

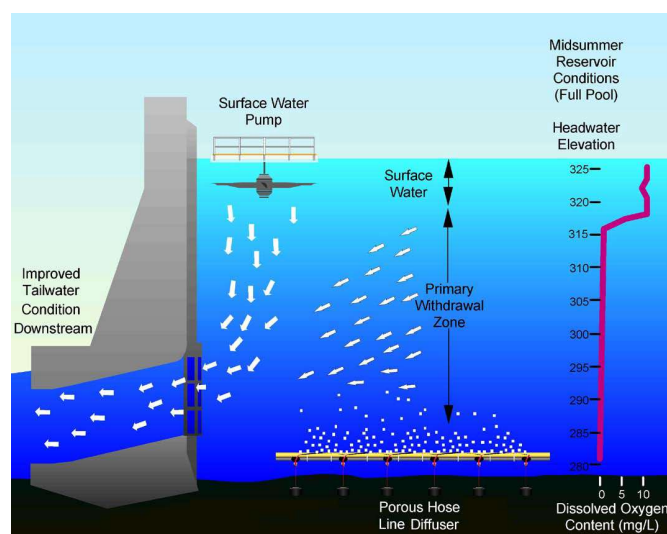
Water Quality Modeling Tools to Evaluate and Forecast Water Quality in Rivers and Reservoirs

Paul J. Wolff, WolffWare Ltd., Norris, Tennessee
Richard J. Ruane, REMI Inc., Chattanooga, Tennessee
Gary E. Hauser, Loginetics, Inc. Knoxville, Tennessee



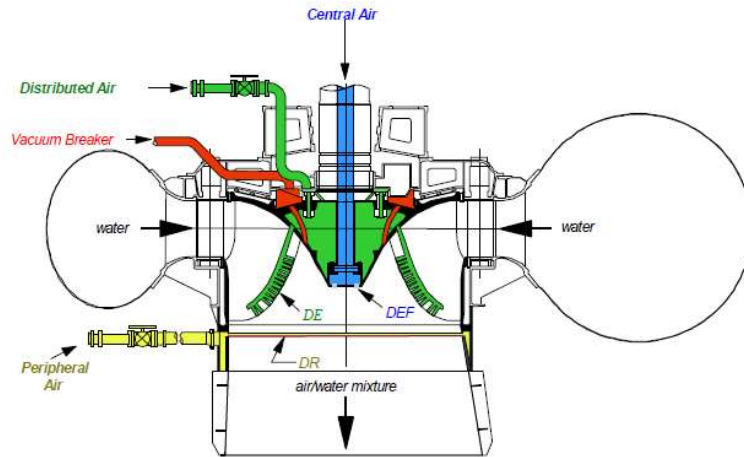
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Forebay Oxygenation



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Turbine Aeration



(From P.A. March, "Hydraulic and Environmental Performance of Aerating Turbine Technologies," www.hydroppi.com)

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Benefits of Modeling

- Reservoir models are an effective framework for using your monitoring data to create a comprehensive framework for understanding how your reservoir works.
- Reservoir models are the only practical way to investigate alternate reservoir management scenarios
 - Modified reservoir levels
 - Alternate hydrological and weather scenarios
 - Investigate control algorithms for forebay diffusers
- Turbine aeration models predict how much dissolved oxygen (DO) turbine aeration can produce, before you implement the system.

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Modeling Tool Kit

- CE-QUAL-W2 – Two-dimensional reservoir model
- ADYN/RQUAL – One dimensional river model
- Wuest Bubble Model – Used to model bubble plumes for forebay diffusers and for turbine and draft tube aeration systems. Contained in two stand alone apps and custom algorithm added to CE-QUAL-W2
 - Bubble Plume Interface (BPi) – Models gas transfer from bubble plumes in reservoirs (Gary Hauser, Loginetics Inc.)
 - Discrete Bubble Model (DBM) – Models gas transfer from bubbles in draft tubes (Dan McGinnis; Assistant Professor; University of Geneva; Geneva, Switzerland)
- Withdrawal Zone Models – Used to predict tailrace DO and temperature based on forebay profiles
- Weir Aeration and TDG Models – Usually empirical models to predict dissolved oxygen (DO) and total dissolved gas (TDG) below an aerating weir.
- Hydropplant Performance Calculator – Used to compute impact of reduced turbine efficiency (from aeration) on energy and revenue production.

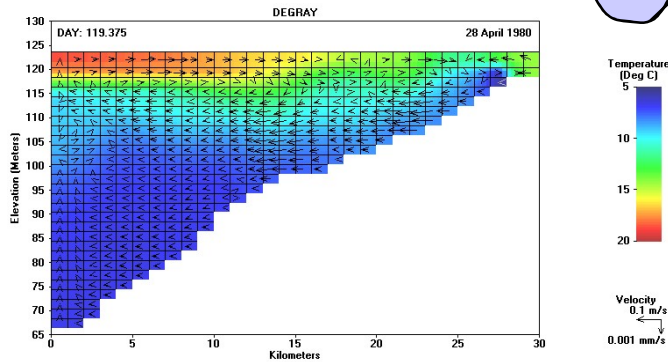
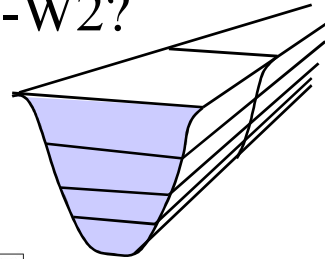
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W2 Overview

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What is CE-QUAL-W2?

2-dimensional, laterally averaged, hydrodynamic and water quality model for reservoirs (and rivers)



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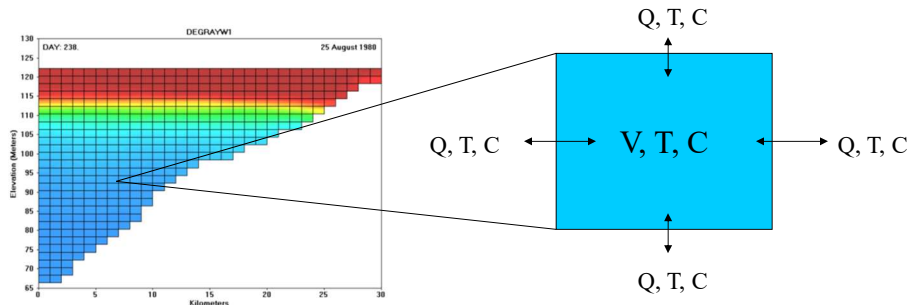
CE-QUAL-W2 is a mechanistic model based on physics of fluid flow and heat/mass transport

Two-dimensional (vertical, longitudinal) reservoir hydrodynamics and water quality

Laterally-averaged conservation of water mass, water momentum, and transported constituents (heat, WQ)

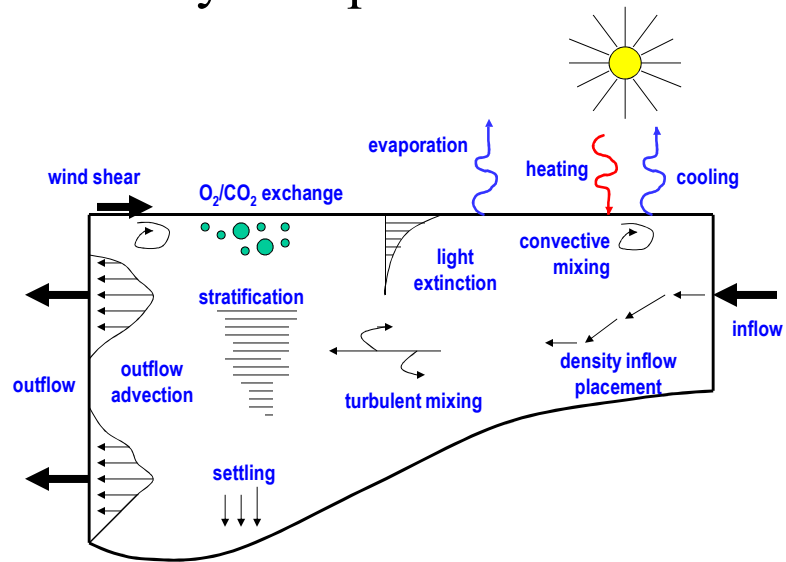
Kinetic fluxes of heat and WQ within cells, between cells, and across boundaries

Forcing functions: meteorology, inflow/outflow, inflow temperature/WQ



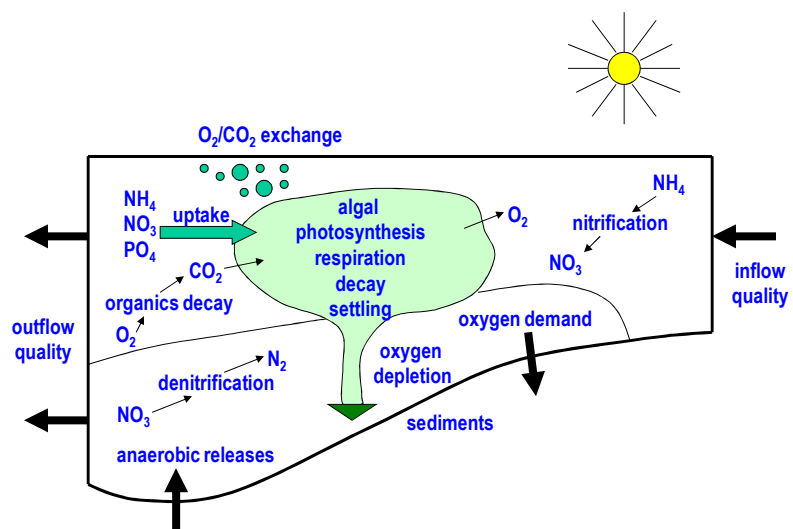
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Physical processes



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Biochemical processes



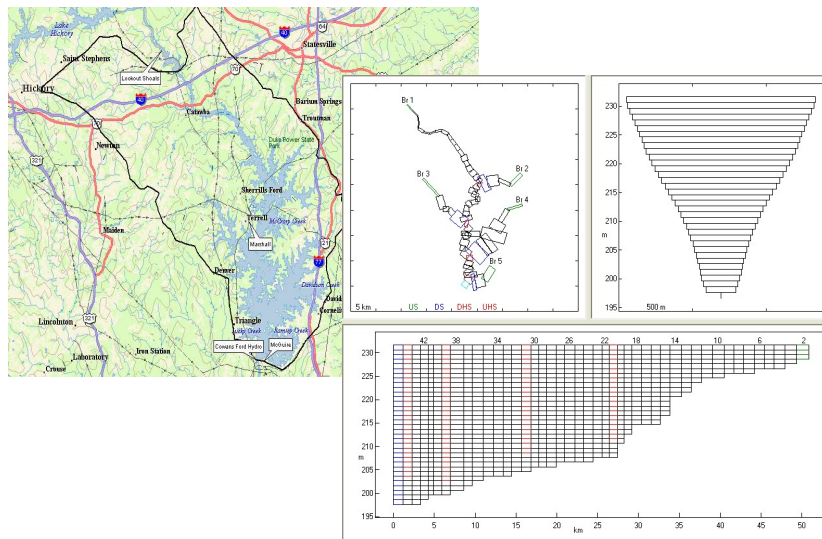
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Data (Requirements)

- Bathymetry – Volume versus depth versus longitudinal location
- Boundary Conditions
 - Inflow Dissolved Oxygen, Temperature, and Water Chemistry
 - Many reservoirs have multiple inflows
 - Meteorological Data
 - Ambient temperature
 - Wet bulb temperature
 - Solar radiation
 - Wind
- Calibration Data
 - Lake monitoring data
 - Forebay station is a really important one
 - Periodic DO and temperature profiles
 - Surface water chemistry samples
 - Tailrace data
 - Time series of DO, temperature, and water chemistry

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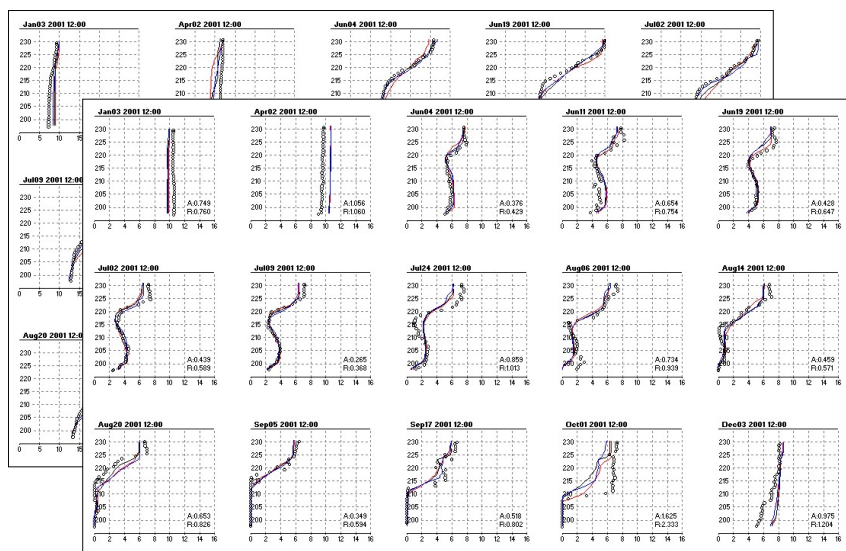
Model Bathymetry



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Model Calibration

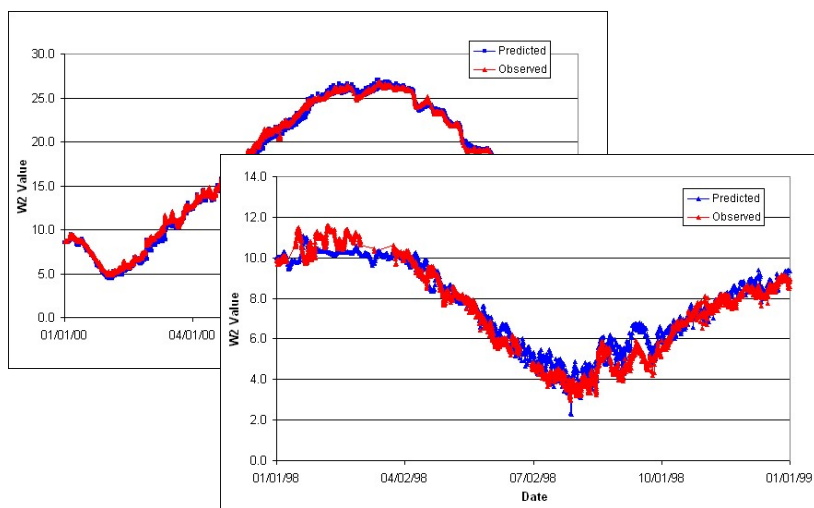
Forebay DO and Temp Profiles



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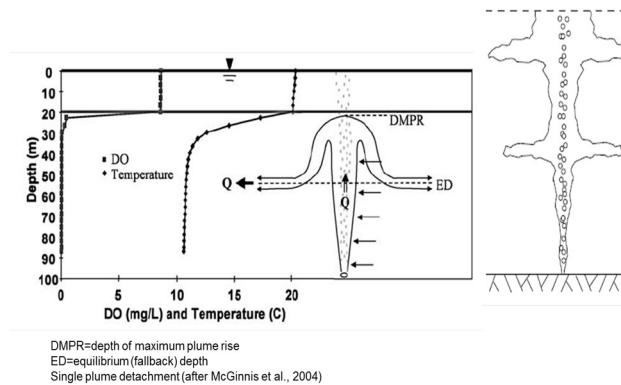
Model Calibration

Tailrace DO and Temperature Time Series



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Wuest Bubble Model Schematic of a Bubble Plume



- Wuest Bubble Model algorithm has been added to CE-QUAL-W2
- Also basis of Discrete Bubble Model (DBM, Dan McGinnis) to compute oxygen transfer efficiency for turbine aeration

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Model Examples

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J S Thurmond Reservoir

Fish Habitat Creation

Problem:

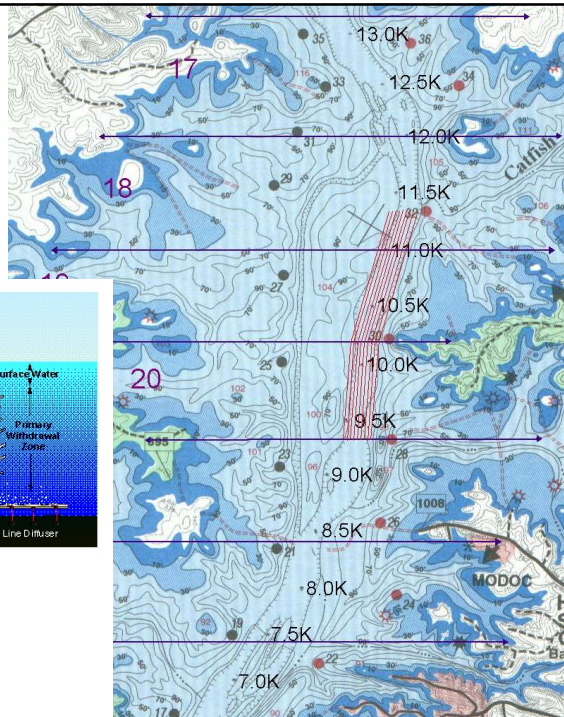
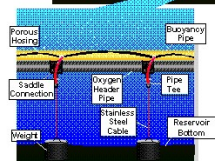
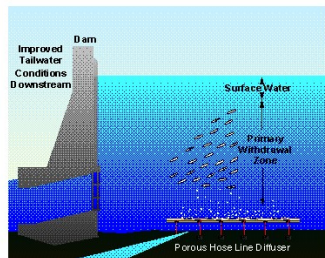
- Design O₂ system to create striper habitat zone to mitigate habitat lost due to pumpback operation.

Diffuser Placement Options:

- Upstream/downstream.
- Shallow/deep.
- High flux/low flux.

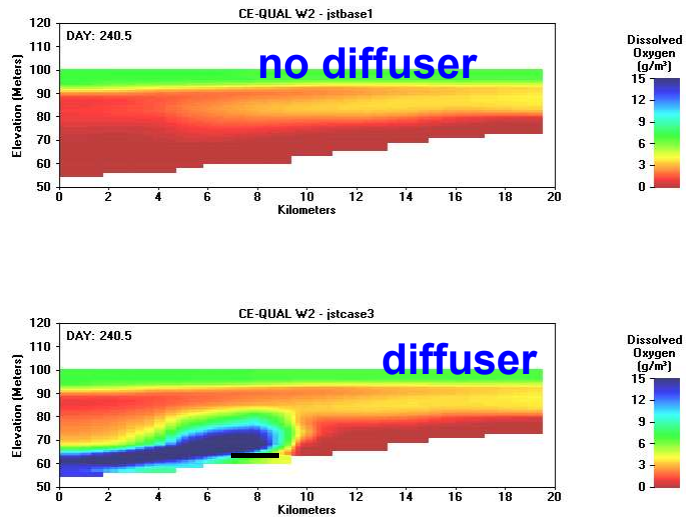
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J S Thurmond Reservoir Diffuser Layout



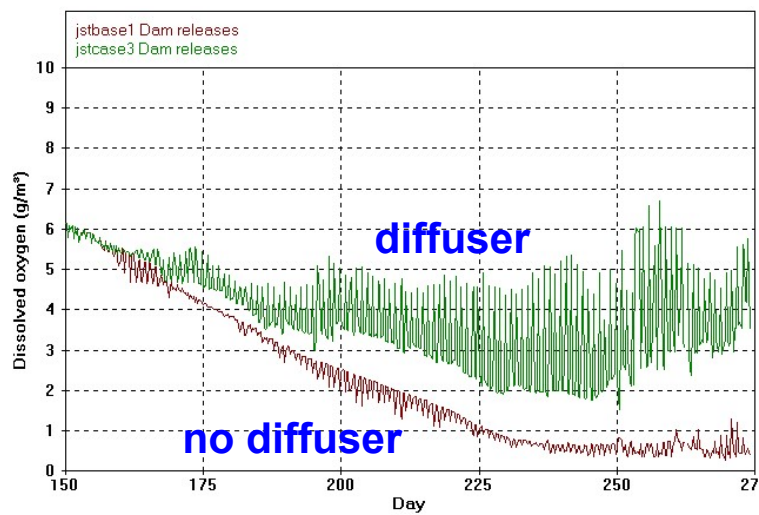
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J S Thurmond Reservoir Reservoir DO With Line Diffuser



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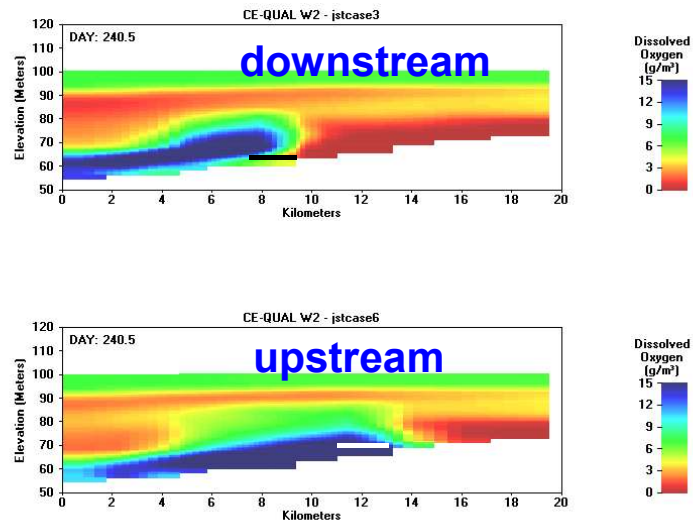
J S Thurmond Reservoir Release DO With Line Diffuser



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J S Thurmond Reservoir

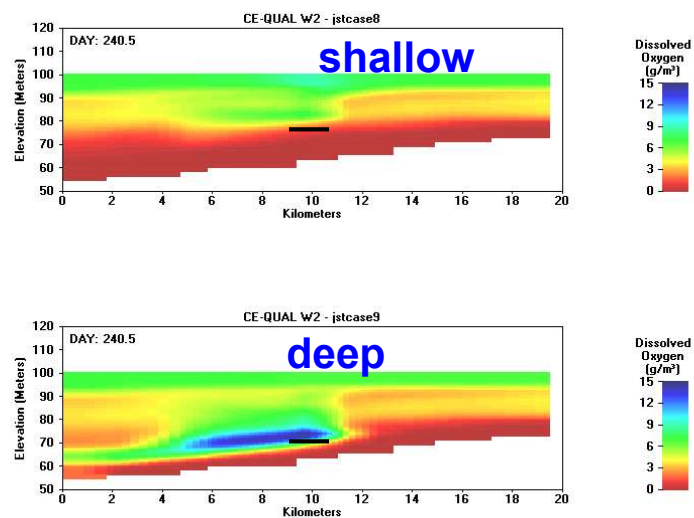
Reservoir DO With Line Diffuser Placement



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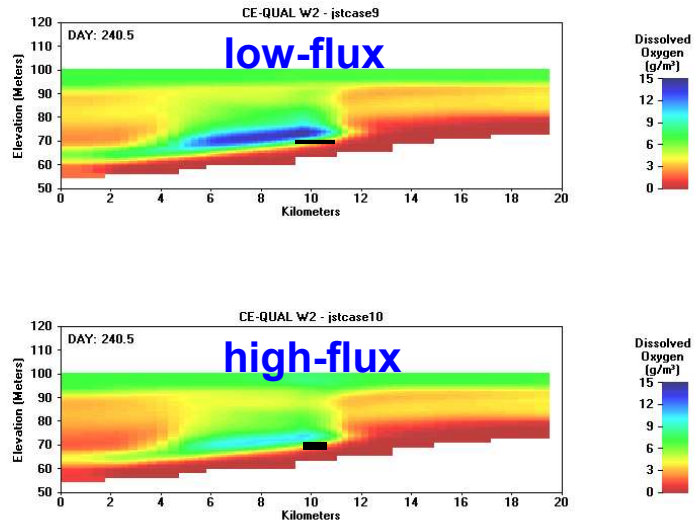
J S Thurmond Reservoir

Reservoir DO With Line Diffuser Depth



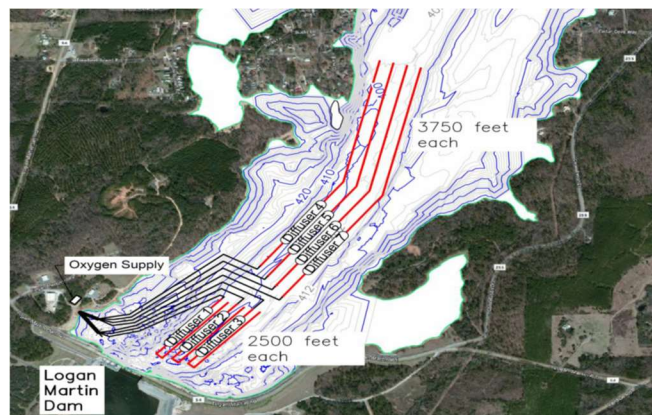
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J S Thurmond Reservoir Reservoir DO With Line Diffuser Flux



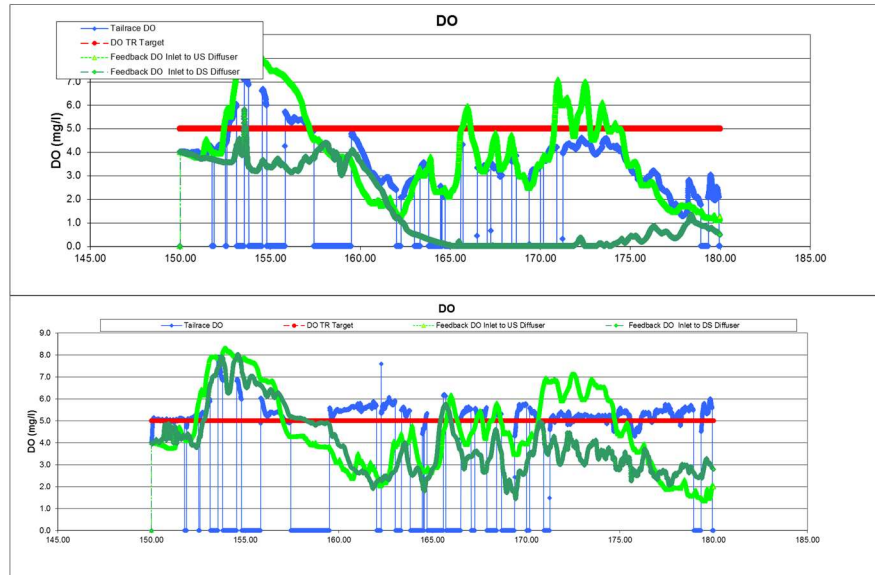
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Control Analyses for Forebay Diffusers Diffuser Layout



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Simulation of Control Algorithm



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Douglas Reservoir Lake Level Policy

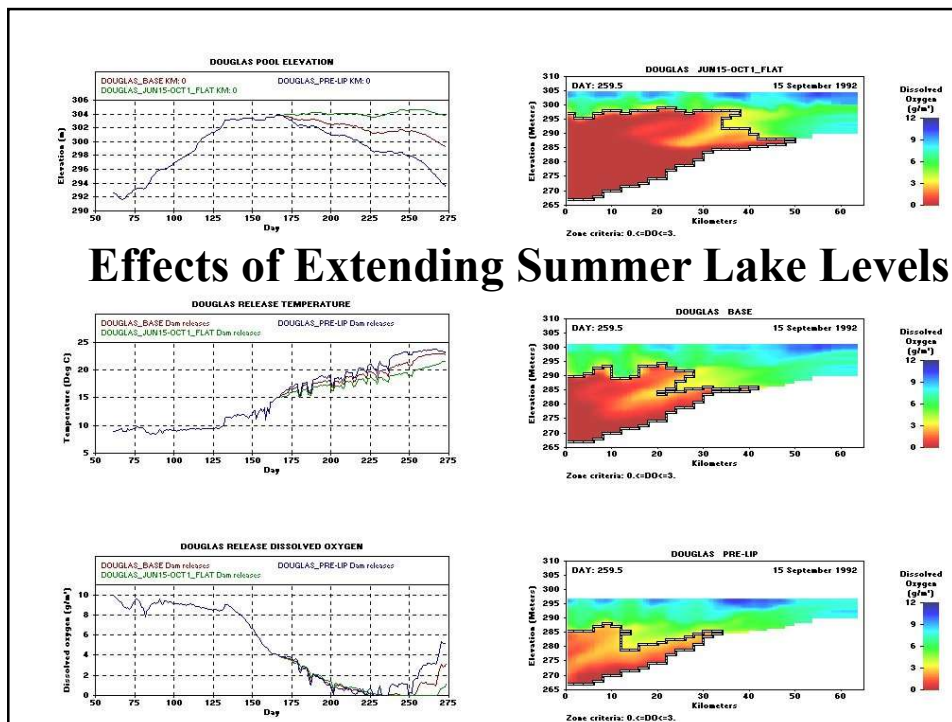
Problem:

- Lake users want longer recreational lake levels and no visible “mud ring”.

Options:

- Hold summer levels later into fall.
- Aggressive spring fill.
- Maintain low winter levels throughout year.
- Raise winter levels.

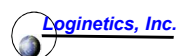
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Thank you for your attention.

Paul Wolff, WolffWare Ltd., pjwolff@wolffwareltd.com



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