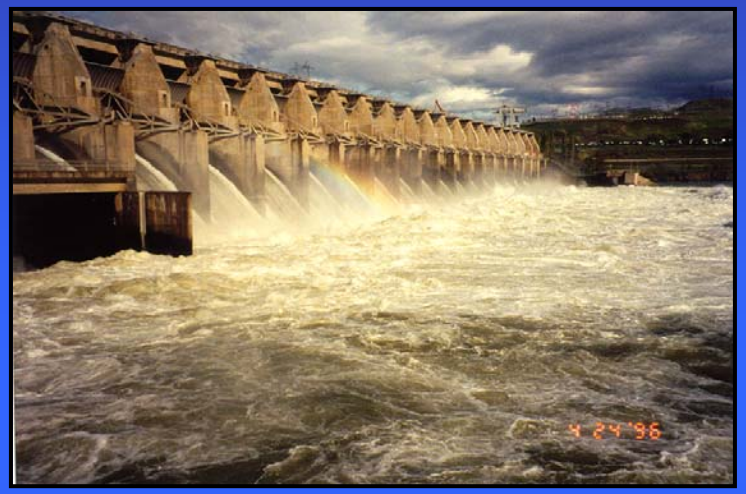
Total Dissolved Gas Properties and Processes



by

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TDG Properties and Processes Scope of Discussion

- Physical Properties of TDG
  - Gas Laws
  - TDG Saturation
  - TDG Calculator
- Transfer Processes of TDG
  - Near-field Mass Exchange Processes
  - Entrainment
  - Mixing and transport
  - Thermal influences
- Monitoring Issues

Physical Properties

- Gas Solubility (effects on C_s)
  - Hydrostatic pressure
    - Air bubbles transported to depth experience high pressures resulting in higher saturation concentrations
    - Every 10 m of additional depth doubles solubility
    - Compensation depth C=Cs
  - Barometric Pressure
    - 7.5 mm decrease in Barometric Pressure causes a 1 percent increase in TDG saturation
    - Elevation dependent
      - For same concentration, TDG saturation is higher at higher elevations (lower barometric pressure)

Physical Properties

- Gas Solubility (effects on C_s)
  - Water Temperature
    - C_s inversely proportional to T
      - 1 degree rise in temperature can cause a 2-3 percentage point rise in TDG saturation
    - Rate heat transfer >> rate mass transfer => thermally induced pressure changes
      - Elevated TDG pressures in warm surface layers

Physical Properties

- TDG Saturation TDG_{sat}
  - Compliance metric
  - TDG Pressure normalized by barometric pressure
    - $TDG_{sat} = TP/BPx100$
    - BP range up to 25 mm Hg (3-4%)
  - Absolute TDG saturation
    - TDG Pressure normalized by total pressure
    - Compensation depth 100%
    - 120% only top 2 m are supersaturated

Physical Properties

- TDG Calculator
  - Temp-Pressure-Concentration relationship
  - Constant Pressure or Concentration Modes
  - Visual Basic Program
  - Compensation Depth
  - Partial pressure of constituent gases

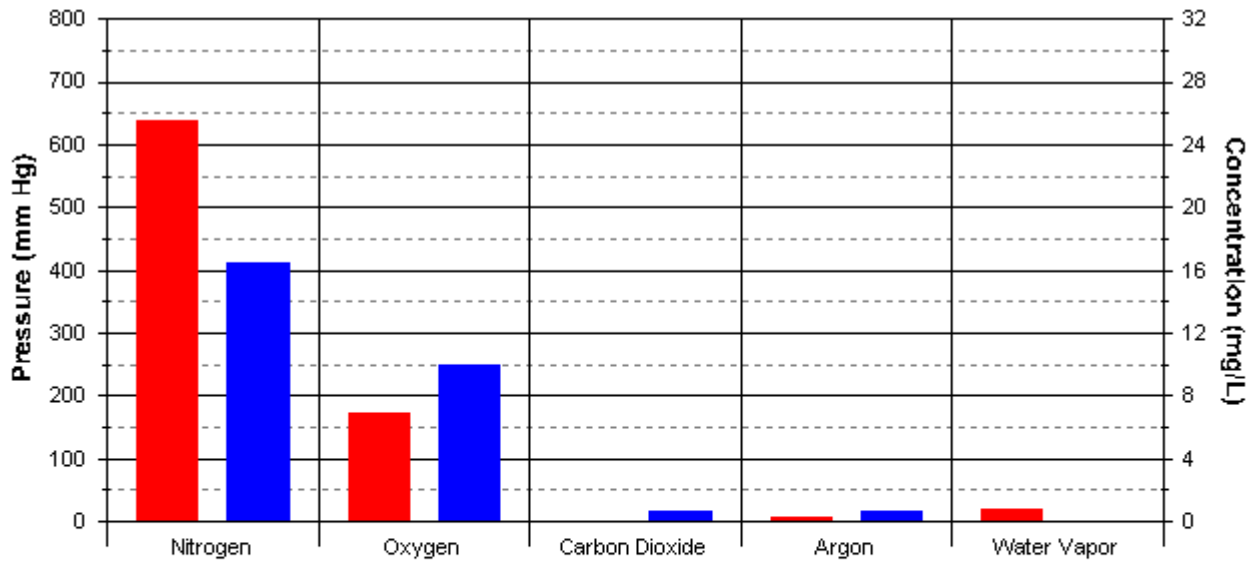
TDG Calculator

- Pressure
- Concentration

TDG (mm Hg)	836
BP (mm Hg)	760
Water Temp (°C)	20
Depth (ft)	15
% Saturation (surface)	110.0
Absolute Saturation	76.3
Compensation Depth (ft)	3.4

	Pressure (mm Hg)	Concentration (mg/L)
Total	836	27.6
Nitrogen	639.2	16.4
Oxygen	171.5	10
Carbon Dioxide	0.3	0.6
Argon	7.6	0.6
H2O Vapor	17.5	

Pressure Concentration



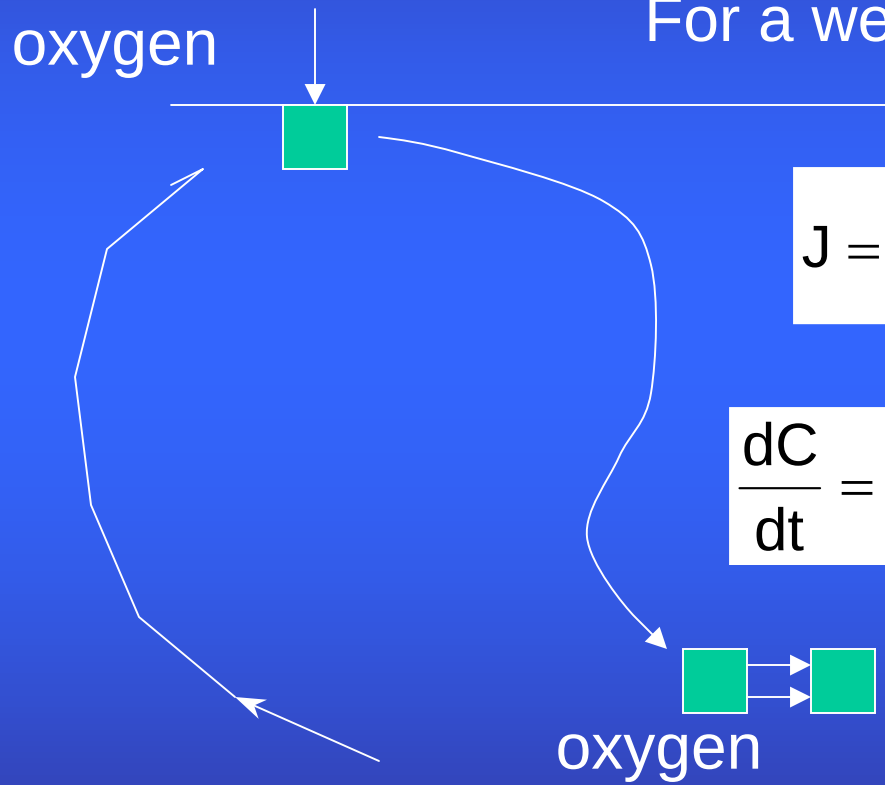
End

TDG Exchange Processes

- Air/Water Interface
  - Entrained bubbles
  - Water surface – stream reaeration
- Pressure time history of bubbles
  - Higher pressures accelerate gas transfer
  - Depth of plunge of highly aerated flow
- Turbulence
  - Water surface renewal
  - Retention of entrained bubbles

TDG Exchange Processes

For a well-mixed system



$$J = K\left(\frac{C_{air}}{H} - C_w\right) = K(C_s - C_w)$$

$$\frac{dC}{dt} = k_L \frac{A}{V}(C_s - C_w) = k_L a(C_s - C_w)$$

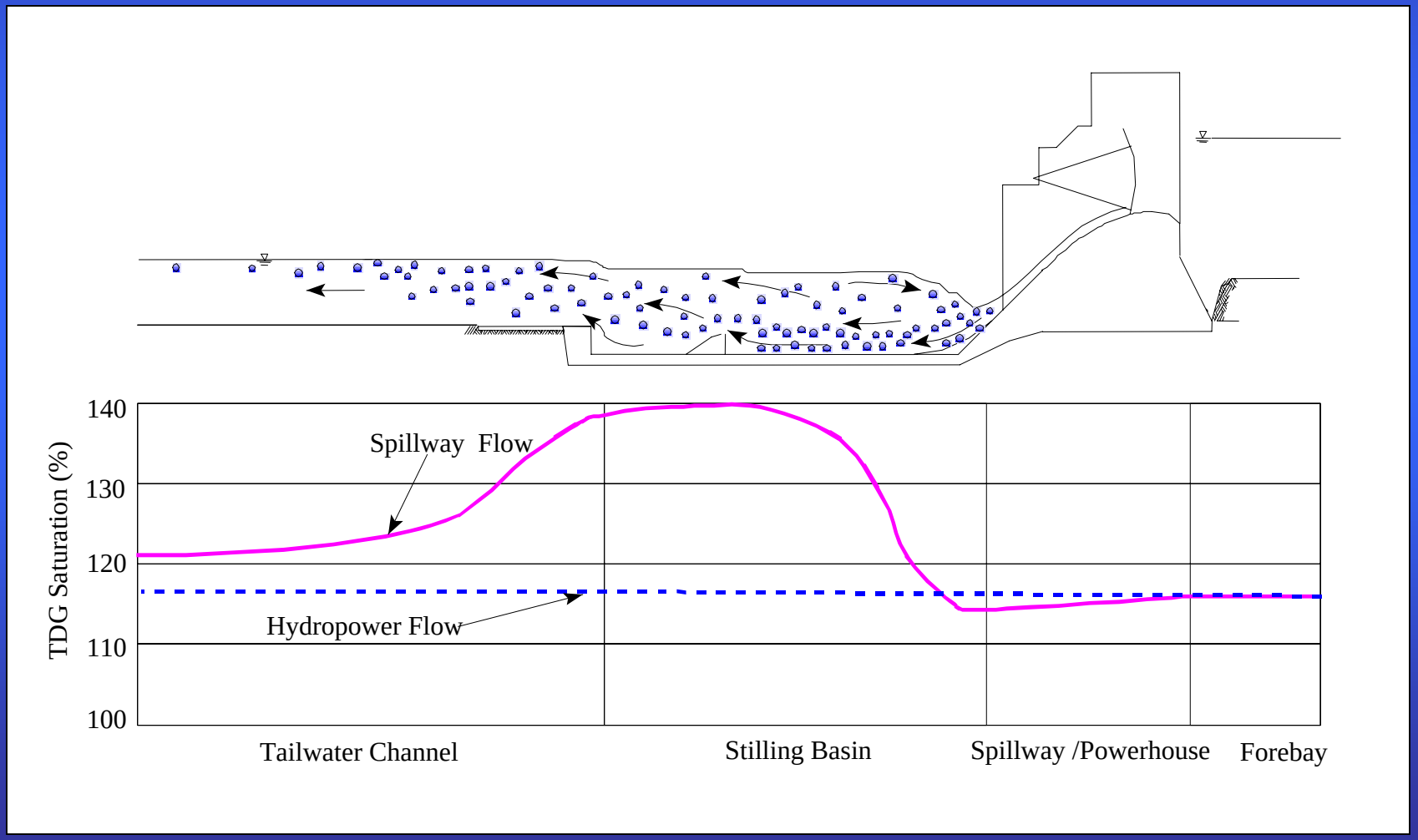
$$\frac{C_s - C_d}{C_s - C_u} = e^{-k_L at}$$

Total Dissolved Gas Exchange Near-Field Processes

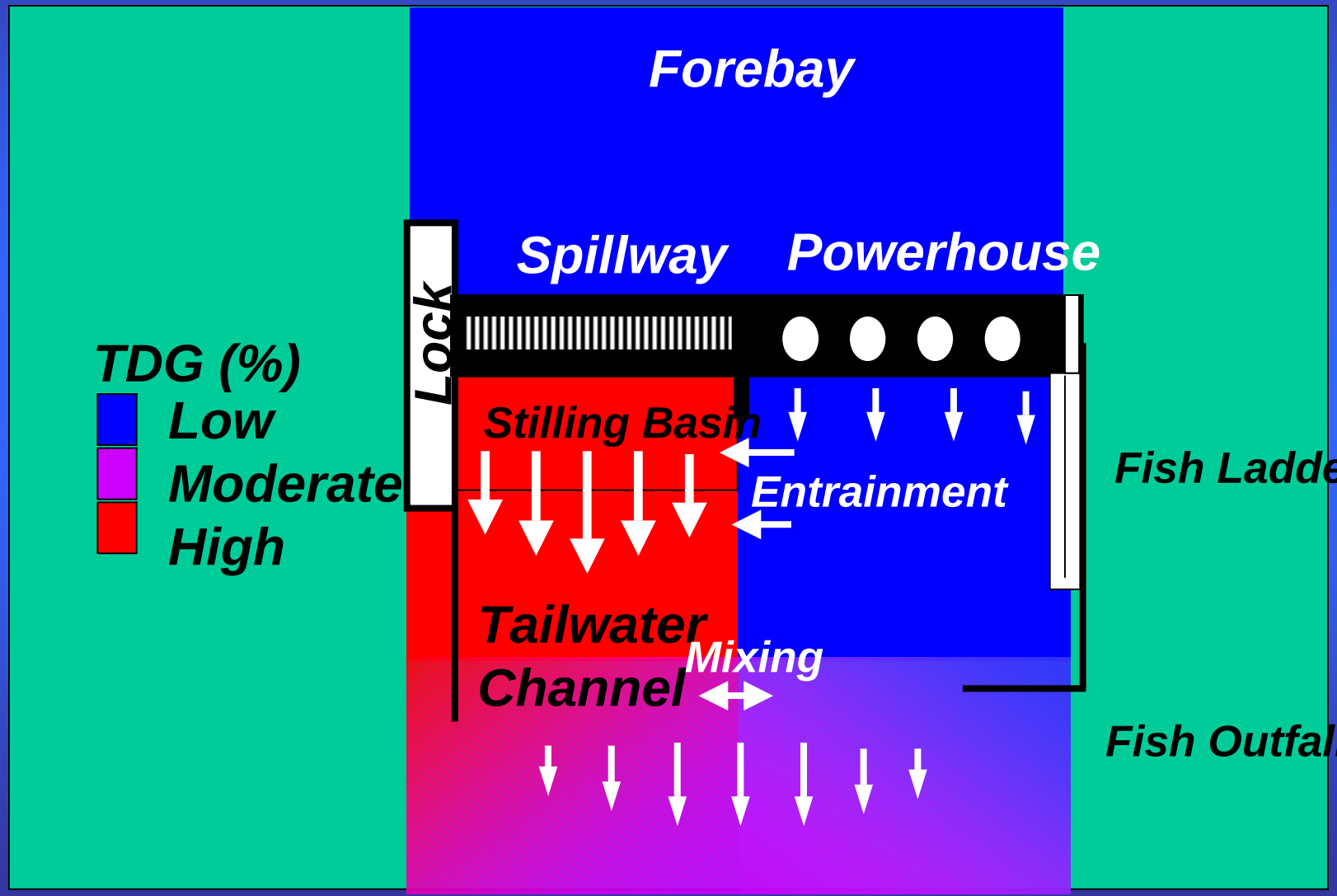
- **Spillway**
  - **Approach to Spillway Gate**
  - **Spillway**
  - **Stilling Basin**
  - **Tailwater Channel**
- **Powerhouse**
  - **Turbine Passage does not change the TDG properties**
    - **Exception when air is introduced during rough settings**
  - **Entrainment into Aerated Spillway Flow**

Total Dissolved Gas Exchange

Application to Stilling Basins

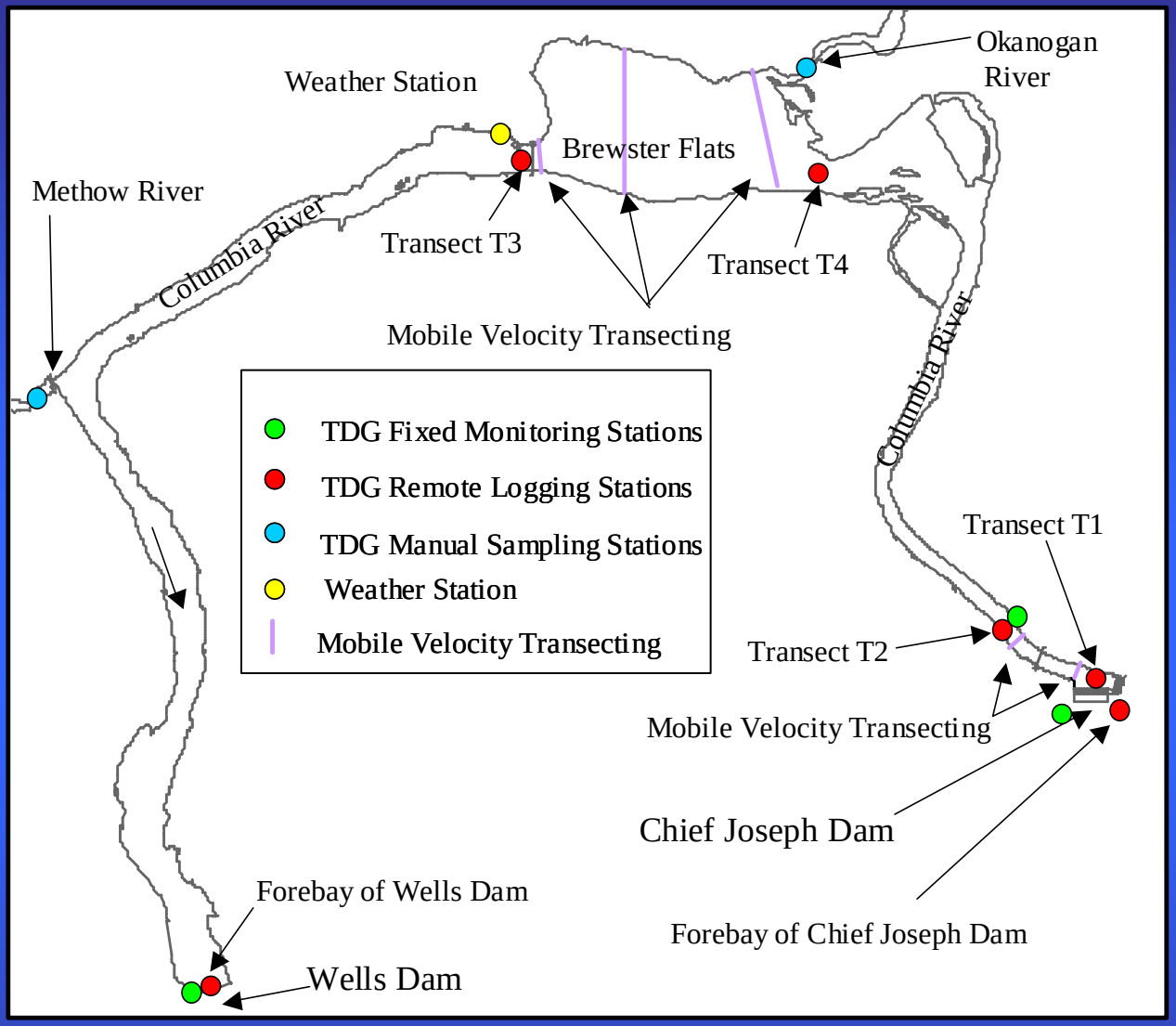


Total Dissolved Gas Exchange at Dams in the Columbia River Basin

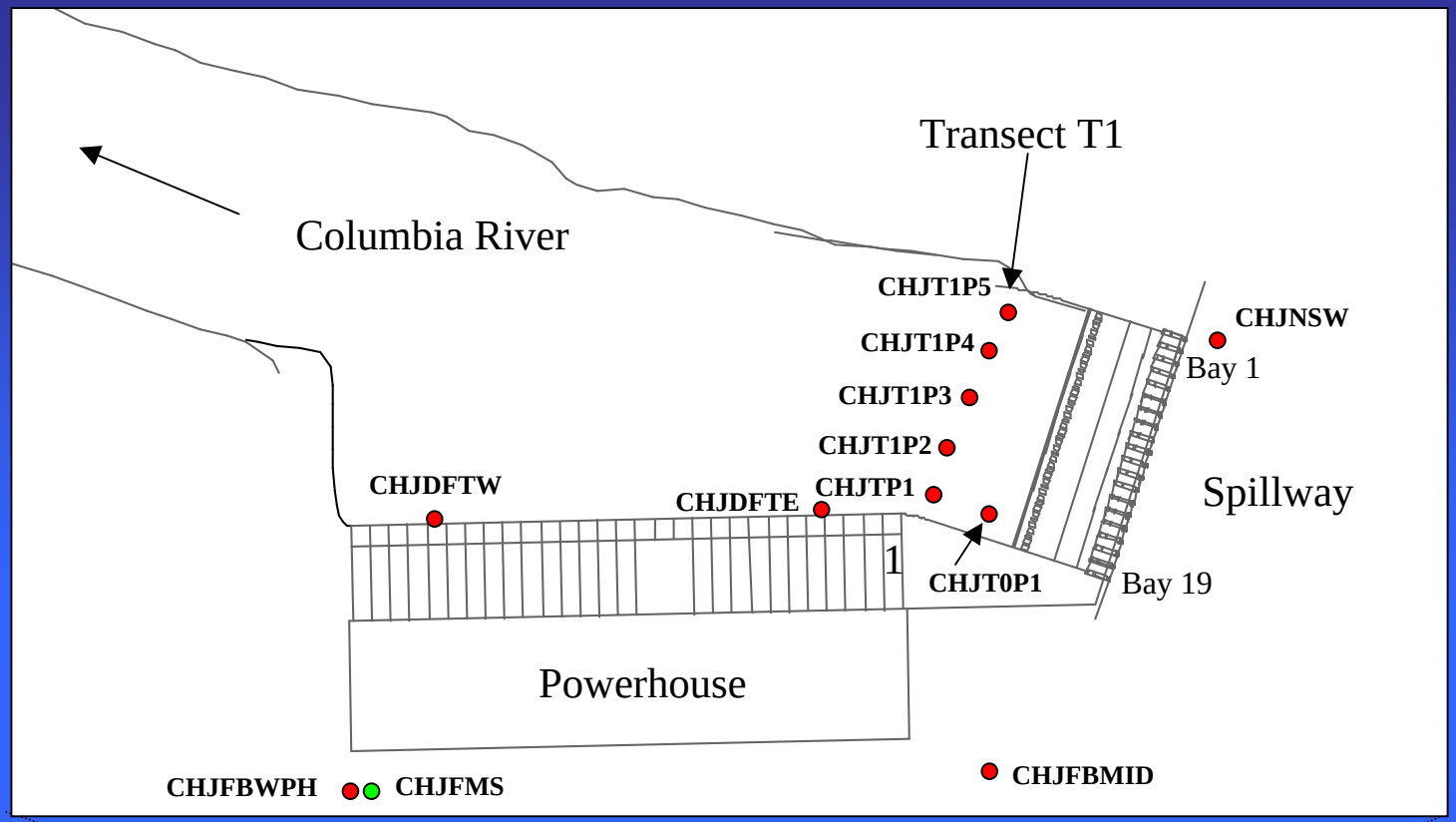


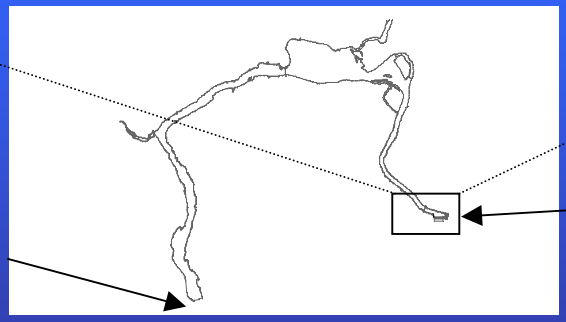
Characterization of TDG Exchange

- Field Data Collection
  - Manual Sampling
  - Logging TDG Sensor Array
  - Velocity Field Determination allows loading estimates
- Laboratory Investigations
  - Section Models
  - General Models
- TDG Functional Relationships
  - TDG Production @ Project
  - System Wide Cumulative Impacts

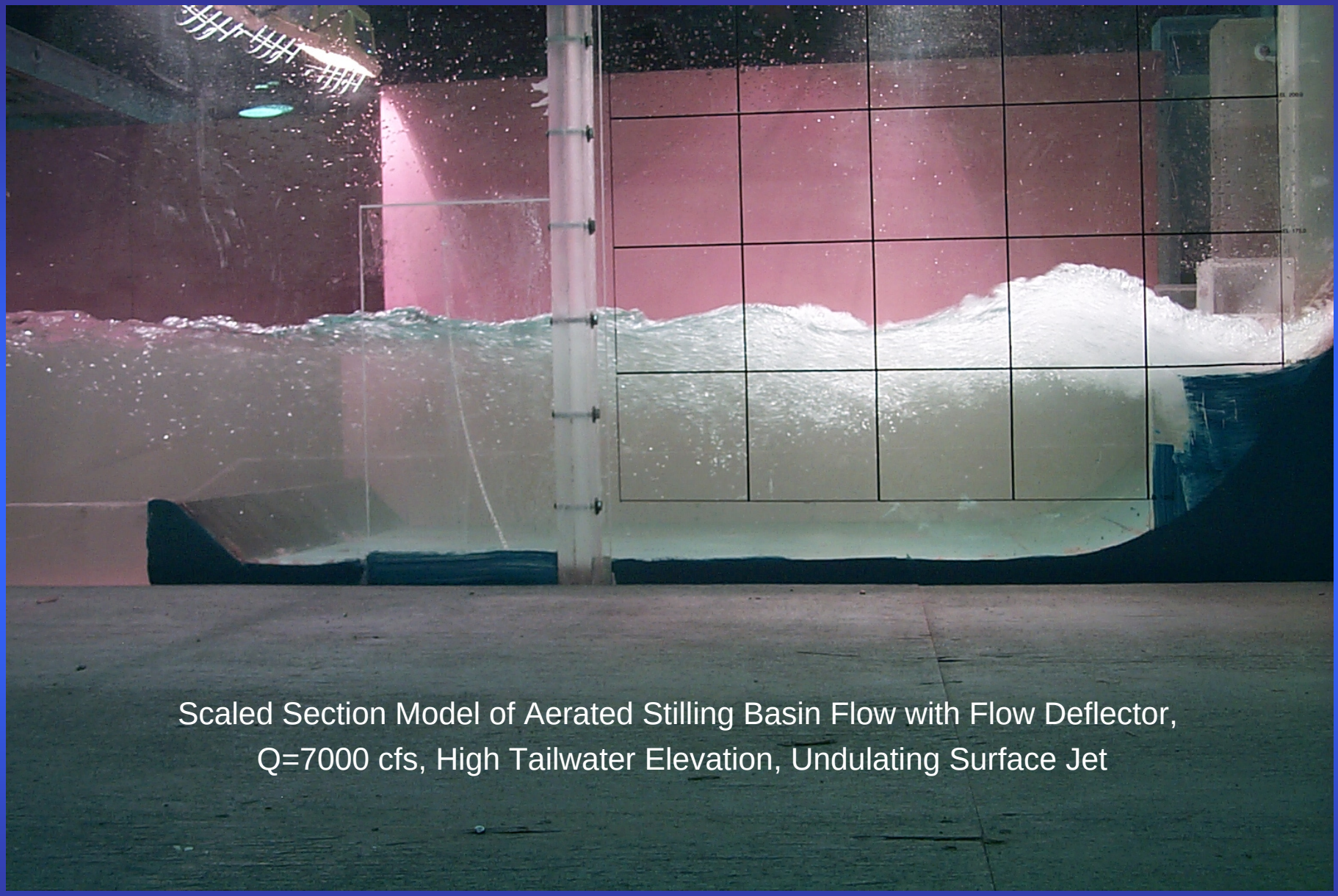


Total Dissolved Gas, Weather, and Velocity Monitoring Locations in Columbia River, June 6-10, 1999.





Total Dissolved Gas Monitoring Stations in the Forebay and Downstream of Chief Joseph Dam, June 6-10, 1999.



Scaled Section Model of Aerated Stilling Basin Flow with Flow Deflector,
Q=7000 cfs, High Tailwater Elevation, Undulating Surface Jet

Total Dissolved Gas Exchange Near-Field Processes

- TDG Exchange Functional Relationships
  - **Spillway Discharge**
    - Unit Discharge qs (kcfs/bay)
      - Spill Pattern
  - **Tailwater Elevation**
    - Stilling Basin and Tailwater Channel Depth
    - Deflector Submergence
      - Aerated Jet Development
      - Entrainment Demand

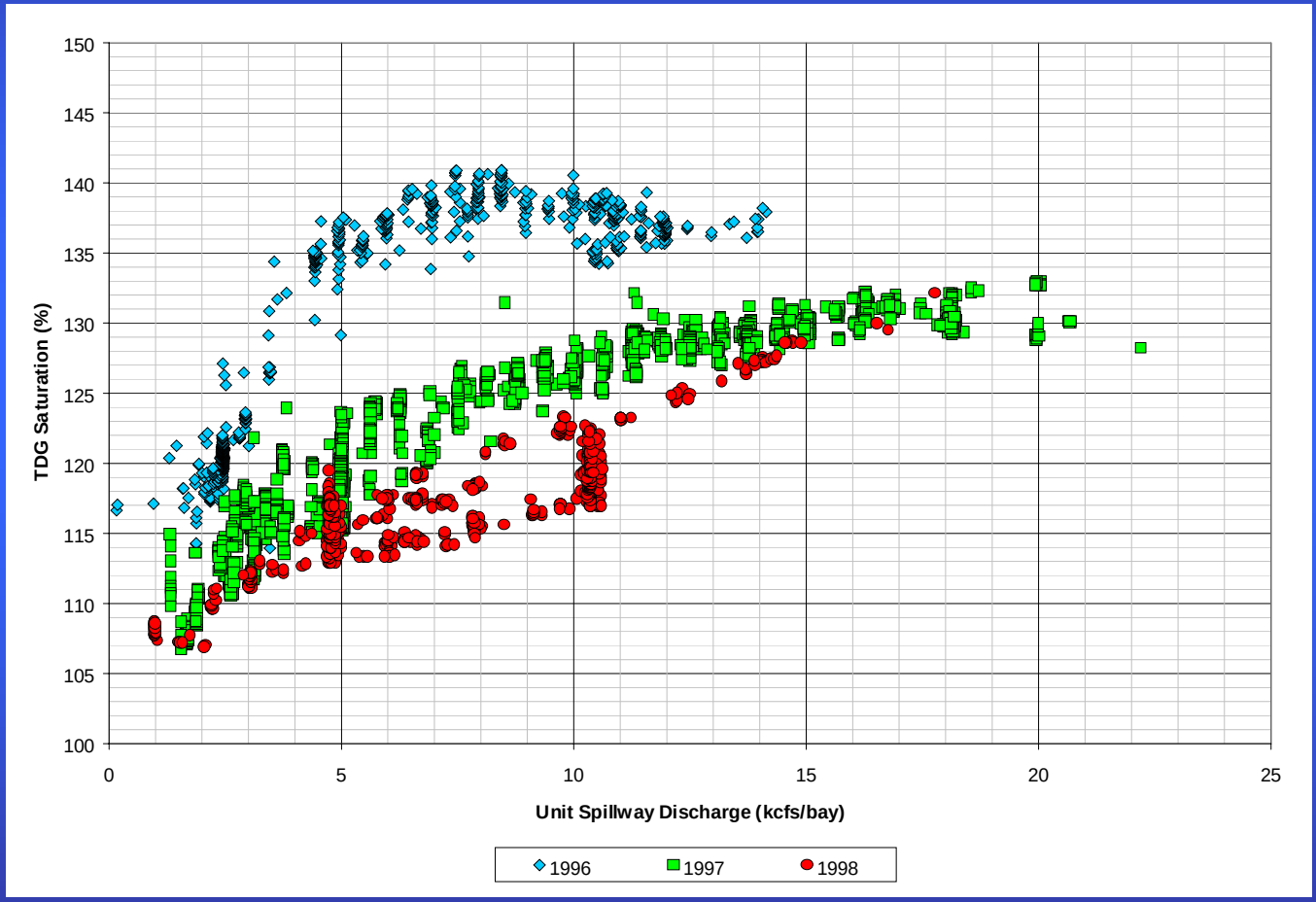
Total Dissolved Gas Exchange Near-Field Processes

- TDG Exchange Functional Relationships
  - Structural Configuration
    - Spillway Gate
    - Spillway Design
      - Flow Deflectors
      - Piers
    - Stilling Basin
      - Depth and Length
      - Endsill and baffle blocks
    - Location and Orientation of Powerhouse

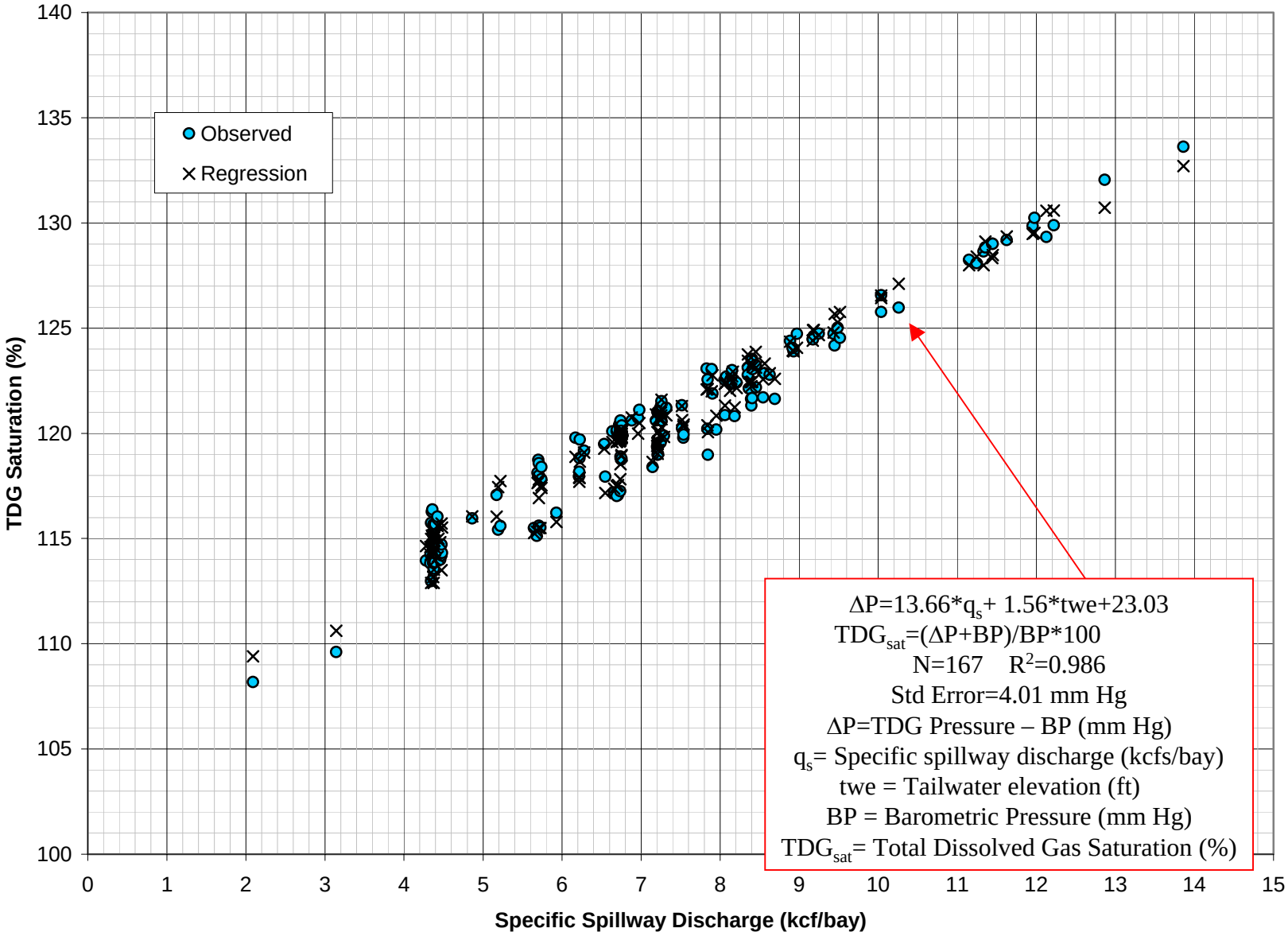
Total Dissolved Gas Exchange Near-Field Processes

- TDG Exchange Functional Relationships
  - Bathymetry
    - Tailwater Channel
- Other parameters ***weakly*** coupled to TDG exchange
  - Total Project Head
  - Water Temperature
  - Initial TDG Pressure

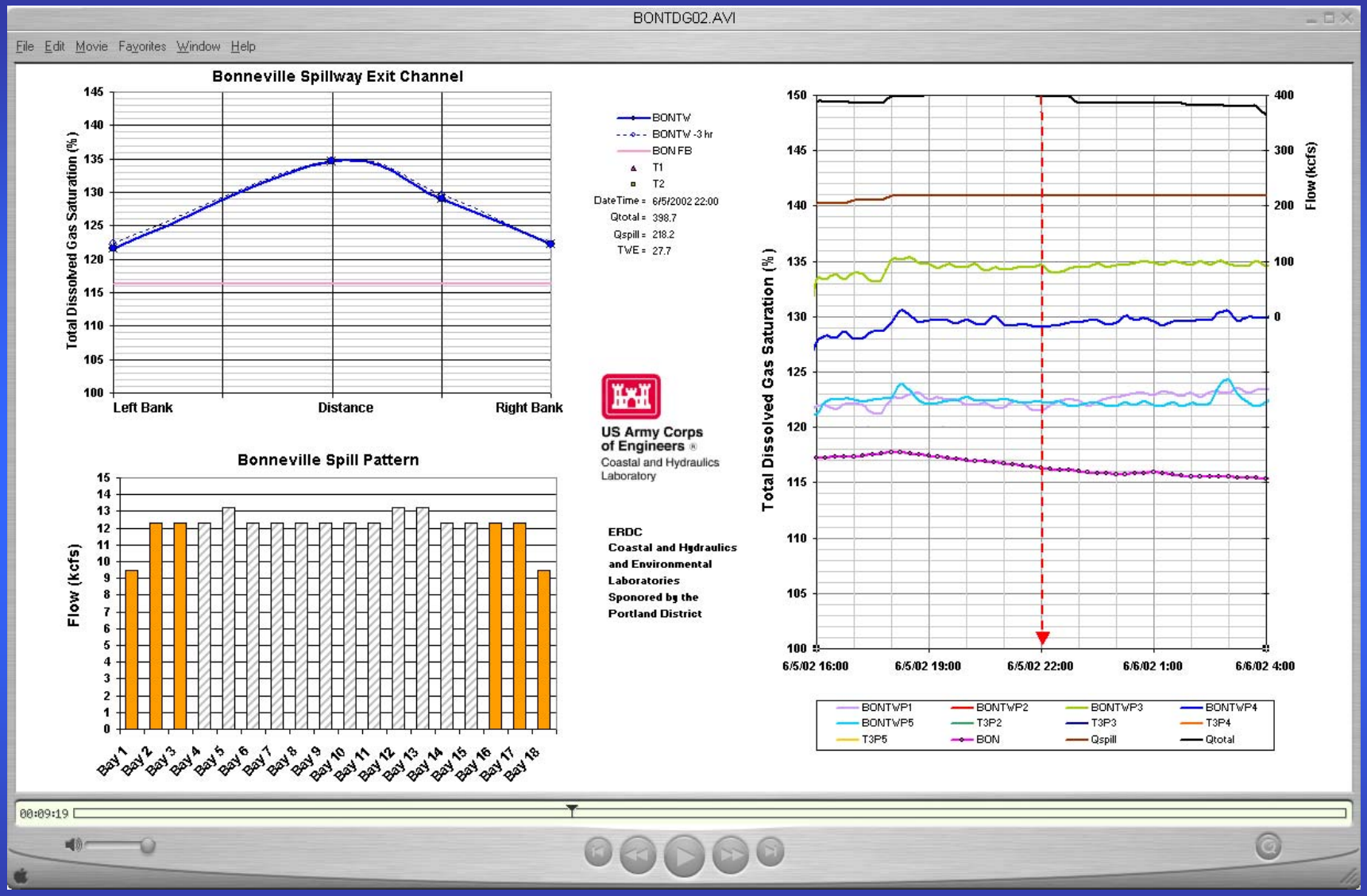
Total Dissolved Gas Exchange Near-Field Measurements



TDG Saturation as a Function of Unit Spillway Discharge at Ice Harbor Dam (1996-No Deflectors, 1997-4 Deflectors, 1998-8 Deflectors)



Observed and calculated average cross-sectional total dissolved gas saturation in the Bonneville spillway exit channel as a function of tailwater elevation and unit spillway discharge by event

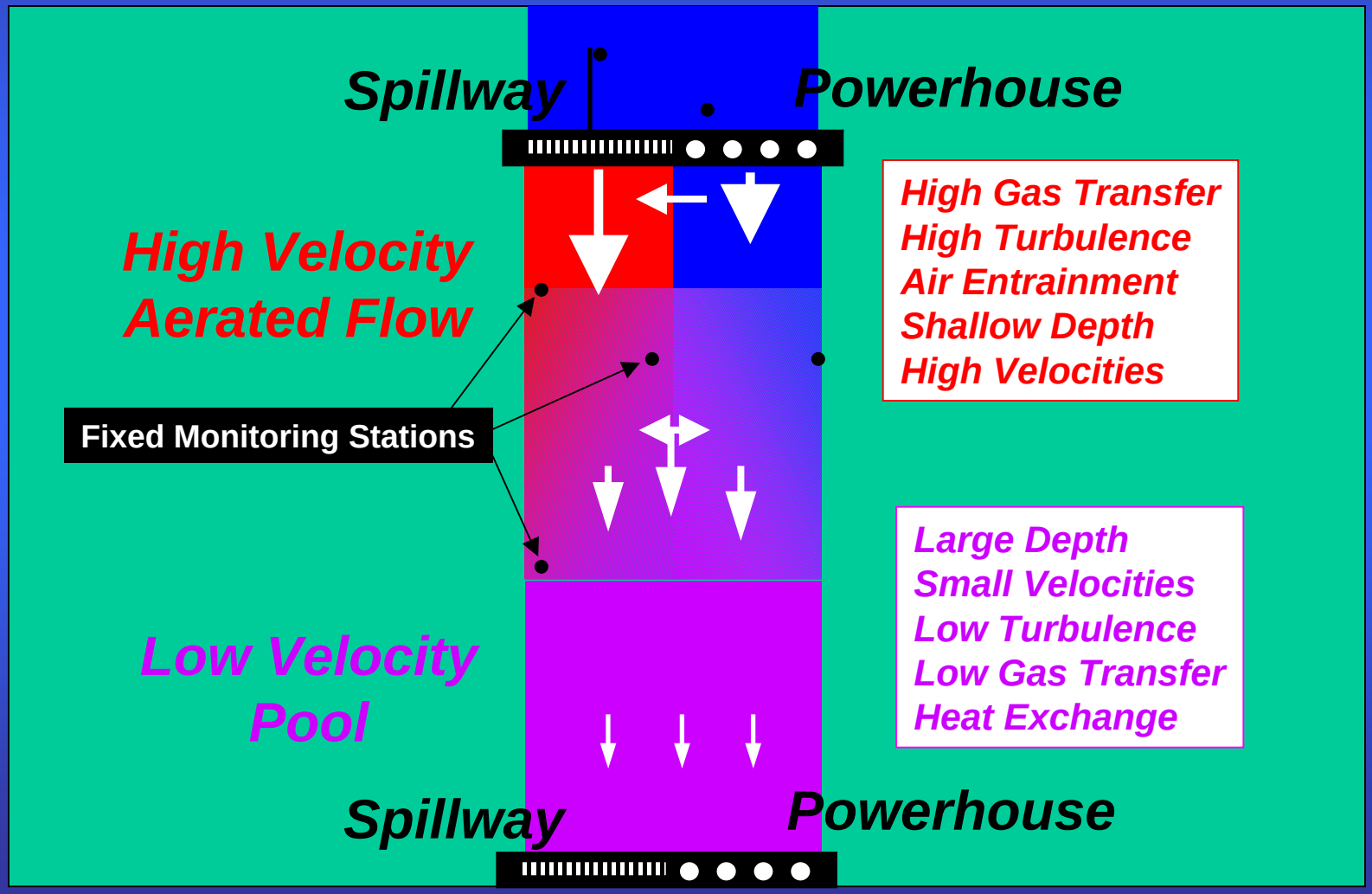

BONTDG02.AVI
File Edit Movie Favorites Window Help
Bonneville Spillway Exit Channel
Total Dissolved Gas Saturation (%)
Left Bank
Distance
Right Bank
BONTW
BONTW -3 hr
BON FB
T1
T2
DateTime = 6/5/2002 22:00
Qtotal = 398.7
Qspill = 218.2
TWE = 27.7
US Army Corps of Engineers
Coastal and Hydraulics Laboratory
ERDC
Coastal and Hydraulics and Environmental Laboratories
Sponored by the Portland District
Bonneville Spill Pattern
Flow (kcfs)
Bay 1 Bay 2 Bay 3 Bay 4 Bay 5 Bay 6 Bay 7 Bay 8 Bay 9 Bay 10 Bay 11 Bay 12 Bay 13 Bay 14 Bay 15 Bay 16 Bay 17 Bay 18
Total Dissolved Gas Saturation (%)
Flow (kcfs)
6/5/02 16:00
6/5/02 19:00
6/5/02 22:00
6/6/02 1:00
6/6/02 4:00
BONTWP1
BONTWP2
BONTWP3
BONTWP4
BONTWP5
T3P2
T3P3
T3P4
T3P5
BON
Qspill
Qtotal
00:09:19

Total Dissolved Gas Exchange In-Pool Processes

- Transport and Mixing
  - Dispersion
  - Mixing Zone Development
- Surface Heat Exchange
- Air/water TDG Exchange
  - Wind/Water interaction
- Biological/Chemical Processes
- Tributary Inflow

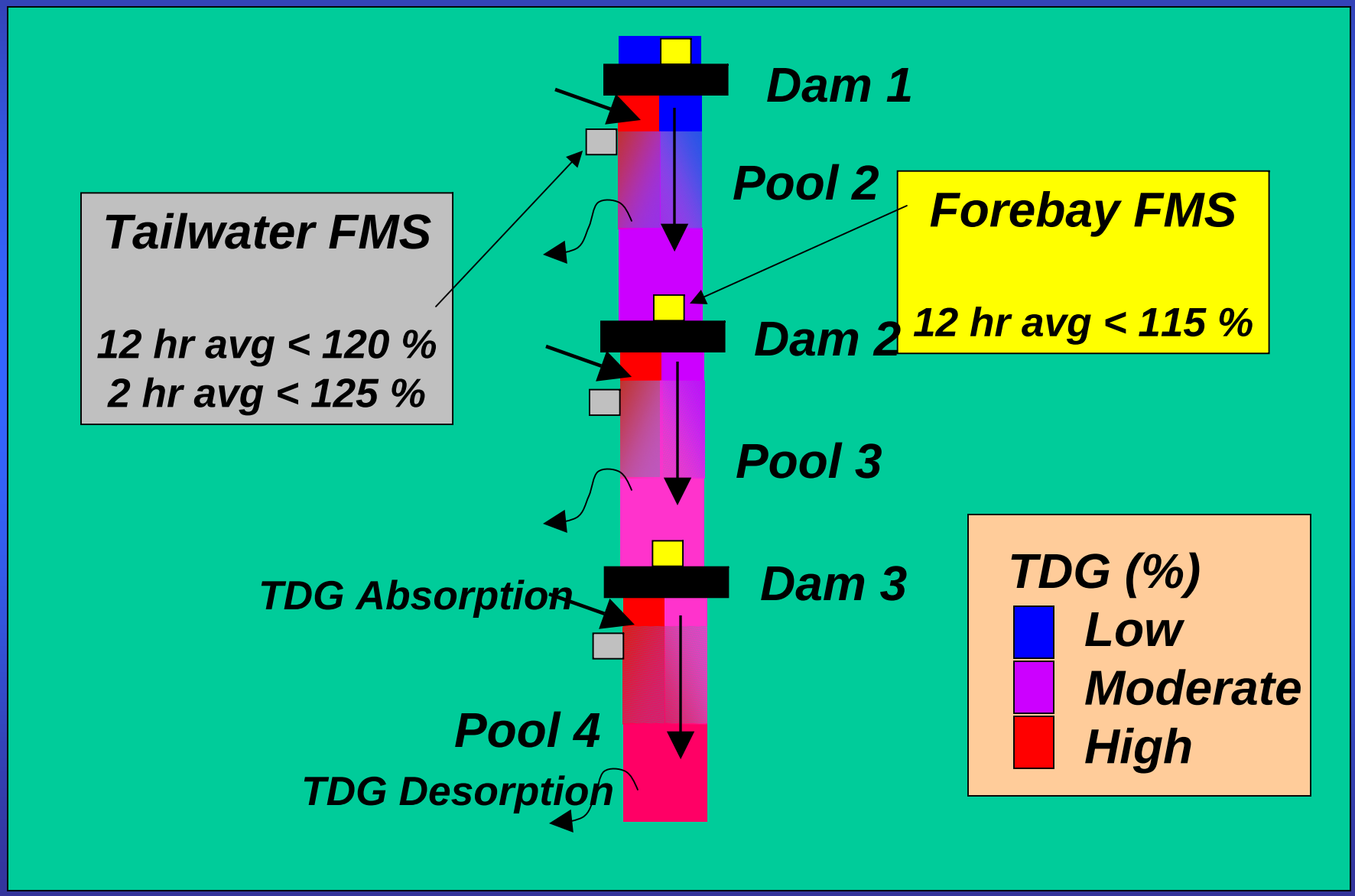
Total Dissolved Gas Exchange

In- Pool Processes

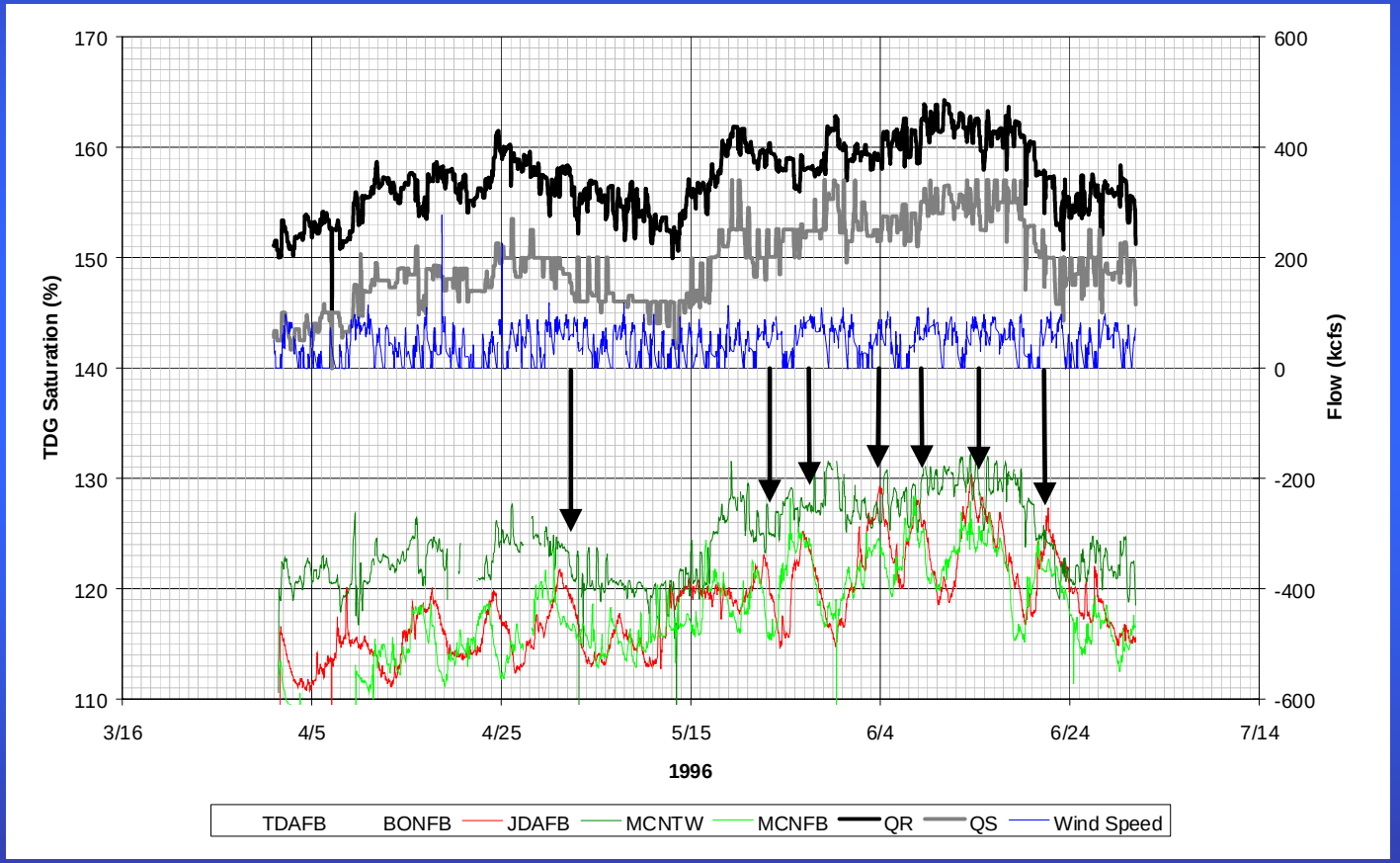


Total Dissolved Gas Exchange

TDG System Properties and Spill Management

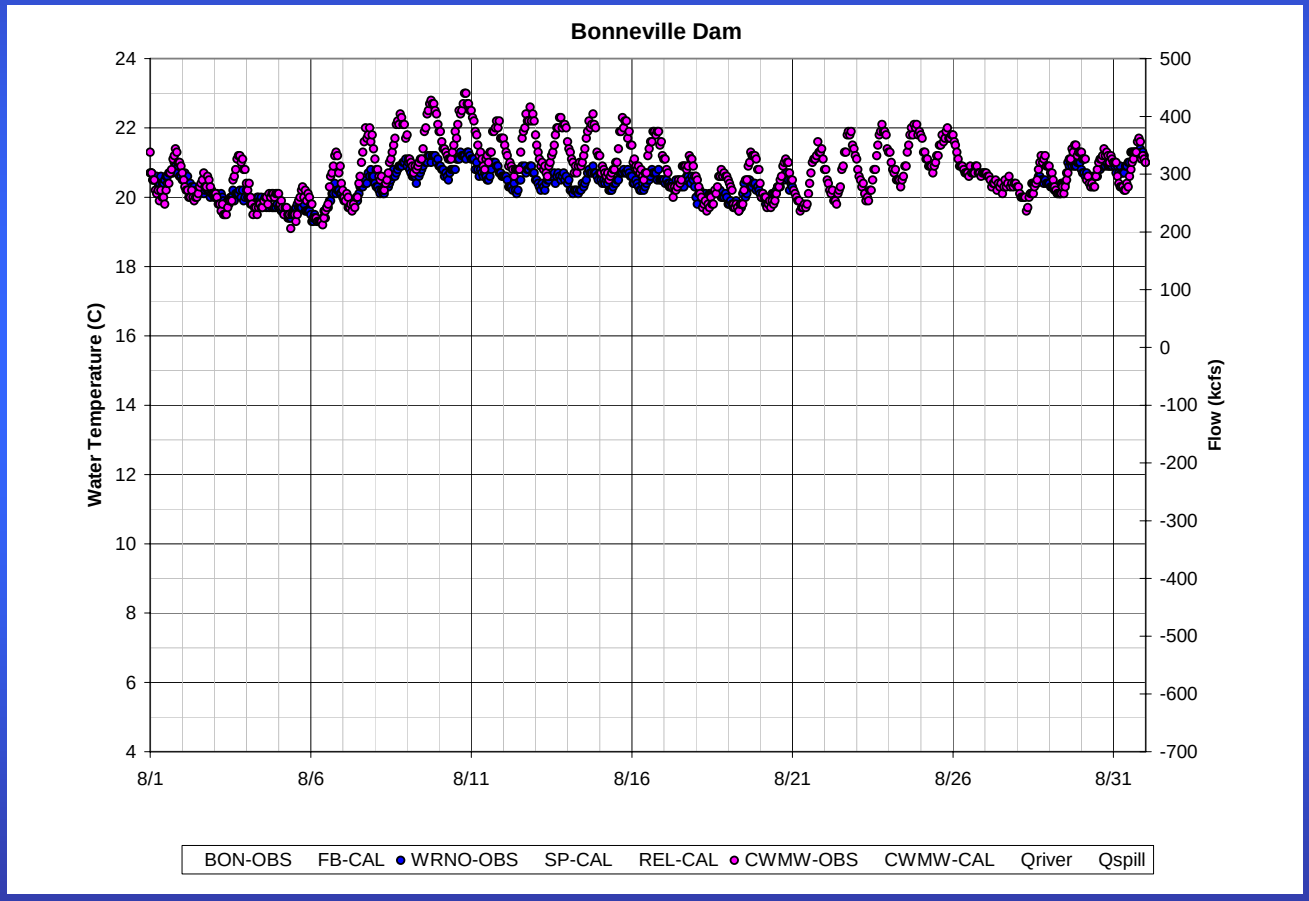


Total Dissolved Gas Exchange and Mixing: In-Pool Processes



Wind and TDG Saturation at McNary and John Day Dams, Spring 1997

Total Dissolved Gas Exchange and Mixing: In-Pool Processes



Water Temperatures at Camas and Warrendale Fixed Monitoring Stations, July 1996

Forrest Gump's Conceptual Model of Columbia River Total Dissolved Gas Processes

Supersaturated

Becomes warm and flat if left unattended

"Life is like a box of chocolates. You never know what your are going to get."