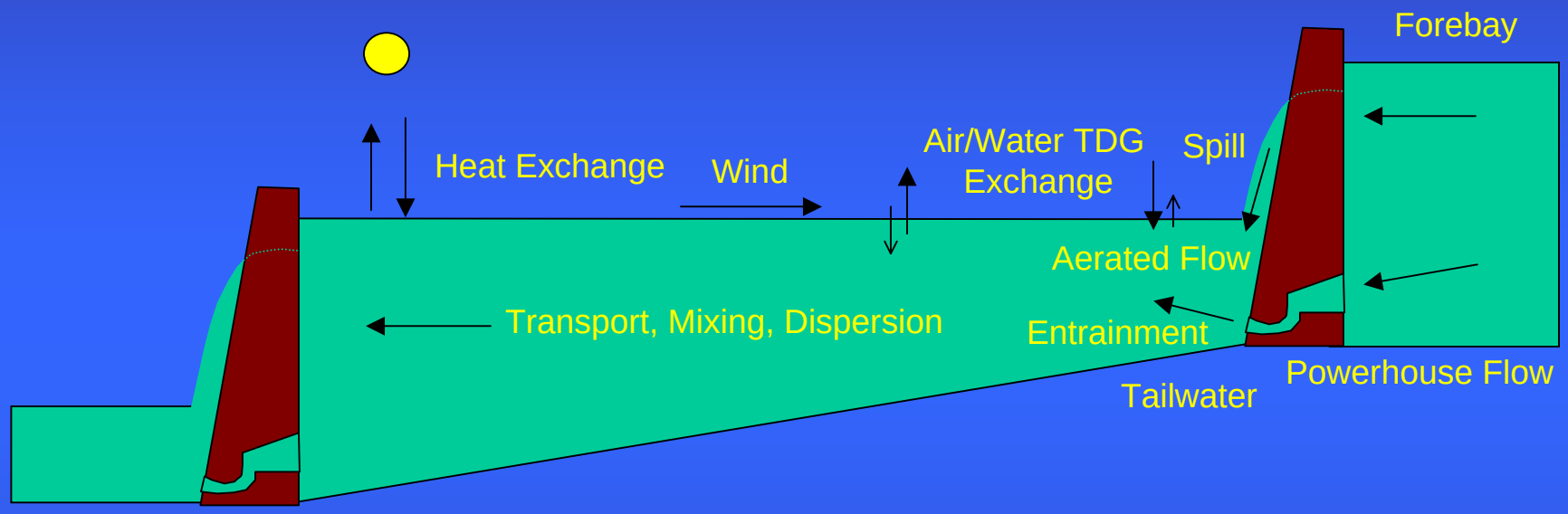
Total Dissolved Gas Decision Support Workshop
SYSTDG Workbook Overview



by
Mike Schneider
US Army Corps of Engineers

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- TDG Models
  - Hydrodynamic and Water Quality Models
  - Governing Equations
    - Momentum, Energy, and Mass
  - Temporal and Spatial Resolution
    - 1 Dimensional
    - 2 Dimensional
  - Solution Techniques

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- SYSTDG Model Capabilities
  - Prediction/Forecasting TDG Pressures in Project Flows
    - Operational
    - Structural
    - Hydrologic Conditions
  - Process Description
  - Real Time Spill Management
    - Minimize TDG
    - Generation Constraints
  - Quality Control Fixed Monitoring System

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- Model Limitations
  - Not Suited for Water Control Simulations
  - Simple Transport Routine
  - No Simulation of Heat Budget
  - Spatial Resolution Limited

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- Approach
  - Empirical TDG Model Developed for Each Dam
    - Intuition was used to develop the independent variables
    - Regressions used to determine equation constants
  - Powerhouse and Spillway Releases Treated Separately
    - Powerhouse Flow
      - Forebay Pressures Delivered Through The Powerhouse
      - Entrainment into Bubbly Flow Qe
      - Residual Qph-Qe Enters into the Lower Pool

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- Approach
  - Spillway Flows $\Delta P = f(q_s, D_{tw})$
    - Composite of Deflectored and Non-Deflectored Bays
    - Spill Pattern - Specific Discharge (qs)
    - Total River Flow - Tailwater Depth (Dtw)
    - Entrained Powerhouse Flows Acquire Spill Flow TDG Pressures

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- Approach
  - TDG Production at Dams
    - Spillway
    - Powerhouse
  - TDG Transport
    - Degassing
    - Temperature
  - Network Reaches Make up System
    - Ledger of Flow and TDG Pressure
    - Spreadsheet Basis
    - Prediction of TDG upstream and downstream of Dam

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- 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 120-Grand Coulee Dam
    - Snake River RM 140
  - Boundary Conditions
    - Historic TDG Loading at GCL and LGW

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

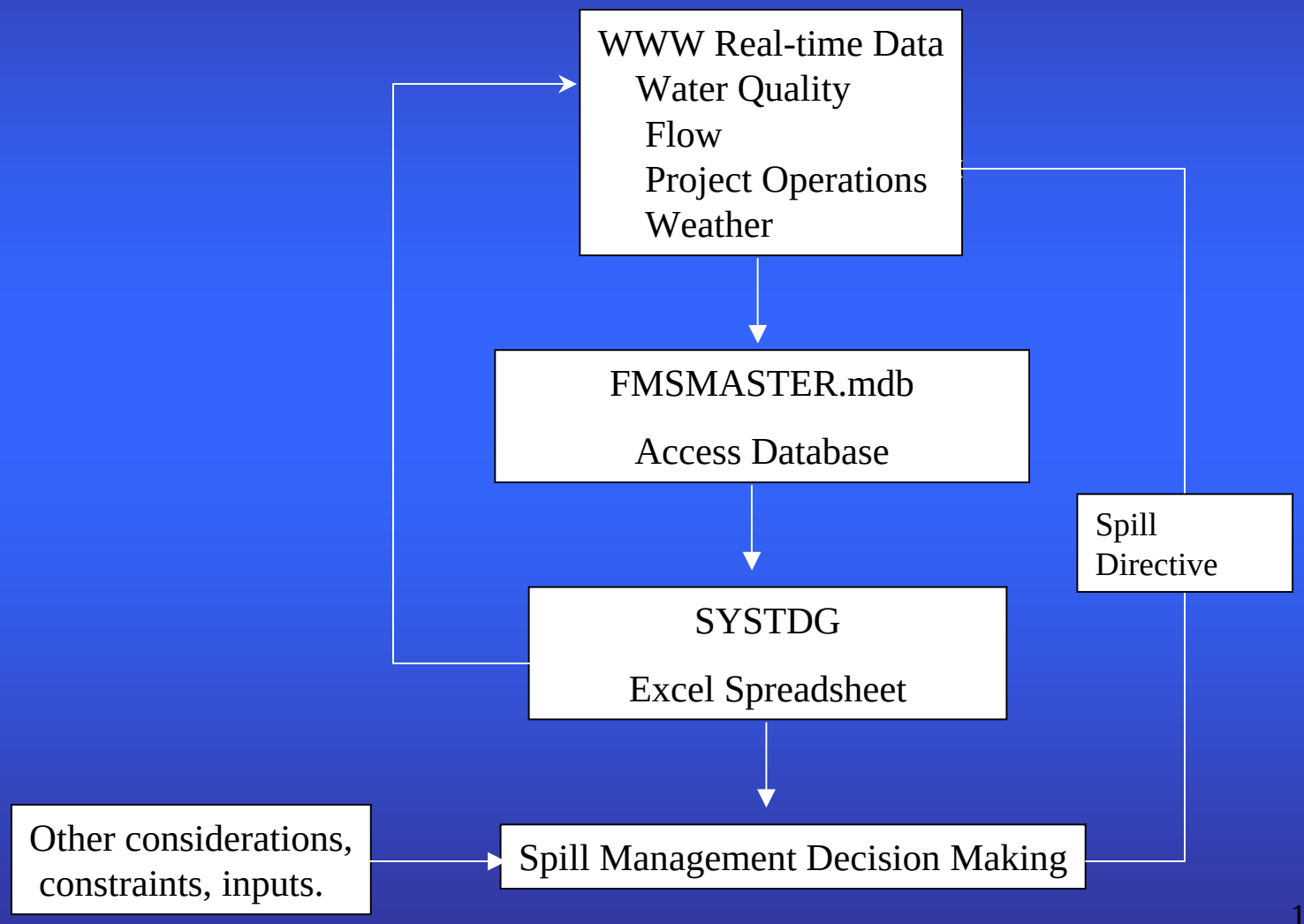
- Approach
  - Spreadsheet (MS Excel 2000)
    - Visual Basic Routines
    - Interactive Graphical Output
    - Statistical Output
    - Database Interaction
    - Commonly Available
    - Ease of Use
    - Computationally Efficient

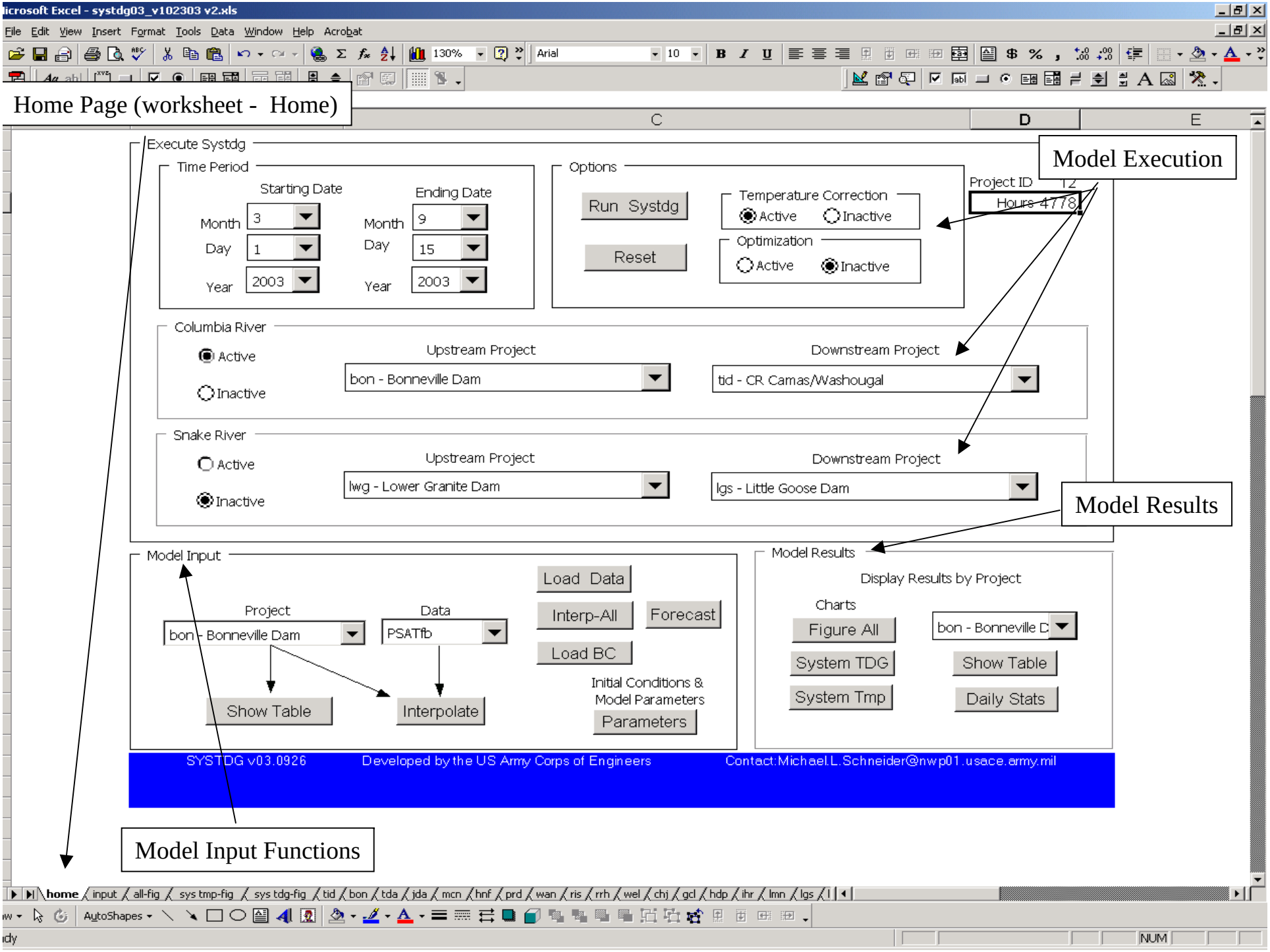
Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

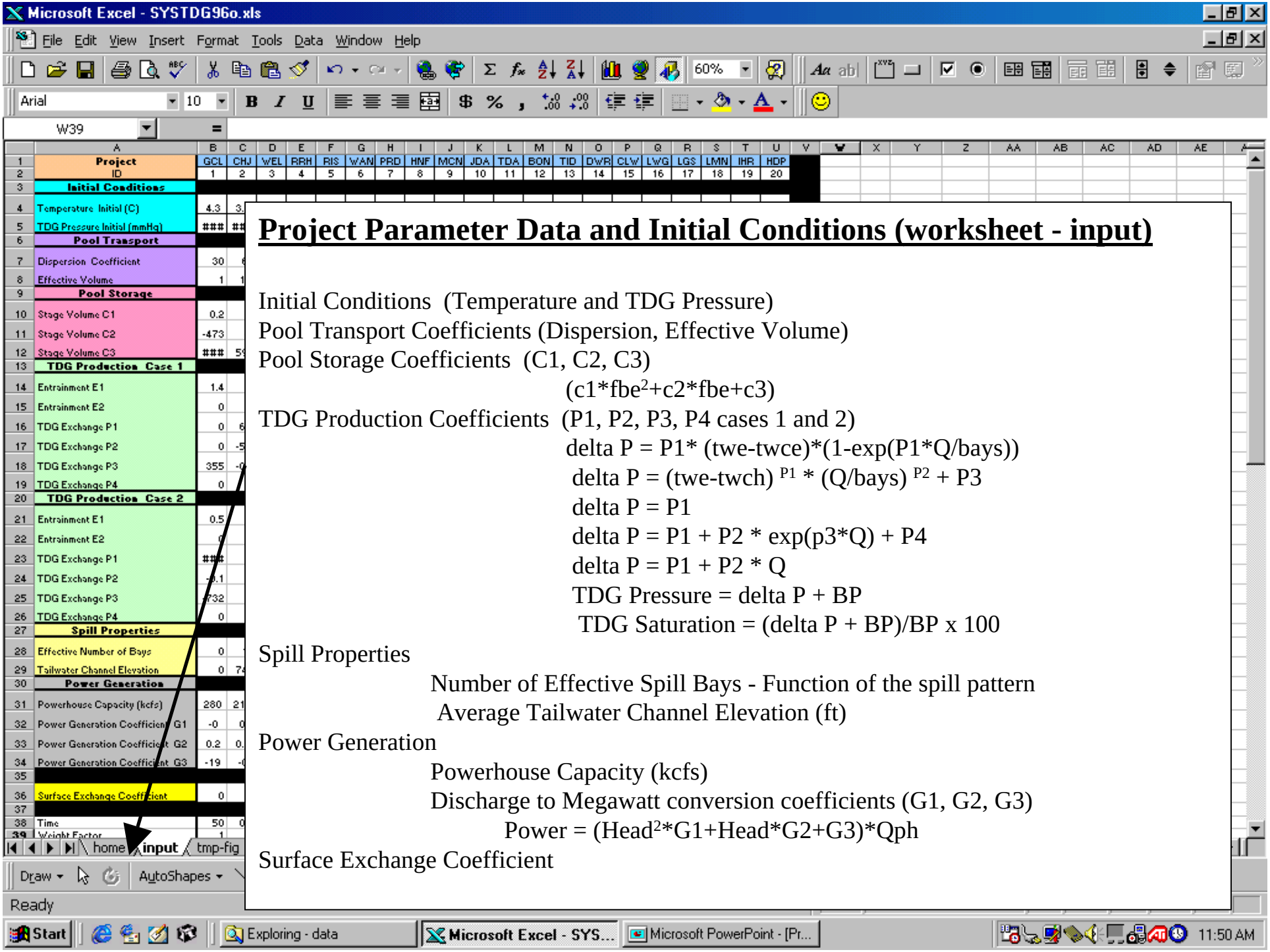
- Results
  - Model Output (hourly)
    - TDG Pressure
      - Spillway
      - Powerhouse
      - Aggregate
    - Water Temperature
    - Project Operations - Optimization
    - Graphs Observed and Calculated Data
    - Statistical Summary

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

Decision Support Flow Chart




Microsoft Excel - systdg03_v102303 v2.xls
File Edit View Insert Format Tools Data Window Help Acrobat
Home Page (worksheet - Home)
Execute Systdg
Time Period
Starting Date
Ending Date
Month 3
Day 1
Year 2003
Month 9
Day 15
Year 2003
Options
Run Systdg
Reset
Temperature Correction
Active
Inactive
Optimization
Active
Inactive
Project ID
Hours 4778
Model Execution
Columbia River
Active
Inactive
Upstream Project
bon - Bonneville Dam
Downstream Project
tid - CR Camas/Washougal
Snake River
Active
Inactive
Upstream Project
lwg - Lower Granite Dam
Downstream Project
lgs - Little Goose Dam
Model Results
Model Input
Project
bon - Bonneville Dam
Data
PSATfb
Load Data
Interp-All
Forecast
Load BC
Show Table
Interpolate
Initial Conditions &
Model Parameters
Parameters
Model Results
Display Results by Project
Charts
Figure All
System TDG
System Tmp
bon - Bonneville D
Show Table
Daily Stats
SYSTDG v03.0926
Developed by the US Army Corps of Engineers
Contact:Michael.L.Schneider@nwp01.usace.army.mil
Model Input Functions



Project Parameter Data and Initial Conditions (worksheet - input)

Initial Conditions (Temperature and TDG Pressure)

Pool Transport Coefficients (Dispersion, Effective Volume)

Pool Storage Coefficients (C1, C2, C3)

$(c1*fbe^2+c2*fbe+c3)$

TDG Production Coefficients (P1, P2, P3, P4 cases 1 and 2)

delta P = P1* (twe-twce)*(1-exp(P1*Q/bays))

delta P = $(twe-twch)^{P1} * (Q/bays)^{P2} + P3$

delta P = P1

delta P = P1 + P2 * exp(p3*Q) + P4

delta P = P1 + P2 * Q

TDG Pressure = delta P + BP

TDG Saturation = (delta P + BP)/BP x 100

Spill Properties

Number of Effective Spill Bays - Function of the spill pattern

Average Tailwater Channel Elevation (ft)

Power Generation

Powerhouse Capacity (kcfs)

Discharge to Megawatt conversion coefficients (G1, G2, G3)

Power = $(Head^2*G1+Head*G2+G3)*Qph$

Surface Exchange Coefficient

Microsoft Excel

File Edit View Insert Format Tools Data Window Help

SYSTDG96o.xls

	A	B	C	D	E	F	G	H	I	J	K
1	Time	Wind	FBE	TWE	Qtotal	Qspill	BP	TMP	Qtr	TMPtr	TDGtr
2	4/1/96 12:00 AM		16.41415	19.5	239	49.7	752	7.2			
3	4/1/96 1:00 AM		16.41415	19.5	239	49.7	751	7.3			
23	4/1/96 9:00 PM		17.1082	20.2	239.7	53.5	753	8.1			
24	4/1/96 10:00 PM		17.43455	20.5	236.6	70.7	755	7.7			
25	4/1/96 11:00 PM		17.262	20.5	256.9	70.9	756	7.9			
26	4/2/96 12:00 AM		16.92375	20.2	261.4	66.1	754	7.8			
27	4/2/96 1:00 AM		17.6722	20.9	255.7	49.9	755	7.8			
28	4/2/96 2:00 AM		17.3671	20.6	256.3	49.8	756	7.7			
29	4/2/96 3:00 AM		17.1912	20.3	241.7	49.8	756	7.5			

home / input / tmp-fig / tdg-fig / pres-fig / tid / bon / tda / jda / Chart1 / mcn / hnf / prd / wan / ris / rr

Hourly Project Input Data - Project Worksheet

Lower Columbia

tid - Columbia River
bon- Bonneville Dam
tda - The Dalles Dam
jda - John Day Dam
mcn - McNary Dam

Mid-Columbia

gcl-Grand Coulee Dam
chj-Chief Joseph Dam
wel-Wells Dam
rrb-Rocky Reach Dam
ris-Rock Island Dam
wan-Wanapum Dam
prd-Priest Rapids Dam
hnf-Columbia River Hanford Reach

Snake River

hdp - Snake River bl IHR
ihr - Ice Harbor Dam Dam
lmn- Lower Monumental
lgs - Little Goose Dam Dam
lwg - Lower Granite
clw - Clearwater River
dwr - Dworshak Dam

Ready

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Microsoft Excel

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B1 = Wind

SYSTDG96o.xls

	A	B	C	D	E	F	G	H	I	J	K
1	Time	Wind	FBE	TWE	Qtotal	Qspill	BP	TMP	Qtr	TMPtr	TDGtr
2	4/1/96 12:00 AM	41.0	338.0	266.2	220.4	67.2	748.5	6.5	4.3	6.5	748.5
3	4/1/96 1:00 AM	20.0	338.0	266.2	220.4	67.2	748.5	6.5	4.3	6.5	748.5
4	4/1/96 2:00 AM	41.0	338.1	266.7	227.2	67.2	748.5	6.5	4.3	6.5	748.5
5	4/1/96 3:00 AM	0.0	338.1	266.9	230.8	67.2	748.5	6.5	4.3	6.5	748.5
6	4/1/96 4:00 AM	0.0	338.2	267.0	230.8	67.2	748.5	6.5	4.3	6.5	748.5
7	4/1/96 5:00 AM	51.0	338.2	267.0	230.8	67.2	748.5	6.5	4.3	6.5	748.5
8	4/1/96 6:00 AM	30.0	338.3	267.1	230.8	67.2	748.5	6.5	4.3	6.5	748.5
9	4/1/96 7:00 AM	20.0	338.3	267.1	230.8	67.2	748.5	6.5	4.3	6.5	748.5
10	4/1/96 8:00 AM	20.0	338.4	267.0	214.4	49.7	748.5	6.5	4.3	6.5	748.5
11	4/1/96 9:00 AM	20.0	338.3	266.9	213.2	49.7	748.5	6.5	4.3	6.5	748.5
12	4/1/96 10:00 AM	18.3	338.3	266.9	214.4	49.7	748.5	6.5	4.3	6.5	748.5
13	4/1/96		338.5	266.3	208.7						
14	4/1/96		338.5	266.3	199.8						
15	4/1/96 1:00 PM	20.0	338.5	266.3	200.8						
16	4/1/96 2:00 PM	25.0	338.6	266.2	200.4						
17	4/1/96 3:00 PM	25.0	338.7	266.3	200.4						
18	4/1/96 4:00 PM	36.0	338.8	266.0	200.5						
19	4/1/96 5:00 PM	51.0	338.9	266.1	200.5						
20	4/1/96 6:00 PM	0.0	339.0	266.0	205.6						
21	4/1/96 7:00 PM	30.0	339.1	265.9	202.8						
22	4/1/96 8:00 PM	36.0	339.0	266.8	267.0						
23	4/1/96 9:00 PM	33.0	339.1	267.1	267.5						
24	4/1/96 10:00 PM	30.0	339.1	267.1	267.5						
25	4/1/96 11:00 PM	35.5	339.0	267.0	267.5						
26	4/2/96 12:00 AM	41.0	338.9	266.9	267.5						
27	4/2/96 1:00 AM	30.0	338.9	266.9	258.2						
28	4/2/96 2:00 AM	36.0	338.6	267.0	254.8						
29	4/2/96 3:00 AM	30.0	338.5	267.1	255.3	99.9	743.3	6.3	5.4	6.3	743.3

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Hourly Data

Model Input Data (Blue)

Wind Speed (fps*10)- Column B
Forebay Water Surface Elevation (ft) - Column C
Tailbay Water Surface Elevation (ft) - Column D
Total River Flow (kcfs) - Column E
Spillway Flow (kcfs) - Column F
Barometric Pressure below Project - Column G
Water Temperature at Project - Column H
Tributary Flow (kcfs) - Column I
Tributary Water Temperature (C) - Column J
Tributary Total Dissolved Gas Pressure (mm Hg) - Column K

Draw AutoShapes

Ready

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Microsoft Excel

File Edit View Insert Format Tools Data Window Help

B2 = 41

SYSTDG96o.xls

	A	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1	Time	TMPfb	TDGfb	TDGsp	TDGrel	ATfb	PSATsp	PSATrel	Qsp-est	mcqo-tmp	mcqo-bp	mcqo-tdg	mcqo-psat	mcpw-tmp	mcpw-bp	mcpw-tdg	mcpw-psat
2	4/1/96 12:00 AM	6.5	834.6	851.3	840.6	111.5	113.7	112.3	0.0								
3	4/1/96 1:00 AM	6.5	834.2	851.3	840.3	111.4	113.7	112.3	6.4								
4	4/1/96 2:00 AM	6.5	834.0	851.3	840.1	111.4	113.7	112.2	7.0								
5	4/1/96 3:00 AM	6.5	833.6	851.3	839.8	111.4	113.7	112.2	6.9								
6	4/1/96 4:00 AM	6.5	833.5	851.3	839.7	111.3	113.7	112.2	4.6								
7	4/1/96 5:00 AM	6.5	833.4	851.3	839.6	111.3	113.7	112.2	0.9								
8	4/1/96 6:00 AM	6.5	832.8	851.3	839.3	111.3	113.7	112.1	1.5								
9	4/1/96 7:00 AM	6.5	832.6	851.3	839.2	111.2	113.7	112.1	0.0								
10	4/1/96 8:00 AM	6.5	832.5	840.2	833.9	111.2	112.2	111.4	0.0								
11	4/1/96 9:00 AM	6.5	832.5	840.2	833.8	111.2	112.2	111.4	0.8								
12	4/1/96 10:00 AM	6.5	832.4	840.2	833.8	111.2	112.2	111.4	1.3								
13	4/1/96 11:00 AM	6.5	832.3	840.2	833.8	111.2	112.2	111.4	1.5								
14	4/1/96 12:00 PM	6.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
15	4/1/96 1:00 PM	6															120.0
16	4/1/96 2:00 PM	6															119.5
17	4/1/96 3:00 PM	6															119.4
18	4/1/96 4:00 PM	6															119.1
19	4/1/96 5:00 PM	6															119.1
20	4/1/96 6:00 PM	6															119.1
21	4/1/96 7:00 PM	6															118.8
22	4/1/96 8:00 PM	6															122.2
23	4/1/96 9:00 PM	6															122.4
24	4/1/96 10:00 PM	6															122.3
25	4/1/96 11:00 PM	6															122.2
26	4/2/96 12:00 AM	6															122.1
27	4/2/96 1:00 AM	6															121.6
28	4/2/96 2:00 AM	6															122.0
29	4/2/96 3:00 AM	6															122.6
30	4/2/96 4:00 AM	6															122.7
31	4/2/96 5:00 AM	6															122.9
32	4/2/96 6:00 AM	6															122.5
33	4/2/96 7:00 AM	6															122.6
34	4/2/96 8:00 AM	6.4	828.9	857.2	840.2	111.1	114.9	112.6	12.6	5.5	749.3	823.3	109.9	6.7	754.1	925.5	122.7
35	4/2/96 9:00 AM	6.4	828.7	857.8	840.4	111.0	114.9	112.5	12.6	5.5	750.0	823.2	109.8	6.8	754.7	926.5	122.8
36	4/2/96 10:00 AM	6.4	828.4	858.1	840.8	110.9	114.9	112.6	3.3	5.6	750.3	823.5	109.8	6.8	755.0	921.9	122.1

Calculated Data (Pink)

TMPfb-Forebay Water Temperature (C) at the forebay of the current project-Column L.

TDGfb- Total Dissolved Gas Pressure (mm Hg) at the forebay of the current project-Column M.

TDGsp- Total Dissolved Gas Pressure (mm Hg) in spillway release only -Column N.

TDGrel- Total Dissolved Gas Pressure (mm Hg) Average of all project releases-Column O.

PSATfb- Total Dissolved Gas Pressure (mm Hg) at the forebay of the current project-Column P.

PSATsp- Total Dissolved Gas Pressure (mm Hg) in spillway release only-Column Q.

PSATrel- Total Dissolved Gas Pressure (mm Hg) Average of all project releases-Column R

Qsp-est - Estimated Spillway Discharge (kcfs) - Column S.

Ready

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Microsoft Excel

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	A	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1	Time	TMPfb	TDGfb	TDGsp	TDGrel	PSATfb	PSATsp	PSATrel	Qsp-est	mcqo-tmp	mcqo-bp	mcqo-tdg	mcqo-psat	mcpw-tmp	mcpw-bp	mcpw-tdg	mcpw-psat
2	4/1/96 12:00 AM	6.5	834.6	851.3	840.6	111.5	113.7	112.3	0.0								
3	4/1/96 1:00 AM	6.5	834.2	851.3	840.3	111.4	113.7	112.3	6.4								
4	4/1/96 2:00 AM	6.5	834.0	851.3	840.1	111.4	113.7	112.2	7.0								
5	4/1/96 3:00 AM	6.5	833.6	851.3	839.8	111.4	113.7	112.2	6.9								
6	4/1/96 4:00 AM	6.5	833.5	851.3	839.7	111.3	113.7	112.2	4.6								
7	4/1/96 5:00 AM	6.5	833.4	851.3	839.6	111.3	113.7	112.2	0.9								
8	4/1/96 6:00 AM	6.5	832.8	851.3	839.3	111.3	113.7	112.1	1.5								
9	4/1/96 7:00 AM	6.5	832.6	851.3	839.2	111.2	113.7	112.1	0.0								
10	4/1/96 8:00 AM	6.5	832.5	840.2	833.9	111.2	112.2	111.4	0.0								
11	4/1/96 9:00 AM	6.5	832.5	840.2	833.8	111.2	112.2	111.4	0.8								
12	4/1/96 10:00 AM	6.5	832.4	840.2	833.8	111.2	112.2	111.4	1.3								
13	4/1/96 11:00 AM	6.5	832.3	840.2	833.8	111.2	112.2	111.4	1.5								
14	4/1/96 12:00 PM	6.5	832.2	840.2	833.8	111.2	112.2	111.4	1.4	5.7	743.7	834.6	112.2				
15	4/1/96 1:00 PM	6.4	832.2	840.2	833.7	111.2	112.2	111.4	7.2	5.7	743.8	834.5	112.2	6.5	748.5	897.9	120.0
16	4/1/96 2:00 PM	6.4	832.1	832.1	830.2	112.4	112.4	112.1	6.6	5.8	743.7	837.2	112.6	6.6	748.3	894.3	119.5
17	4/1/96 3:00 PM	6.4	832.0	831.6	829.9	112.4	112.4	112.2	6.6	5.9	743.2	837.8	112.7	6.7	747.7	893.0	119.4
18	4/1/96 4:00 PM	6.4	831.9	831.7	829.9	112.4	112.4	112.1	6.6	6.0	743.5	840.3	113.0	6.7	747.7	890.5	119.1
19	4/1/96 5:00 PM	6.4	831.7	831.8	829.8	112.4	112.4	112.1	6.9	6.2	743.5	842.9	113.4	6.7	747.6	890.2	119.1
20	4/1/96 6:00 PM	6.4	831.2	831.7	829.6	112.3	112.4	112.1	1.2	6.3	743.5	843.4	113.4	6.6	747.6	890.4	119.1
21	4/1/96 7:00 PM	6.4	831.1	831.9	829.6	112.3	112.4	112.1	1.6	6.1	743.6	840.6	113.0	6.6	747.8	888.7	118.8
22	4/1/96 8:00 PM	6.4	831.0	863.4	845.7	112.2	116.6	114.2	35.0	6.2	743.9	840.1	112.9	6.6	748.3	914.1	122.2
23	4/1/96 9:00 PM	6.4	830.8	863.9	84											16.4	122.4
24	4/1/96 10:00 PM	6.4	830.6	864.2	84											15.9	122.3
25	4/1/96 11:00 PM	6.4	830.5	864.9	84											16.5	122.2
26	4/2/96 12:00 AM	6.4	830.3	865.4	84											16.5	122.1
27	4/2/96 1:00 AM	6.4	830.0	865.3	84											13.2	121.6
28	4/2/96 2:00 AM	6.4	829.9	865.9	84											16.2	122.0
29	4/2/96 3:00 AM	6.4	829.7	866.0	84											20.9	122.6
30	4/2/96 4:00 AM	6.4	829.6	866.3	84											22.4	122.7
31	4/2/96 5:00 AM	6.4	829.5	866.9	84											24.1	122.9
32	4/2/96 6:00 AM	6.4	829.2	855.9	83											22.0	122.5
33	4/2/96 7:00 AM	6.4	829.1	856.7	84											23.7	122.6
34	4/2/96 8:00 AM	6.4	828.9	857.2	84											25.5	122.7
35	4/2/96 9:00 AM	6.4	828.7	857.8	84											26.5	122.8
36	4/2/96 10:00 AM	6.4	828.4	858.1	84											21.9	122.1

home

Fixed Monitoring Station Observed Water Quality Data (Tan)

Forebay FMS Temperature (C) - Column T

Forebay FMS Barometric Pressure-Column U

Forebay FMS Total Dissolved Gas Pressure- Column V

Forebay FMS Total Dissolved Gas Saturation - Column W

Tailwater FMS Temperature (C) - Column X

Tailwater FMS Barometric Pressure-Column Y

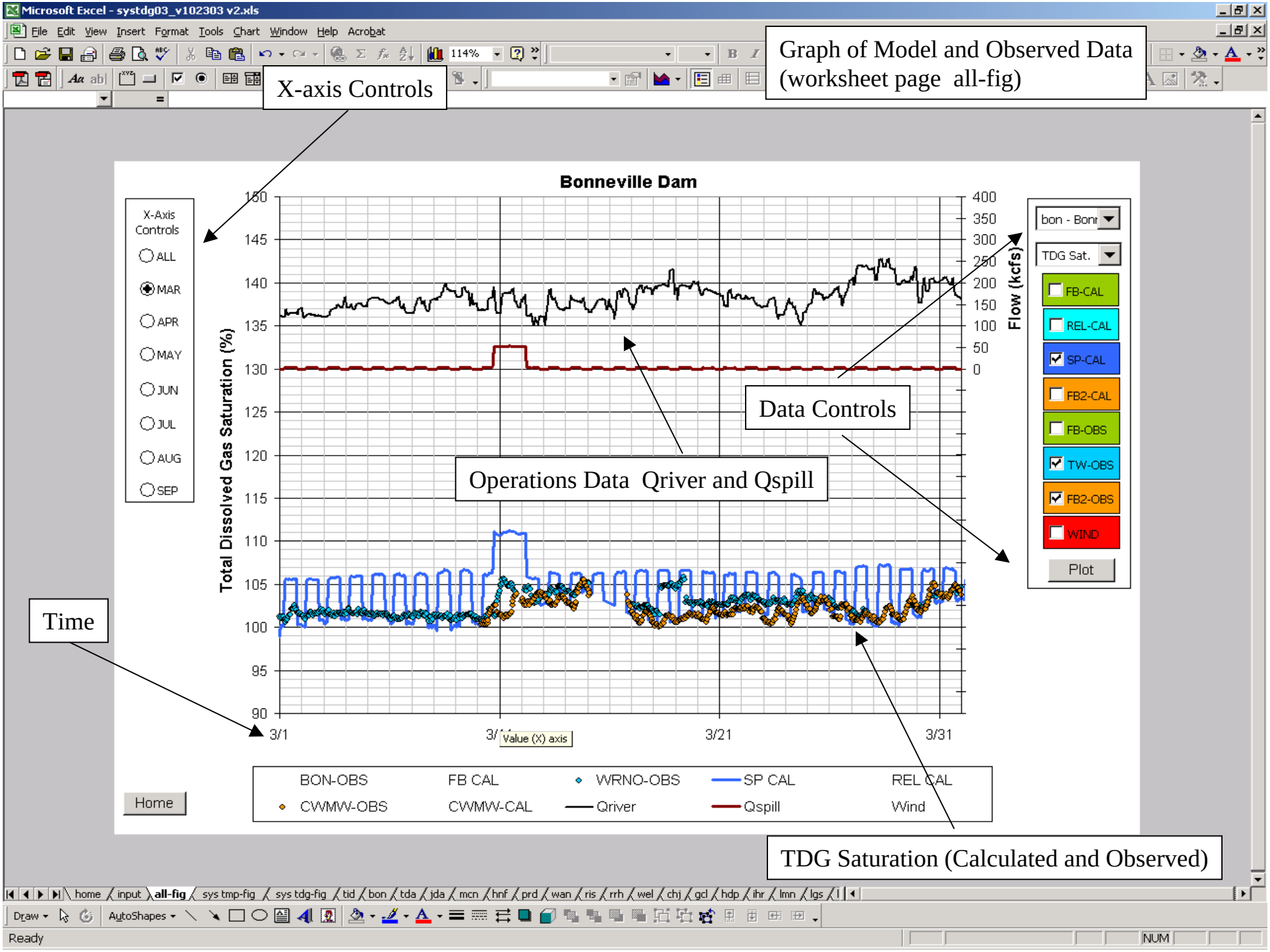
Tailwater FMS Total Dissolved Gas Pressure- Column Z

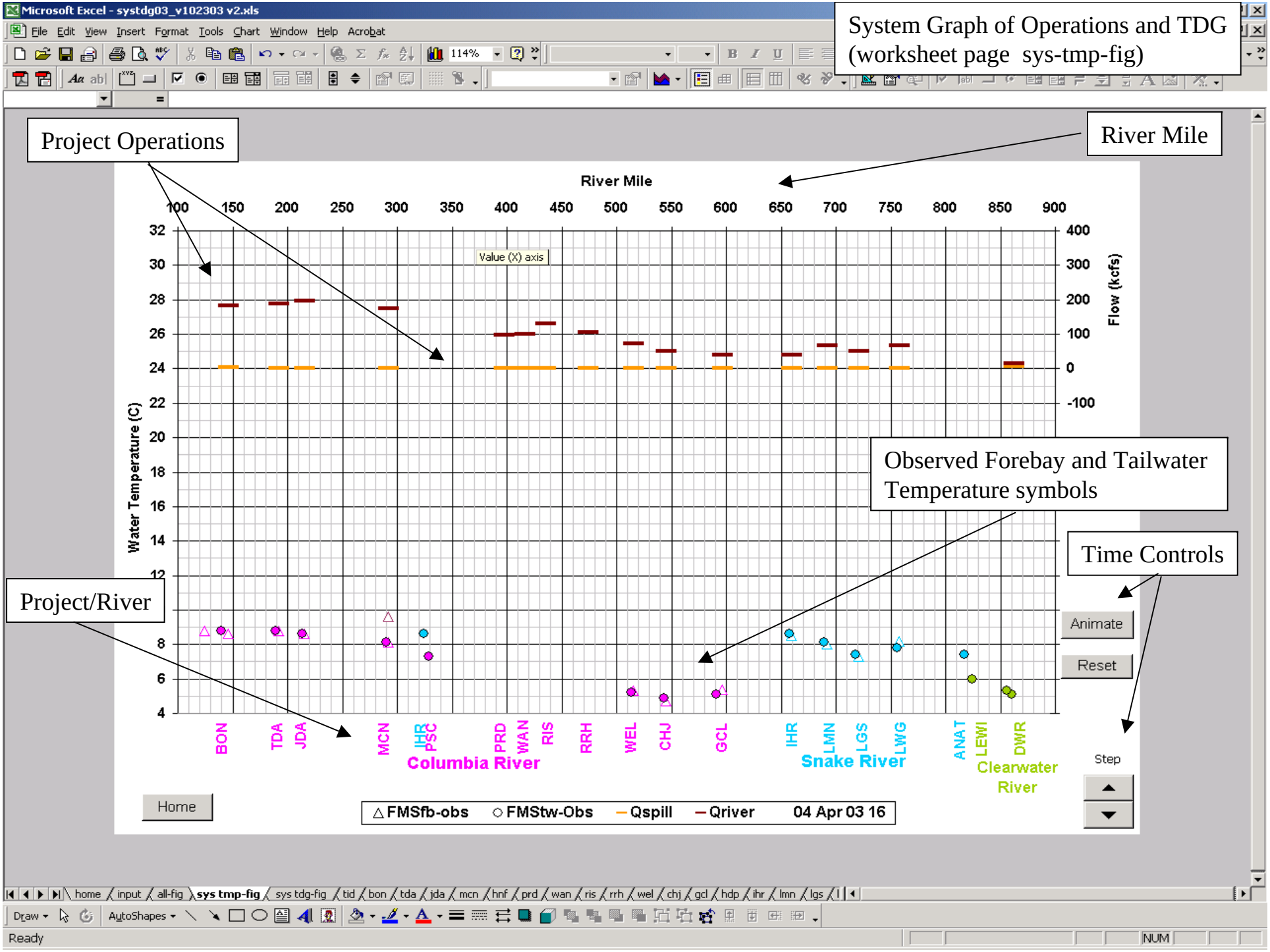
Tailwater FMS Total Dissolved Gas Saturation - Column AA

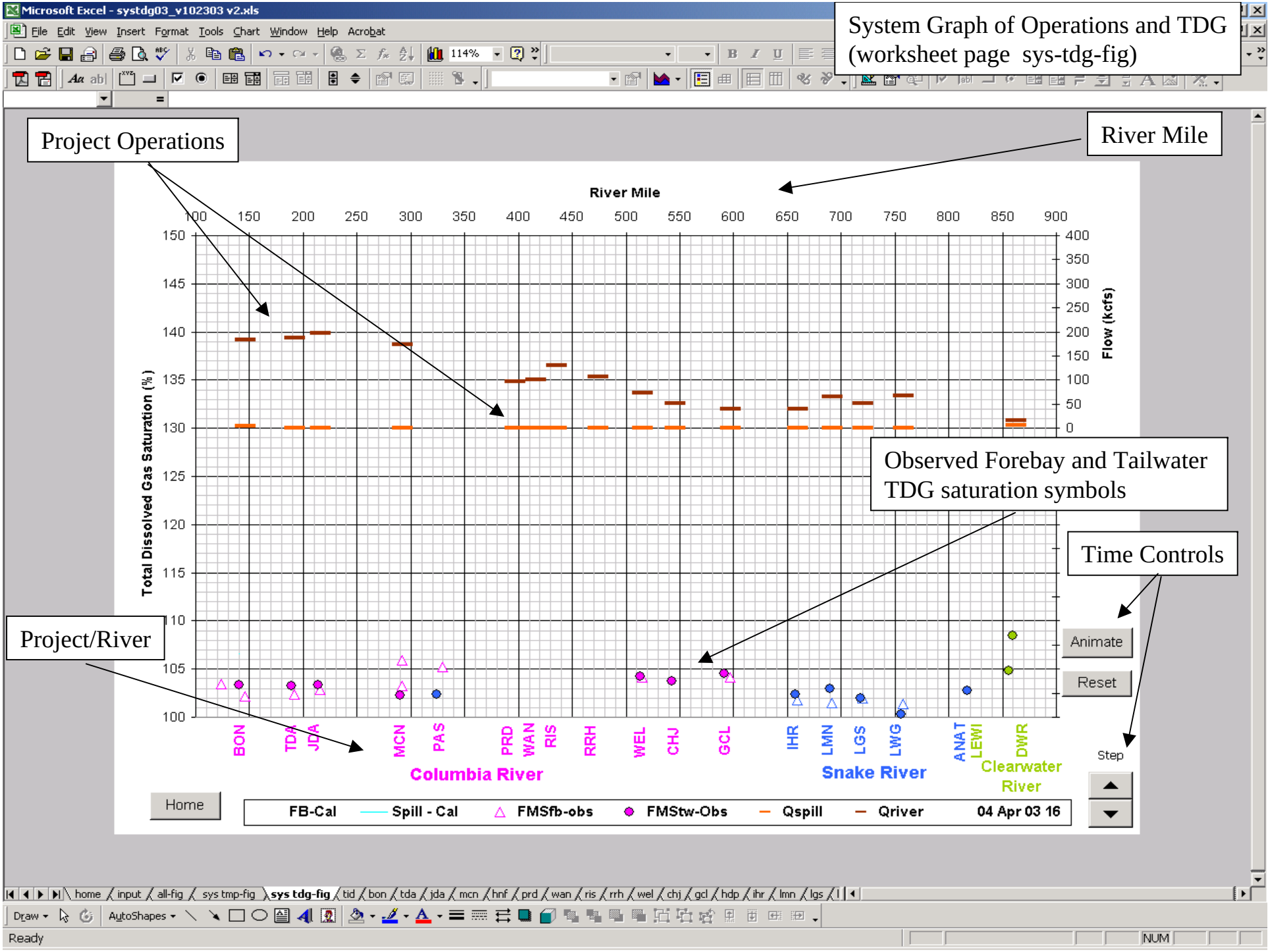
Draw AutoShapes

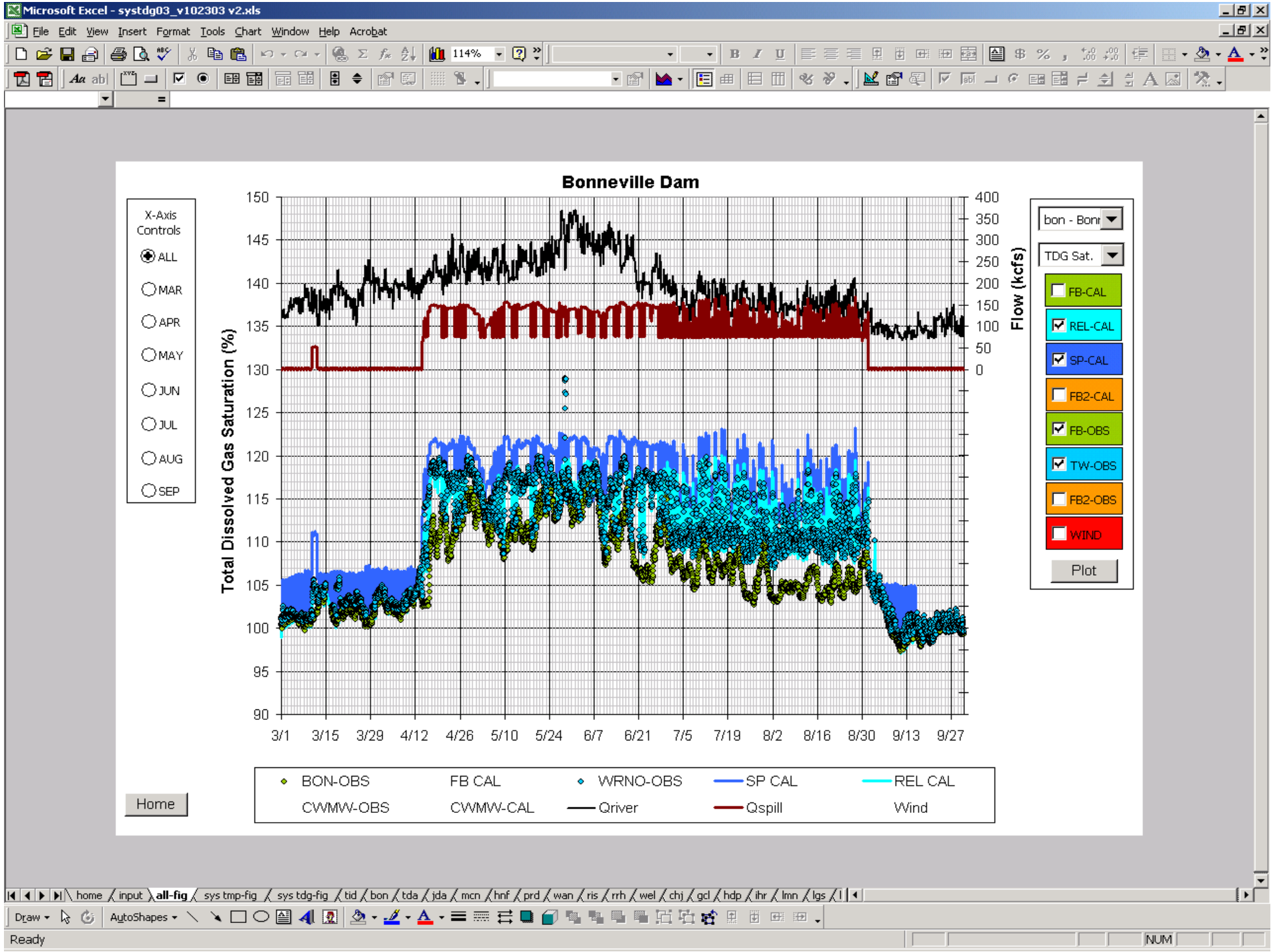
Ready

Start | Exploring - data | Microsoft Excel | Microsoft PowerPoint - [Pr... | 11:56 AM


Microsoft Excel - systdg03_v102303 v2.xls
Graph of Model and Observed Data (worksheet page all-fig)
X-axis Controls
Bonneville Dam
X-Axis Controls
ALL
MAR
APR
MAY
JUN
JUL
AUG
SEP
Total Dissolved Gas Saturation (%)
Flow (kcfs)
bon - Bonr
TDG Sat.
FB-CAL
REL-CAL
SP-CAL
FB2-CAL
FB-OBS
TW-OBS
FB2-OBS
WIND
Plot
Data Controls
Operations Data Qriver and Qspill
Time
3/1
3/21
3/31
Value (X) axis
BON-OBS
FB CAL
WRNO-OBS
SP CAL
REL CAL
CWMW-OBS
CWMW-CAL
Qriver
Qspill
Wind
Home
TDG Saturation (Calculated and Observed)


System Graph of Operations and TDG (worksheet page sys-tmp-fig)
Project Operations
River Mile
Observed Forebay and Tailwater Temperature symbols
Time Controls
Project/River
River Mile
Water Temperature (C)
Flow (kcfs)
Value (X) axis
BON
TDA
JDA
MCN
IHR
PSC
PRD
WAN
RIS
RRH
WEL
CHJ
GCL
IHR
LMN
LGS
LWG
ANAT
LEWI
DWR
Columbia River
Snake River
Clearwater River
Animate
Reset
Step
Home
FMSfb-obs
FMStw-Obs
Qspill
Qriver
04 Apr 03 16


System Graph of Operations and TDG (worksheet page sys-tdg-fig)
Project Operations
River Mile
Observed Forebay and Tailwater TDG saturation symbols
Time Controls
Project/River
River Mile
Total Dissolved Gas Saturation (%)
Flow (kcfs)
BON
TDA
JDA
MCN
PAS
PRD
WAN
RIS
RRH
WEL
CHJ
GCL
IHR
LMN
LGS
LWG
ANAT
LEWI
DWR
Columbia River
Snake River
Clearwater River
Animate
Reset
Step
Home
FB-Cal
Spill - Cal
FMSfb-obs
FMStw-Obs
Qspill
Qriver
04 Apr 03 16


Microsoft Excel - systdg03_v102303 v2.xls
Bonneville Dam
X-Axis Controls
ALL
MAR
APR
MAY
JUN
JUL
AUG
SEP
Total Dissolved Gas Saturation (%)
Flow (kcfs)
150
145
140
135
130
125
120
115
110
105
100
95
90
400
350
300
250
200
150
100
50
0
3/1
3/15
3/29
4/12
4/26
5/10
5/24
6/7
6/21
7/5
7/19
8/2
8/16
8/30
9/13
9/27
bon - Bonr
TDG Sat.
FB-CAL
REL-CAL
SP-CAL
FB2-CAL
FB-OBS
TW-OBS
FB2-OBS
WIND
Plot
BON-OBS
FB CAL
WRNO-OBS
SP CAL
REL CAL
CWMW-OBS
CWMW-CAL
Qriver
Qspill
Wind
Home
home
input
all-fig
sys tmp-fig
sys tdg-fig
tid
bon
tda
jda
mcn
hnf
prd
wan
ris
rrh
wel
chj
gcl
hdp
ihr
lmn
lgs
Ready
NUM

Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools

- Model Enhancements
  - Forecasting short-term conditions
  - Update Project TDG Exchange Descriptions
    - Mid-Columbia PUD's
  - Streamline Input Data Management
  - Data Screening (Quality control)
  - Post-processing Model Output
    - Statistical Summary
  - Documentation and Training
    - Web based framework