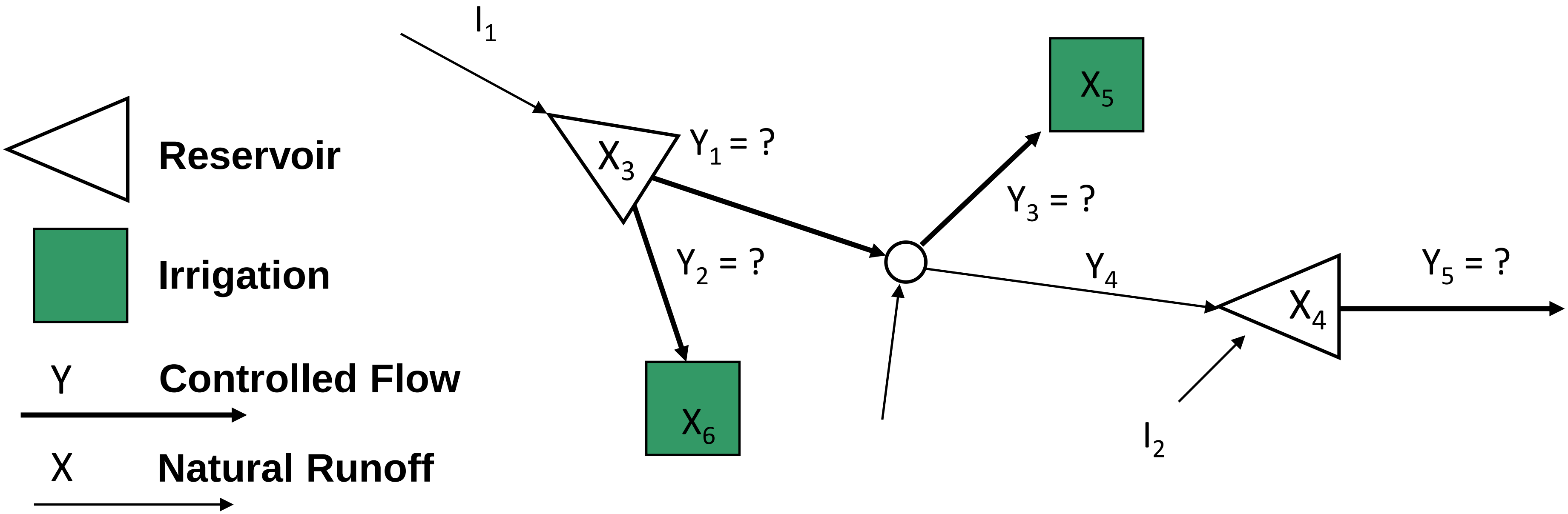
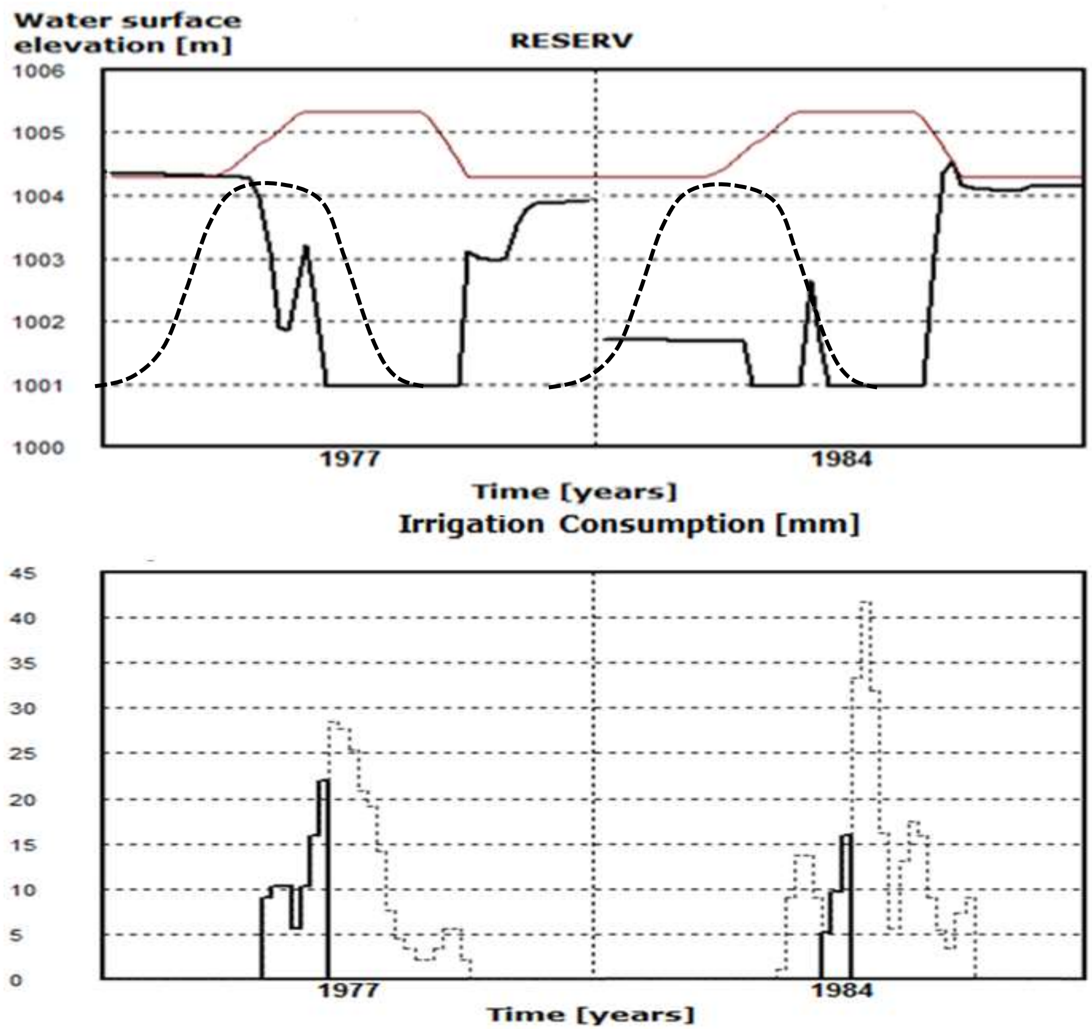
THE ULTIMATE GOAL OF MATHEMATICAL OPTIMIZATION

The use of mathematical optimization in reservoir operation together with artificial intelligence techniques and remote sensing for runoff forecasting will introduce the kind of revolution into water resources that driverless cars are introducing to transportation industry.



- Basin Management models focus on DECISION MAKING, which amounts to finding the best way to set reservoir releases and water abstractions from the river at water intake structures.

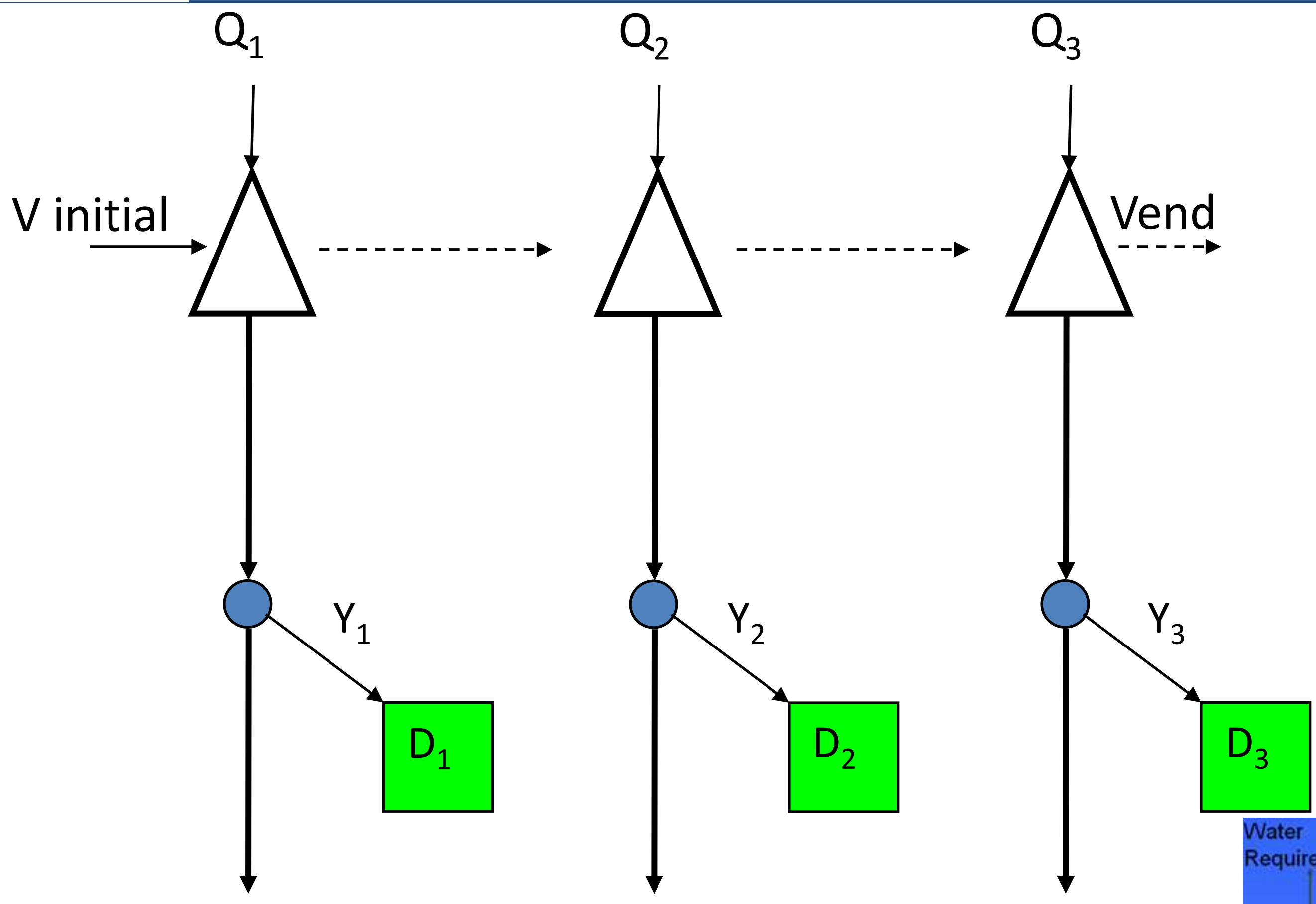
- Reservoir Releases are DEMAND DRIVEN.



Most models nowadays rely on the concept of "Reservoir Rule Curve" which was introduced to prevent reservoirs from premature emptying.

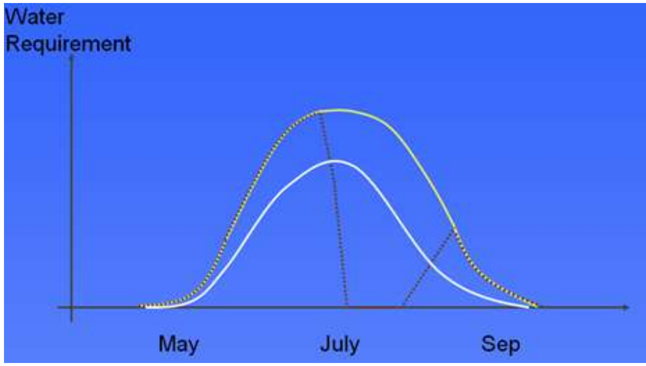
The problem associated with designing the shape of the rule curve is that its ideal shape is unique for each hydrologic year and it depends on the starting storage.

The best possible solution for each year that was requested by NCA cannot be guaranteed by relying on the rule curve concept.



Since the rule curve concept cannot deliver the best solution, an alternative is the MTO concept, which can be used to simultaneously optimize reservoir operation and demand reduction.

$$\frac{Y_t}{D_t} = \frac{Y_{t+1}}{D_{t+1}} \quad for\ t = 0, n-1$$

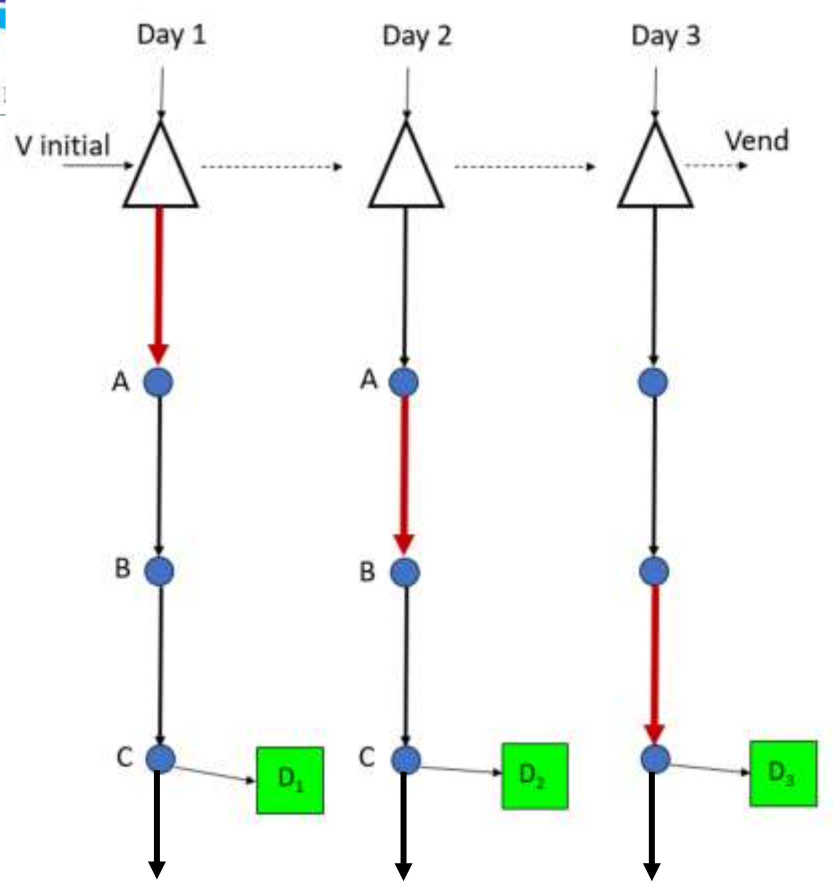


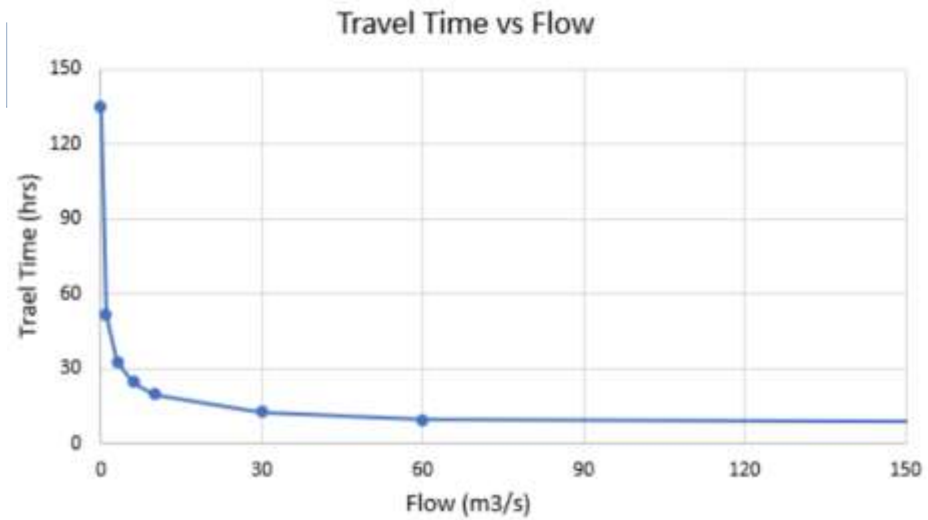
Basin Models with MTO capabilities

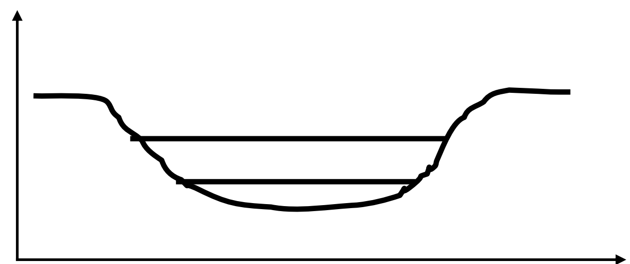
a) **RIVERWARE (CADSWES Institute, Colorado);**
b) **OASIS (Hydrologics Inc., USA)**
c) **HEC-ResPRM (only monthly time steps, network flow solver)**
d) **WEB.BM (Optimal Solutions Ltd., Canada)**

The first two models are offered through commercial license, while the other two are free. HEC is no longer providing a download link for HEC-ResPRM on their official web site.

Channel Routing within MTO framework



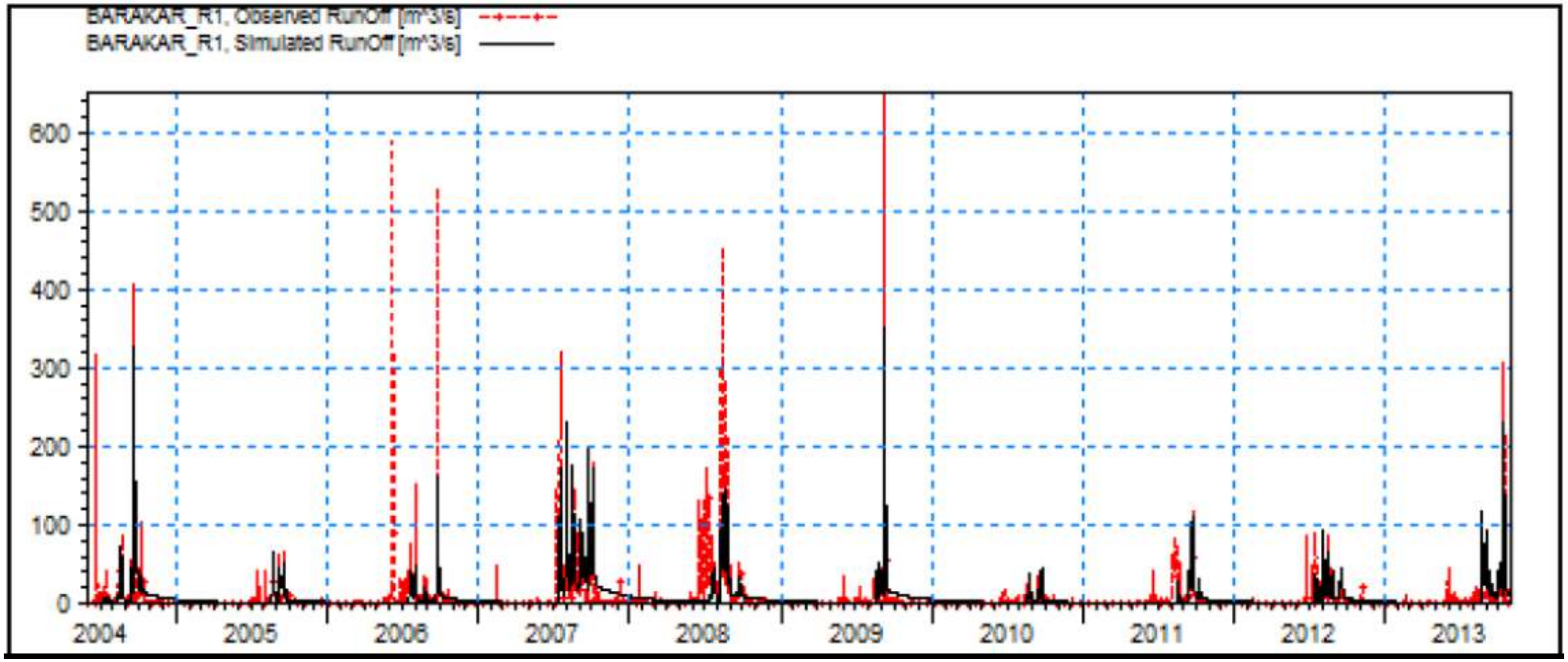


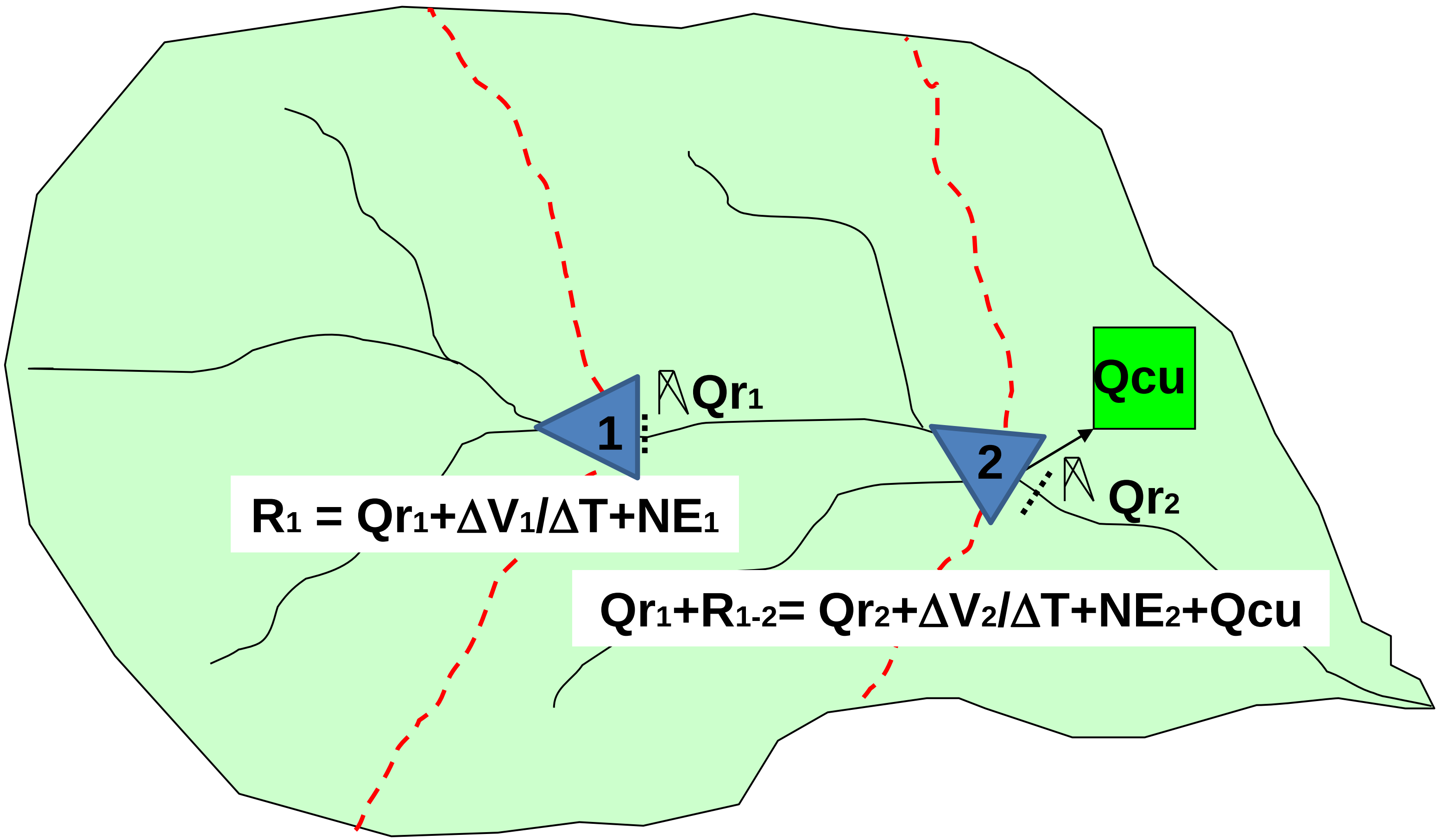


	3MAY	4MAY	5MAY	6MAY	7MAY	8MAY	9MAY
RES	943.488	941.826	941.829	941.922	942.019	942.194	942.336
R-A	22.310	305.164	32.320	22.310	21.970	21.810	21.420
A-B	26.914	135.325	162.166	67.864	40.192	29.781	25.470
B-c	30.420	65.843	131.357	118.539	72.665	48.660	36.195
C-	16.000	26.469	68.607	16.000	85.171	57.099	37.699
D1	15.000	15.000	15.000	100.000	15.000	15.000	15.000

Upper Narmada River Basin

a) Accuracy of input is important. The current practice is to use rainfall-runoff models to estimate natural flows, which leads to this:

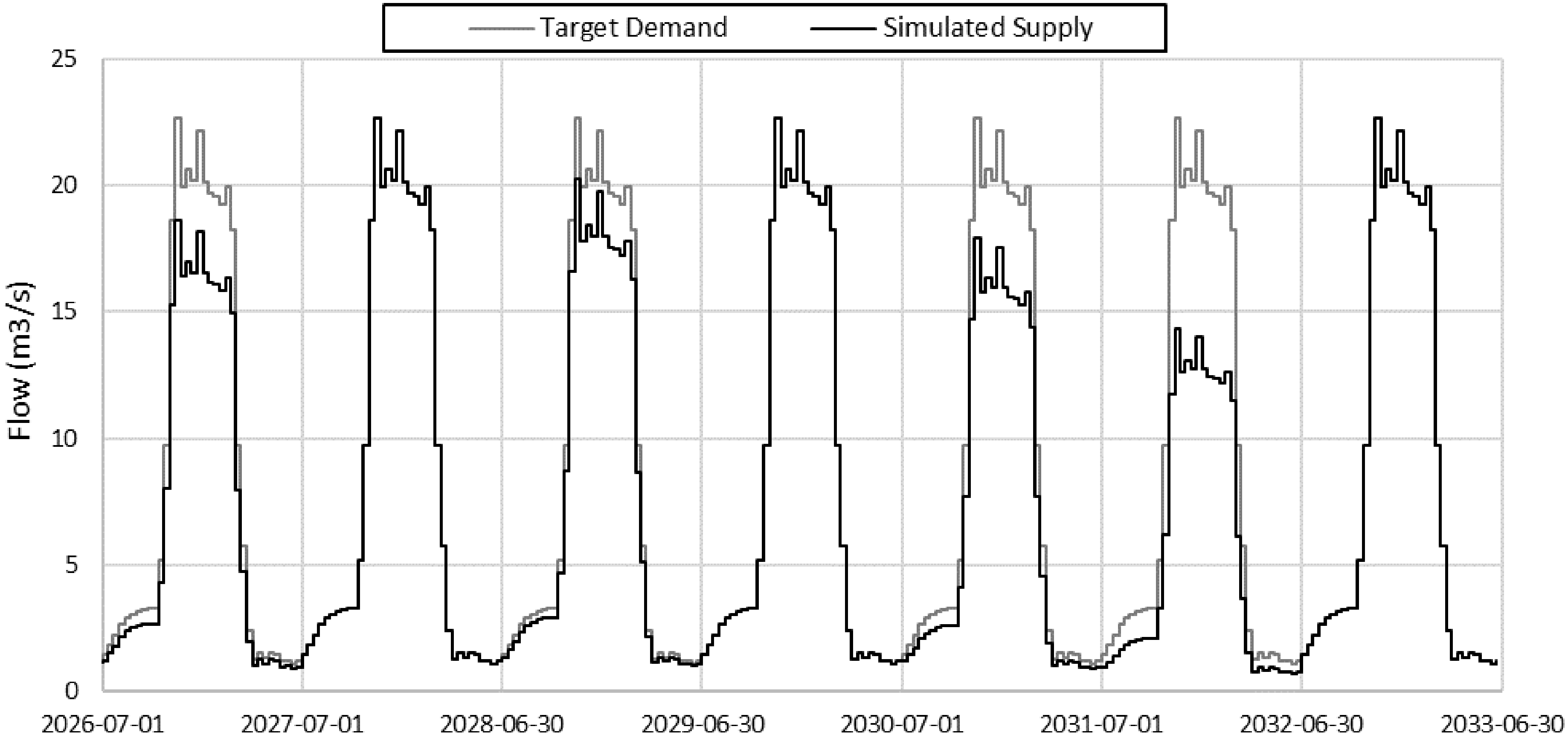




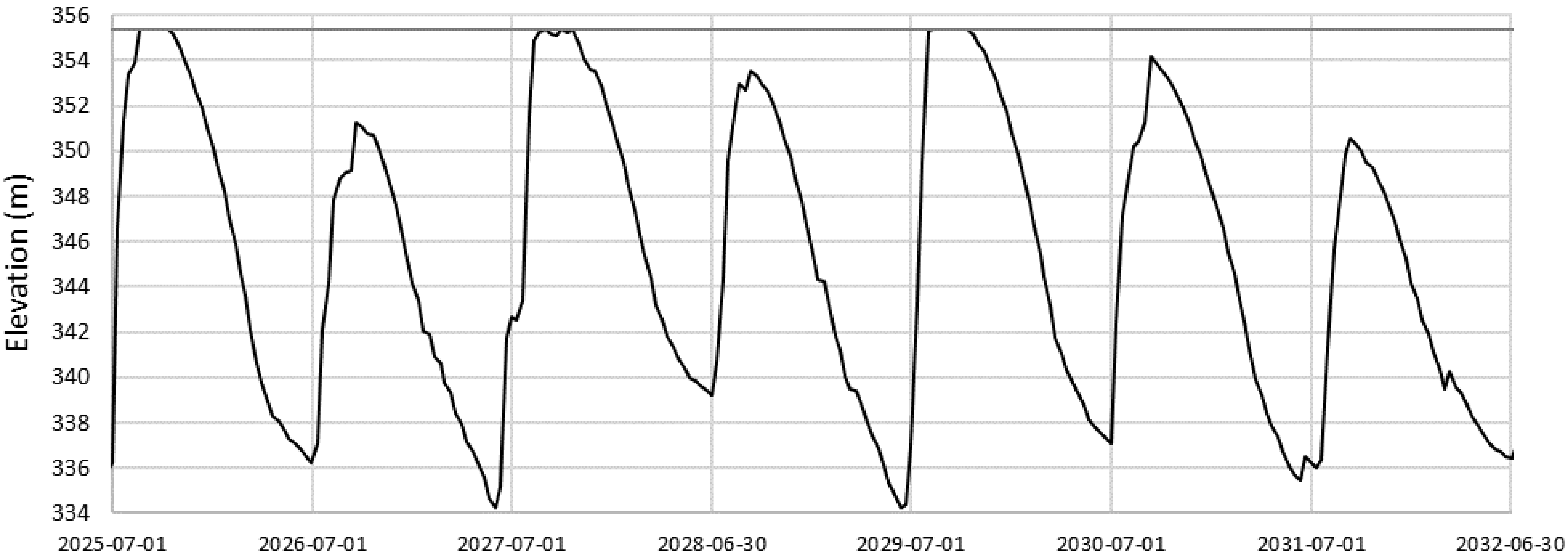
$$R_1 = Qr_1 + \Delta V_1/\Delta T + NE_1$$

$$Qr_1 + R_{1\text{-}2} = Qr_2 + \Delta V_2/\Delta T + NE_2 + Qcu$$

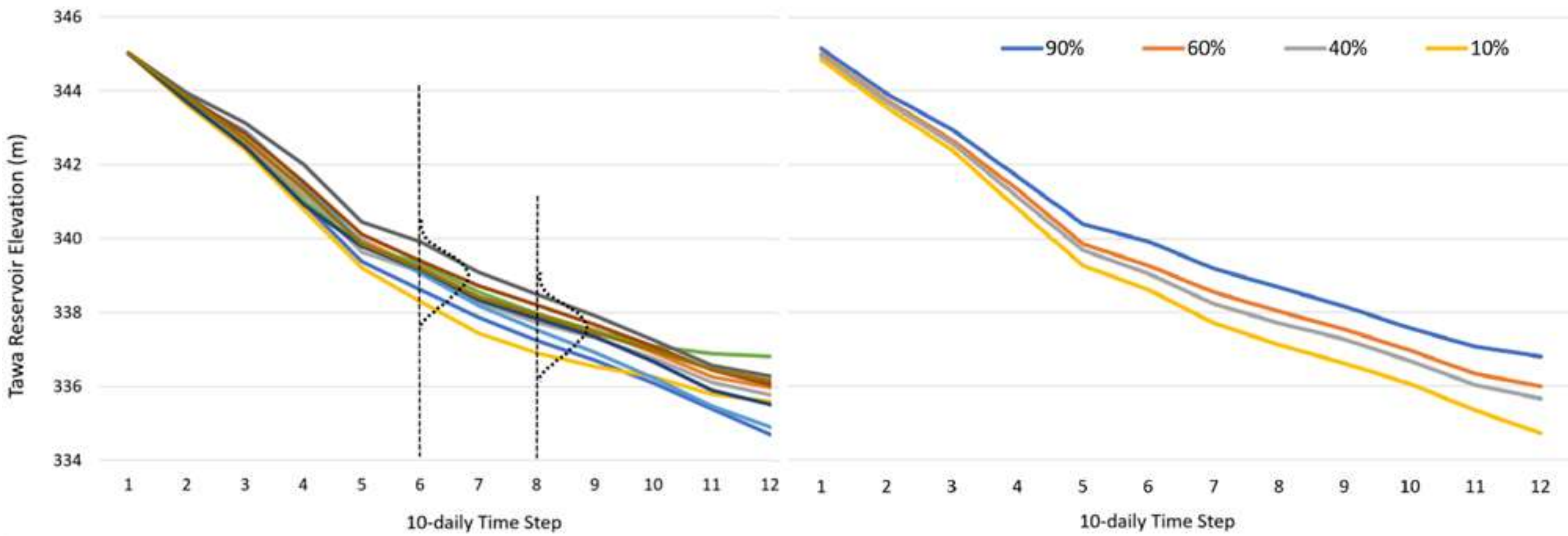
OPTIMIZATION RESULTS- TAWA RESERVOIR WATER SUPPLY



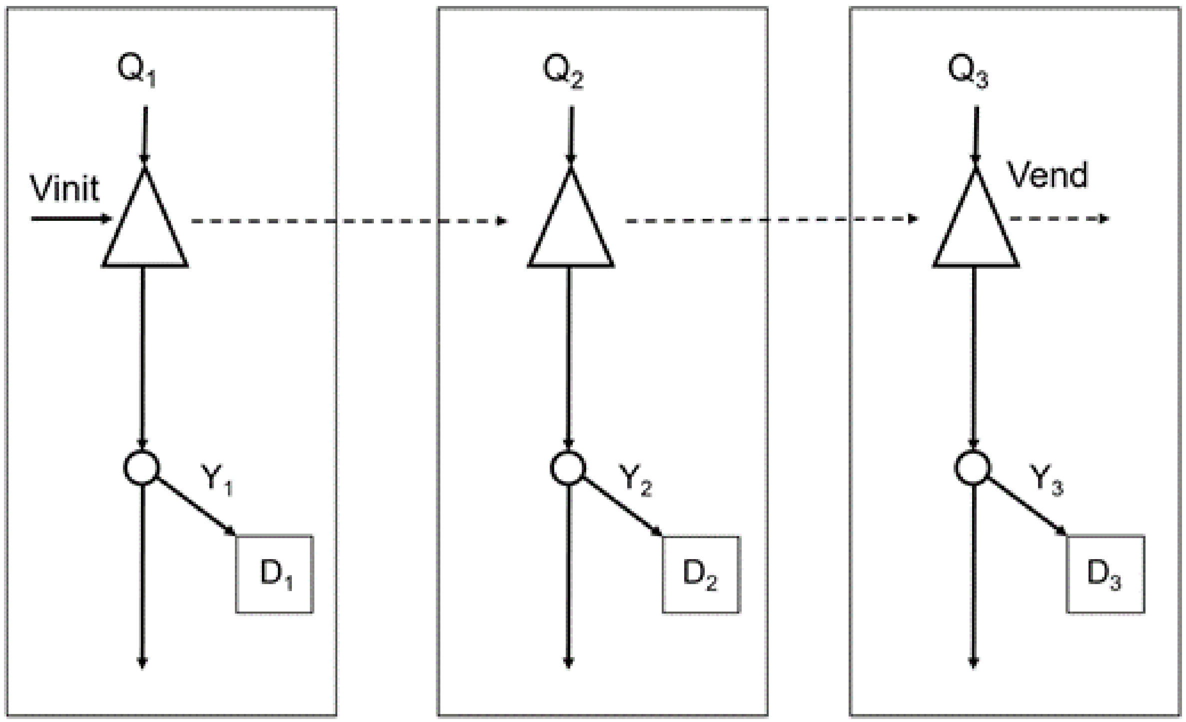
OPTIMIZATION RESULTS- TAWA RESERVOIR OPERATION



- Use historical natural flows as input into a stochastic hydrologic model to generate 1000 years of inflows
- Create 1000 years of perfect rule curves
- Analyze the solutions statistically



solution / weeks	1	2	3	4	5
1					
2					
3					



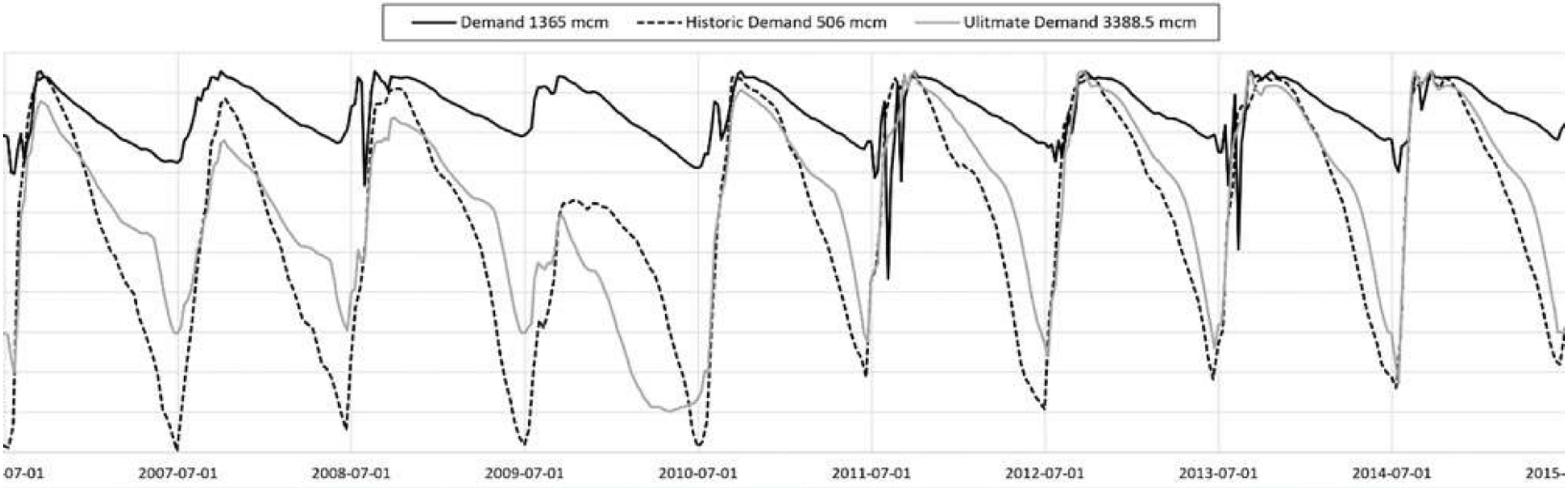


Table 1. Mean Annual Economic Benefits of Improved Reservoir Operation

	Mean Annual output		Monetary Benefits in millions of Rupees		
Scenario	Irrigation (MCM)	Power (GWh/MU)	Irrigation	Electricity	Total Value
1 (Historical)	506.0	379	1518	1326.5	2845
2 (Current)	1365.0	299	4095	1046.5	5142
3 (Ultimate)	3388.5	271	10166	948.5	11114

WEB.BM Solution Modes

- **STO with rule curves or reservoir zones**

- **STO/MTO combined for short term forecasts (seasonal option allows overwriting input data with current data from the field)**

solution / days	1	2	3	4	5	6	7	8	9
1									
2									
3									
4									
5									

- **MTO for one year at a time or for all years at once (used only for planning studies)**

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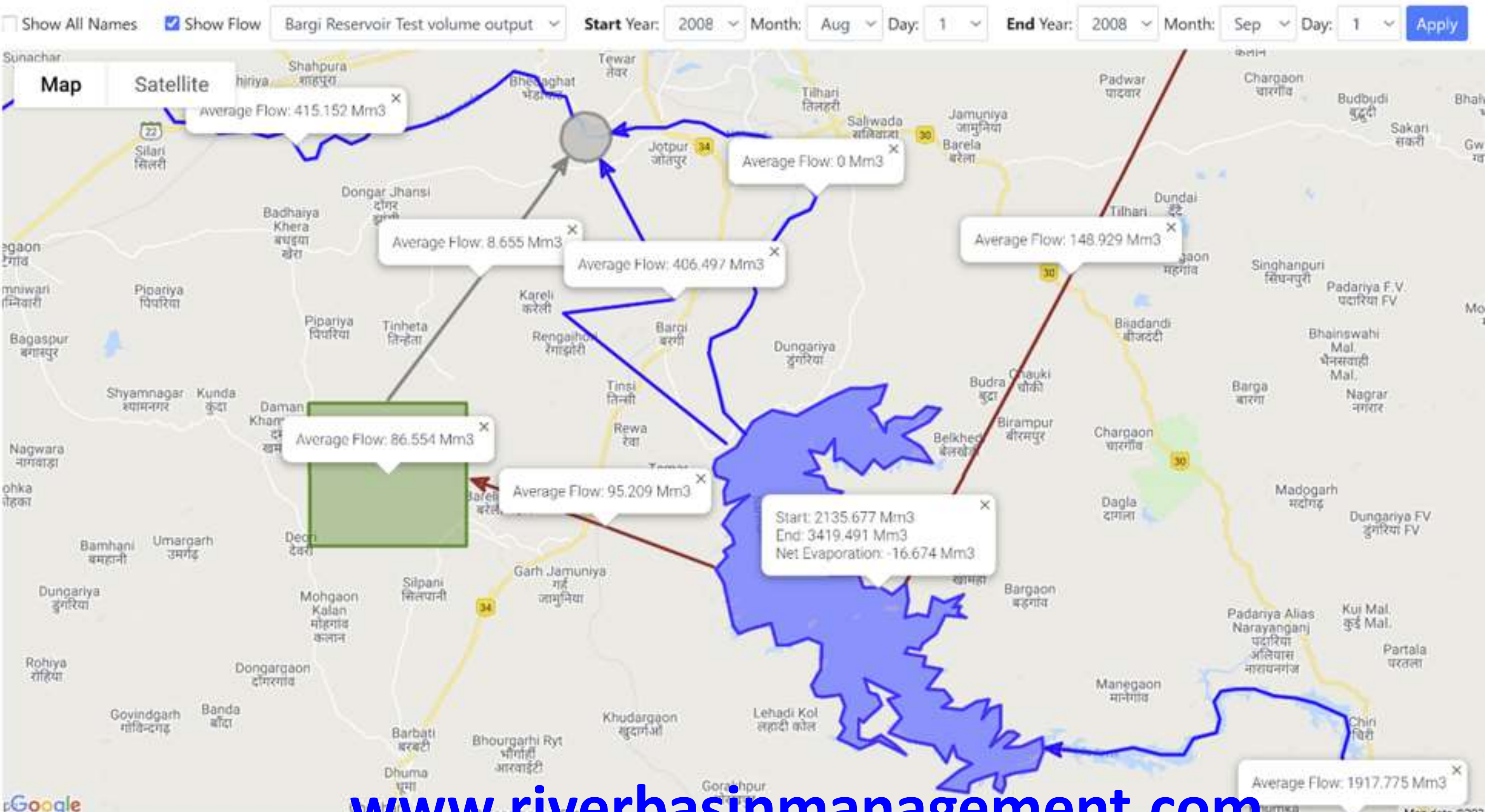

www.riverbasinmanagement.com
www.optimal-solutions-ltd.com

Main WEB.BM Features

- Web application LP-based River Basin Management model (COIN-OR library)
- Free access (www.riverbasinmanagement.com)
- Google Maps interface
- Able to model variable time step length as well as to include both reservoir and channel routing equations directly into the optimization process as constraints to optimization.

Thank you