System Model for Total Dissolved Gas

by
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US Army Corps of Engineers
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Grand Coulee Dam

Chief Joseph Dam

System Model for Total Dissolved Gas
Grand Coulee Dam

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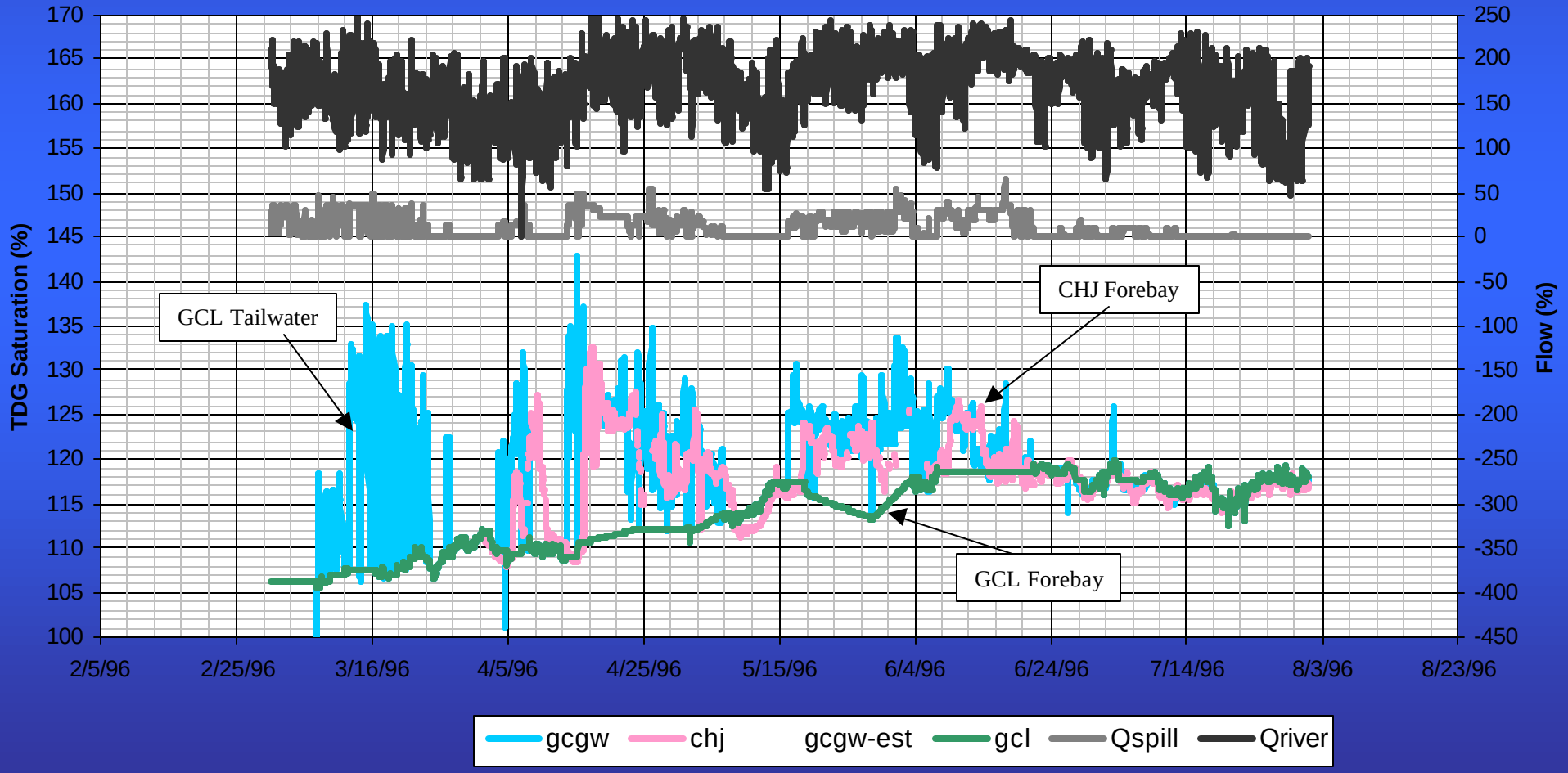

System Model for Total Dissolved Gas
Chief Joseph Dam

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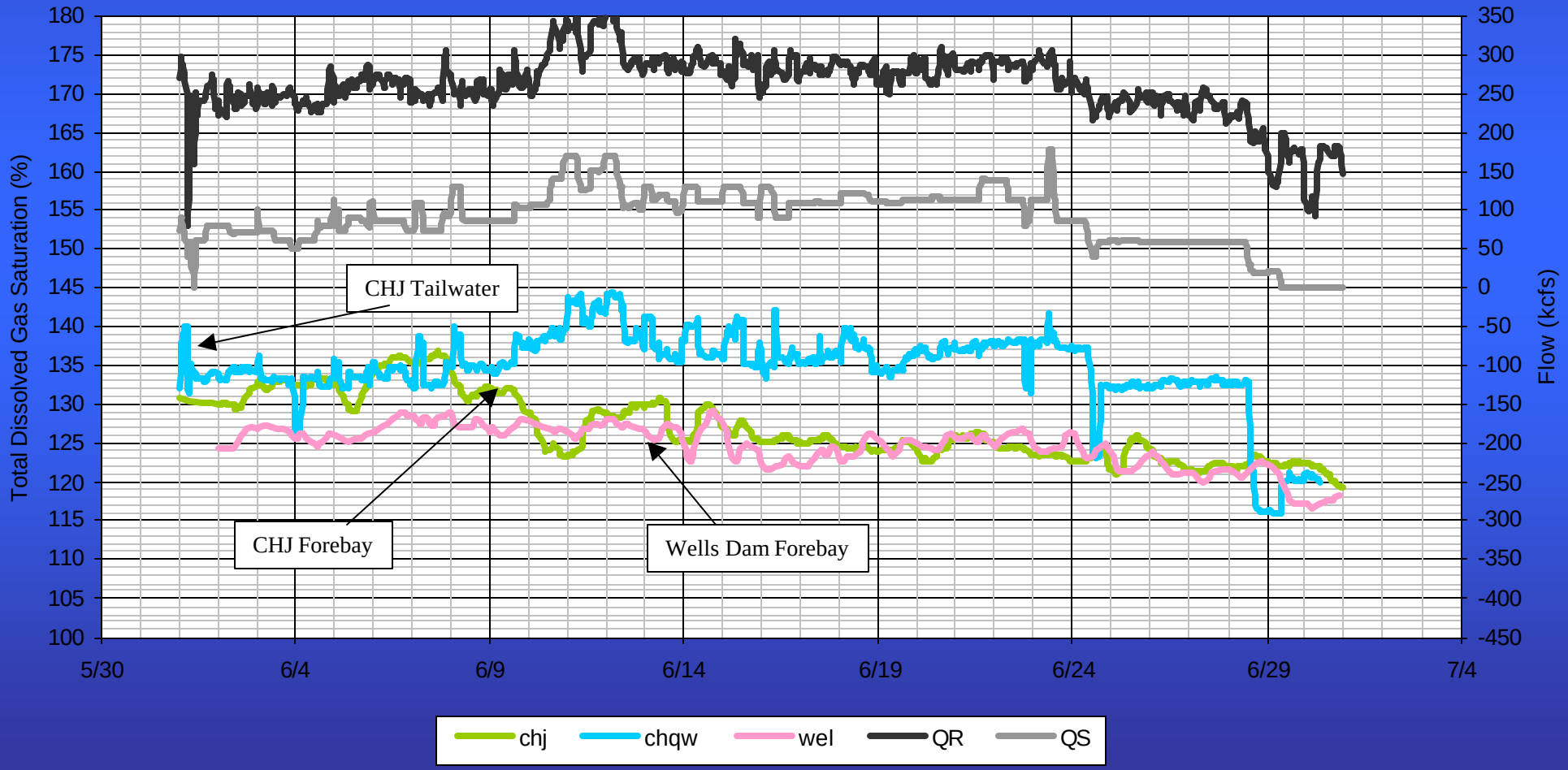

System Model for Total Dissolved Gas

- Introduction - DGAS Abatement Called for by the NMFS Biological Opinion
  - Joint Study at Chief Joseph and Grand Coulee Dam for Abatement of TDG
  - Funded by BPA
  - System Approach Spill Management and Power Production

System Model for Total Dissolved Gas

- Objectives
  - Prediction/Forecasting
    - Operational
    - Structural
    - Hydrologic Conditions
  - Optimization
    - Minimize TDG
    - Generation Constraints
  - Quality Control
    - Monitoring System

System Model for Total Dissolved Gas

- Approach
  - TDG Production at Dams
    - Spillway
    - Powerhouse
  - TDG Transport
    - Degassing
    - Temperature
  - Linked Node Network
    - Ledger of Flow and TDG Pressure
    - Spreadsheet Basis
    - Prediction of TDG upstream and downstream of Dam

System Model for Total Dissolved Gas

- Approach
  - Model Input
    - Total Flow – Stage - Temperature
    - Spill Management Strategy
      - Spill Caps and Priority
      - Minimized TDG subject to System Power Need
    - Operational Parameters and Constraints
    - TDG Exchange Coefficients
  - Domain
    - Columbia River RM 42-Grand Coulee Dam
    - Snake River RM 140
  - Boundary Conditions
    - Historic TDG Loading at GCL and LGW

System Model for Total Dissolved Gas

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- Findings
  - TDG Production
    - Grand Coulee Dam – FMS and Supplemental Field Data
      - Drum Gate
      - Sluiceway
    - Chief Joseph Dam – Near Field Study and FMS Data
    - Wells Dam – FMS Data and Supplemental Field Data
    - Rocky Reach Dam – FMS Data
    - Rock Island Dam – Near Field Study and FMS Data
    - Wanapum Dam – Near Field Study and Supplemental Field Data
      - Pending Flow Deflectors
    - Priest Rapids Dam – FMS Data and Supplemental Field Data

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- Findings
  - TDG Production (DGAS Program)
    - Lower Granite – FMS and Supplemental Field Data
    - Little Goose Dam – Near Field and FMS Data
    - Lower Monumental Dam – Near Field and FMS Data
    - Ice Harbor Dam – Near Field and Supplemental Field Data
    - McNary Dam – Near Field and FMS Data
    - John Day Dam – Near Field and FMS Data
    - The Dalles Dam – Near Field and Supplemental Data
    - Bonneville Dam – Near Field and FMS Data

System Model for Total Dissolved Gas

Mass Conservation

$$TDG_{rel} = \frac{(Q_{sp} + Q_{ent})TDG_{sp} + (Q_{ph} - Q_{ent})TDG_{ph}}{Q_{sp} + Q_{ph}} \quad (1)$$

Empirical TDG Production

Case 1

$$TDG_{sp} = C_1 \quad (2)$$
$$Q_{ent} = 0$$

Case 2

$$TDG_{sp} = C_1 \quad (3)$$
$$Q_{ent} = C_2 Q_{sp}$$

Case 3

$$TDG_{sp} = C_1 + C_2 e^{-C_3 q_s} \quad (4)$$
$$Q_{ent} = 0$$

Case 4

$$TDG_{sp} = C_1 + C_2 e^{-C_3 q_s} \quad (5)$$
$$Q_{ent} = C_2 Q_{sp}$$

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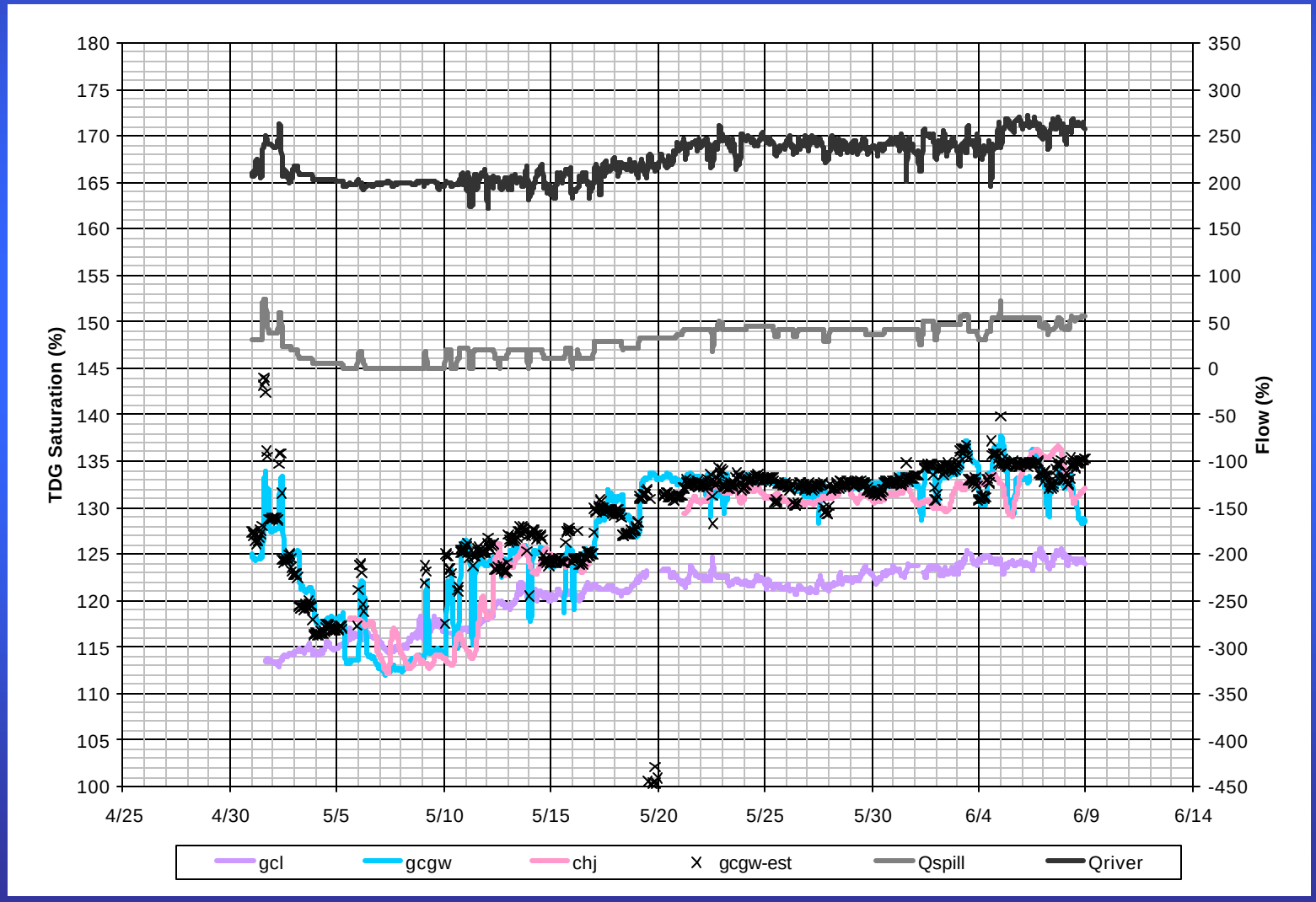
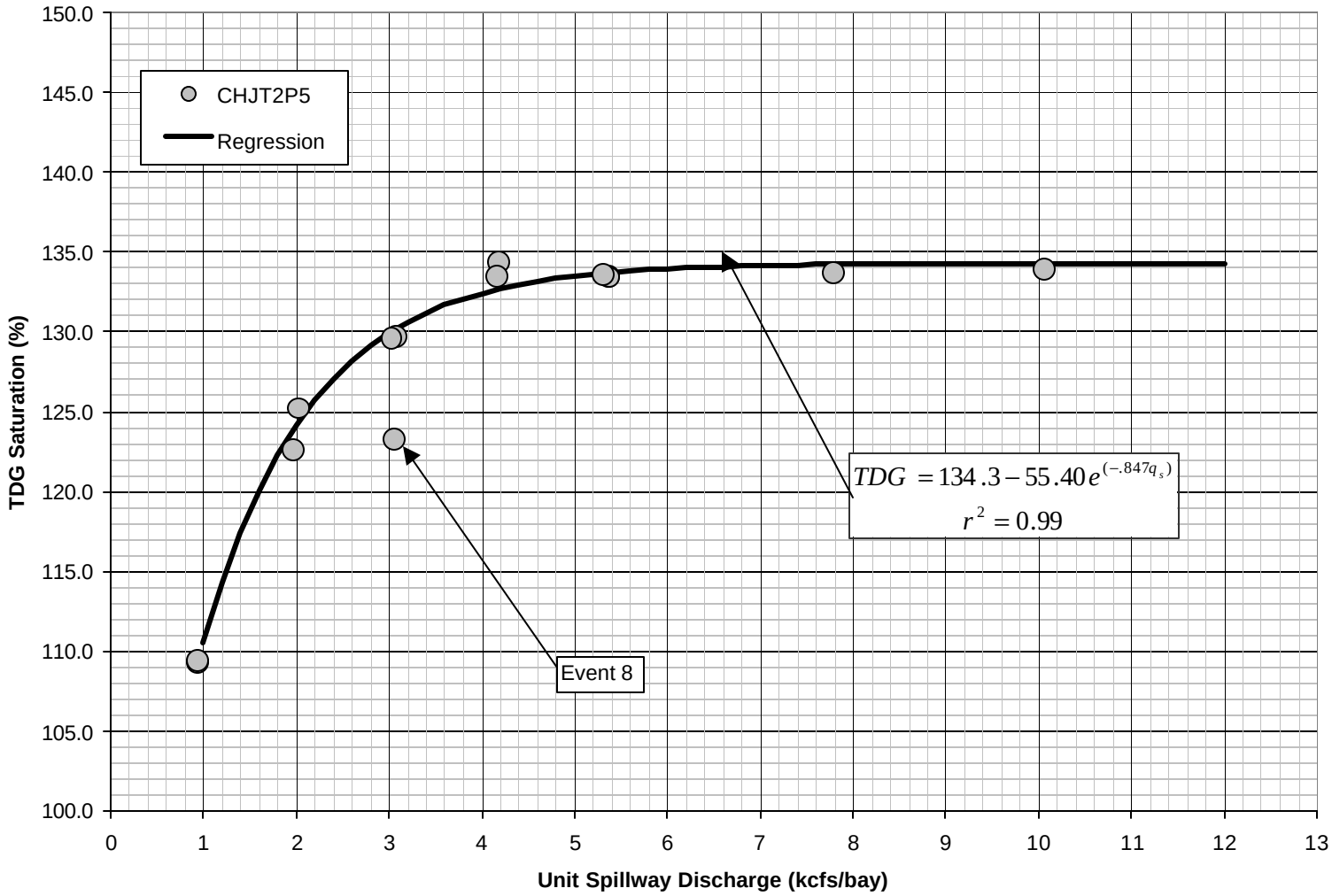


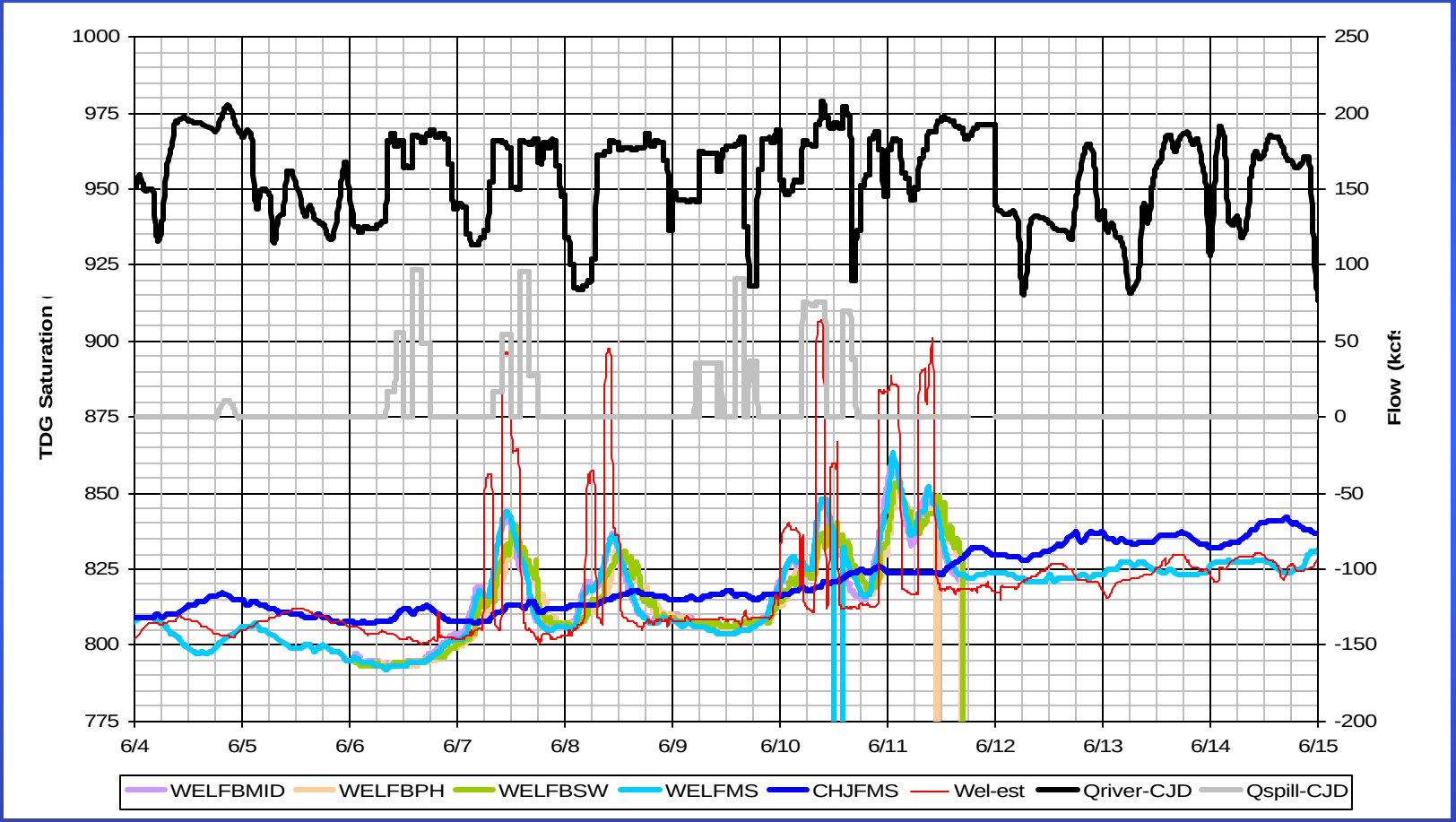


Total Dissolved Saturation at CHJT2P5 as a Function of Unit Spillway Discharge at Chief Joseph Dam, June 6-12, 1999.

System Model for Total Dissolved Gas

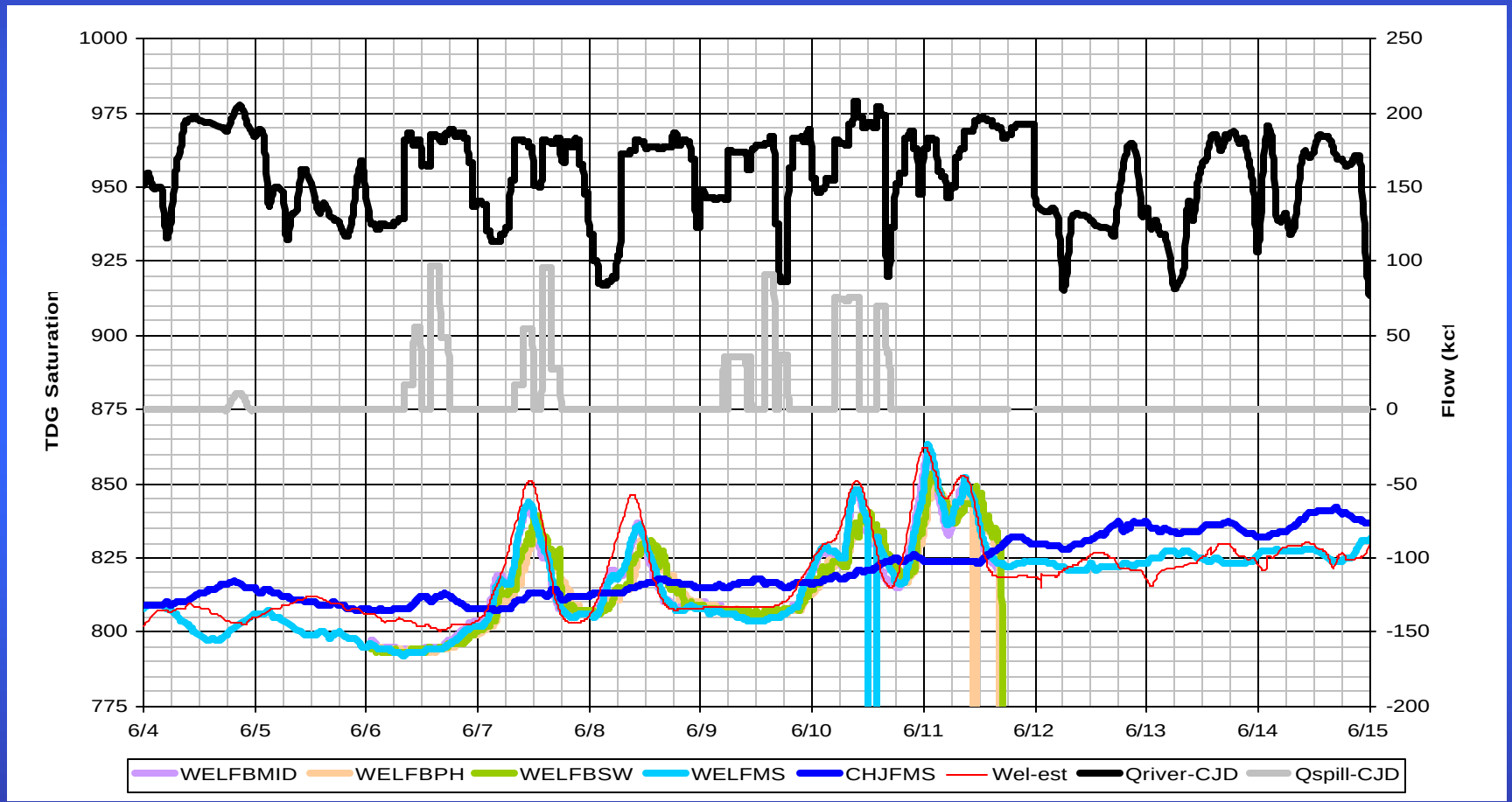
- Findings
  - TDG Transport
    - Retention Time = f(storage,flow)
    - Dissipation – Normally Distributed
    - Wind Generated Degassing

System Model for Total Dissolved Gas



Routing of TDG Plume Through Lake Pateros with No Dispersion, June 4-15, 1999.

System Model for Total Dissolved Gas



Routing of TDG Plume Through Lake Pateros with Normally Distributed Dispersion, June 4-15, 1999.

System Model for Total Dissolved Gas

- Decision Support System
  - Optimization of Project Operations
    - TDG Objective Function
      - Minimize system TDG levels
    - Power generation constraints
    - TDG Constraints
      - FMS compliance

System Model for Total Dissolved Gas

Optimization Framework

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Notes: This worksheet poses a hypothetical problem where power production is scheduled
Notes: based upon the minimization of TDG loading throughout a system of projects.
Notes: Both Power Generation and TDG Production relationships are fictitious.
Notes: Enter Model Input Variables. (Generation Target and River Discharge)
Notes: Implement the Optimizer by selecting "tools-solver-solve"
Notes: The decision variables will be updated to meet the generation target while minimizing the TDG loading across all projects.

Generation Capacity Mw	21030
Generation Target Mw	15000

Project	*GCL*	*CHJ*	*WEL*	*RRH*	*RIS*	*WAN*	*PRD*	*DWR*	*LWG*	*LGS*	*LMN*	*IHR*	*MCN*	*JDA*	*TDA*
Active (1=yes,o=no)	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
Qriver (kcfs)	150	150	150	150	150	150	150	50	100	100	100	100	250	250	250
Generaton-fraction	1.00	0.65	0.64	0.64	0.64	0.84	0.64	0.66	0.64	0.64	0.64	0.55	0.72	0.65	0.45
Qspill (kcfs)	0	52	54	54	55	25	54	17	36	36	36	45	70	87	136
Qpowerhouse (kcfs)	150	98	96	96	95	125	96	33	64	64	64	55	180	163	114
GenCoef (Mw/kcfs)	25.2	13	5.3	6.9	3.1	6.1	6	47.6	7.3	7.2	7.2	7.4	5.2	7.7	6.3
Net Generation Mw	3780	1270	508	664	296	765	576	1562	466	460	460	405	934	1253	716
TDG C1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
TDG C2	40	35	35	35	35	40	35	35	35	35	35	35	45	35	29
# spillbays	12	12	12	12	12	12	12	4	8	8	8	10	23	20	22
TDG spill (%)	100.0	120.4	120.8	120.7	120.9	113.4	120.8	120.2	120.8	120.8	120.8	120.9	120.6	120.4	120.6
TDG powerhouse (%)	121.0	121.0	121.0	121.0	121.0	125.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0
TDG avg (%)	121.0	120.8	120.9	120.9	121.0	123.1	120.9	120.7	120.9	120.9	120.9	120.9	120.9	120.8	120.8

Calculated
Decision Variables
Objective Function
Model Input
Constraints
Model Parameters

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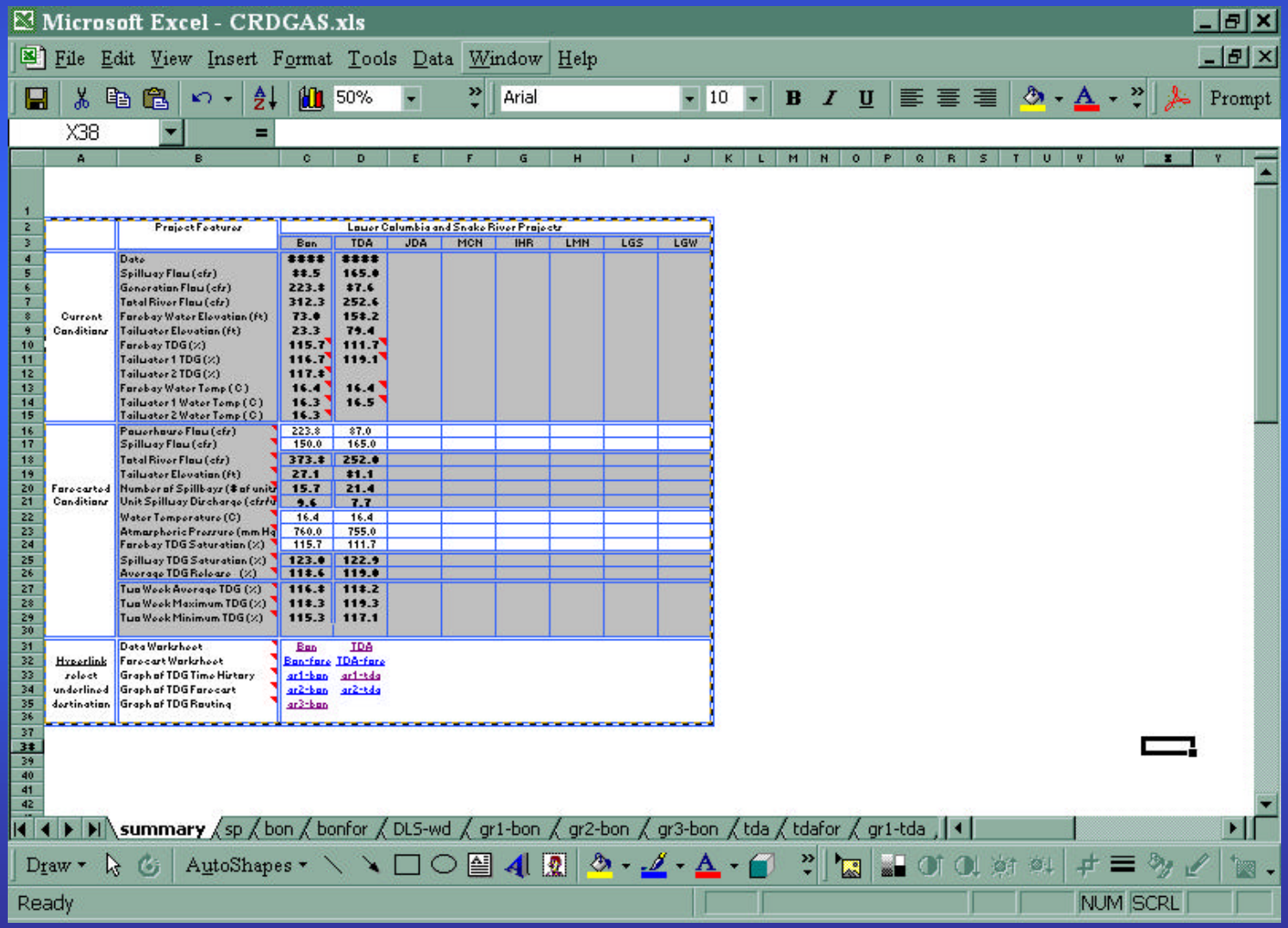

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Wells Dam

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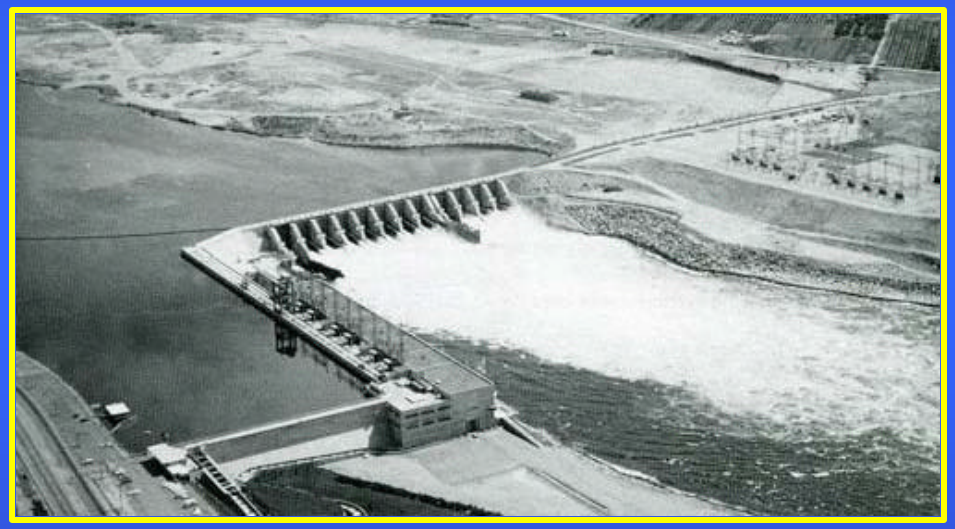
Rocky Reach Dam



System Model for Total Dissolved Gas
Rocky Island Dam

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Wanapum Dam

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Priest Rapids Dam

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Dworshak Dam

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Lower Granite Dam

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Little Goose Dam

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Lower Monumental Dam

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Ice Harbor Dam

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