The Delta Salinity Gradient (DSG) Model

Bay-Delta Science Conference
October 28, 2014

Paul Hutton, Ph.D., P.E.
Metropolitan Water District

The Delta Salinity Gradient (DSG) Model

Introduction

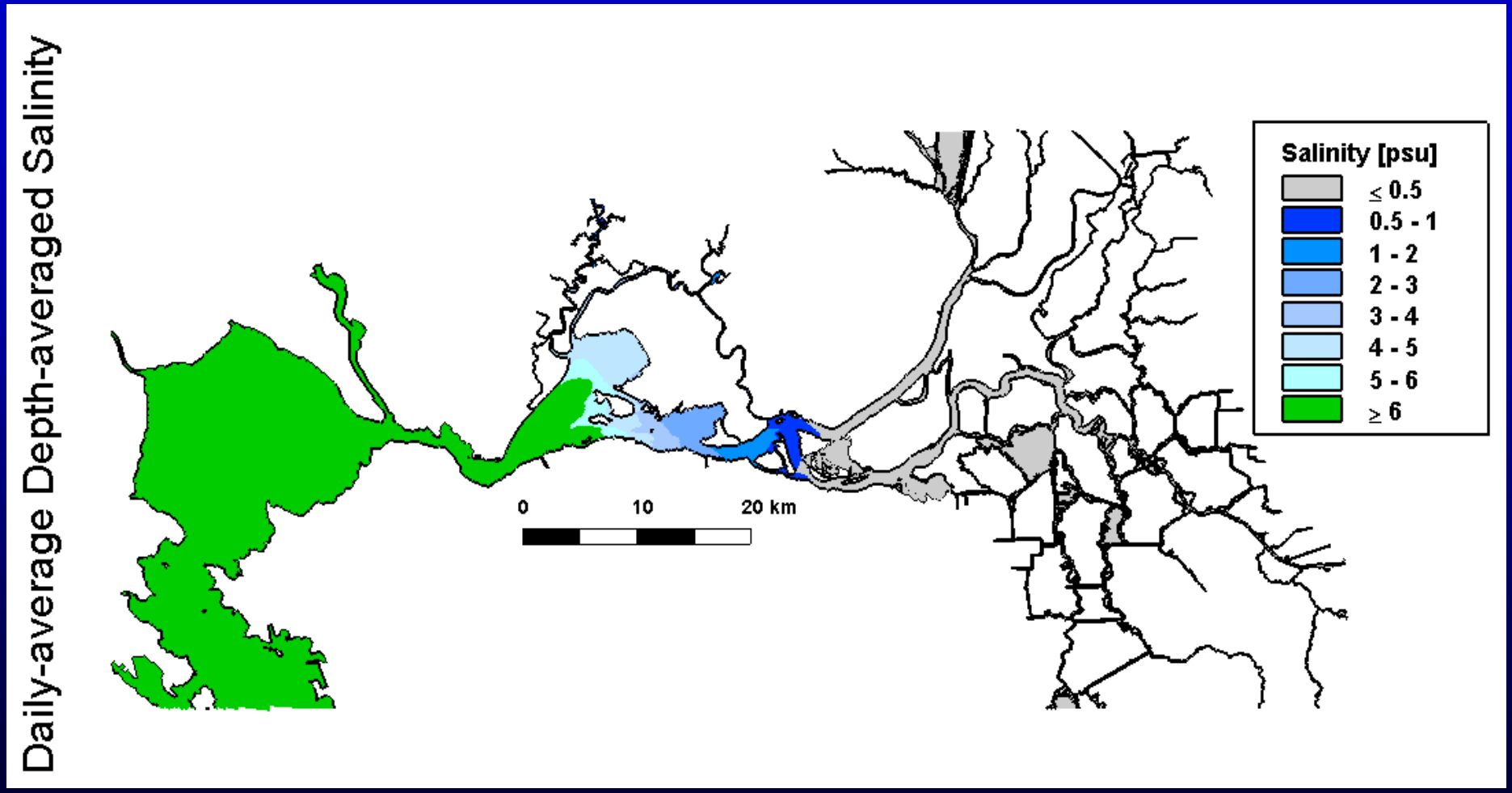
Formulation/Calibration/Validation

Perturbation Analysis & Possible Next Steps

Definition of Low Salinity Zone

The “Low Salinity Zone” occurs at the inland edge of estuaries where average daily salinities range from 1 to 6 practical salinity units.

Predicting Spatial Extent of the Low Salinity Zone



(from MacWilliams 2014)

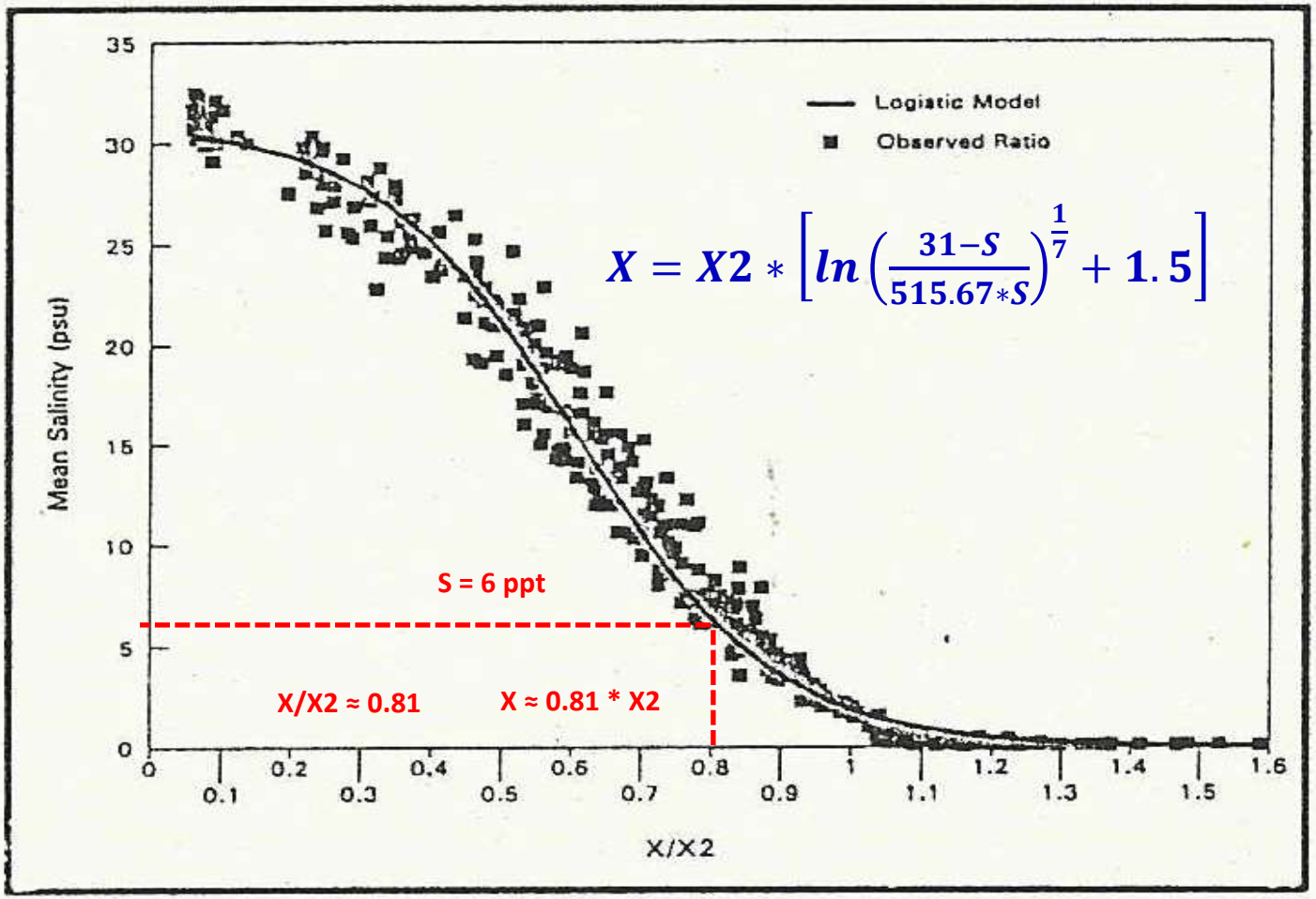
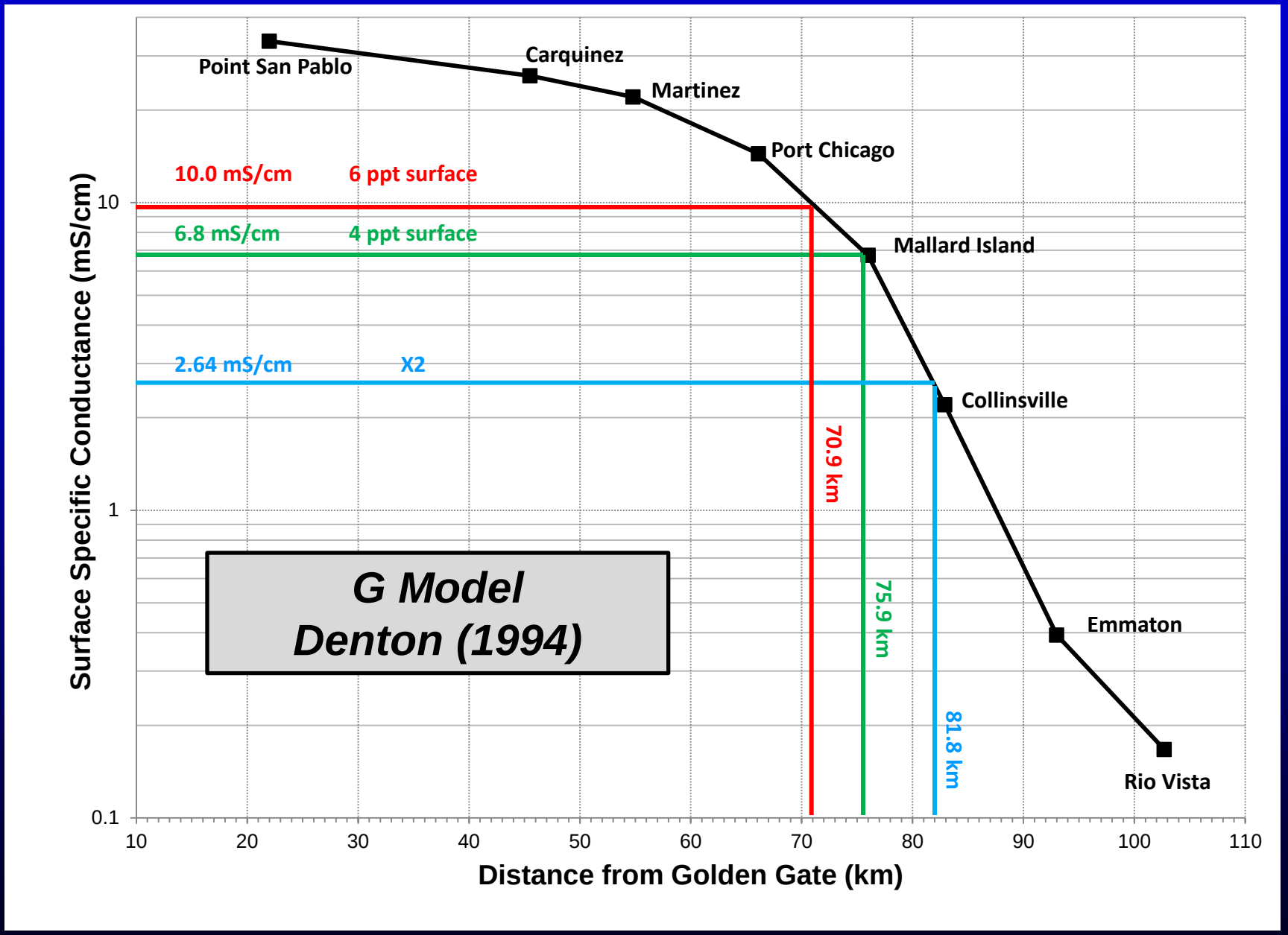


Figure 2
MEAN SALINITY AS A FUNCTION OF X/X_2

From Unger (1994)


Point San Pablo
Carquinez
Martinez
Port Chicago
Mallard Island
Collinsville
Emmaton
Rio Vista
10.0 mS/cm
6 ppt surface
6.8 mS/cm
4 ppt surface
2.64 mS/cm
X2
70.9 km
75.9 km
81.8 km
G Model
Denton (1994)
Surface Specific Conductance (mS/cm)
10
1
0.1
10
20
30
40
50
60
70
80
90
100
110
Distance from Golden Gate (km)

The Delta Salinity Gradient (DSG) Model

Introduction

Formulation/Calibration/Validation

Perturbation Analysis & Possible Next Steps

DSG Model Formulation

Advantages

- Speed and simplicity – spreadsheet application
- Parsimony – 5 fitting parameters
- Robustness – valid under extremely low outflow conditions

DSG Model Formulation

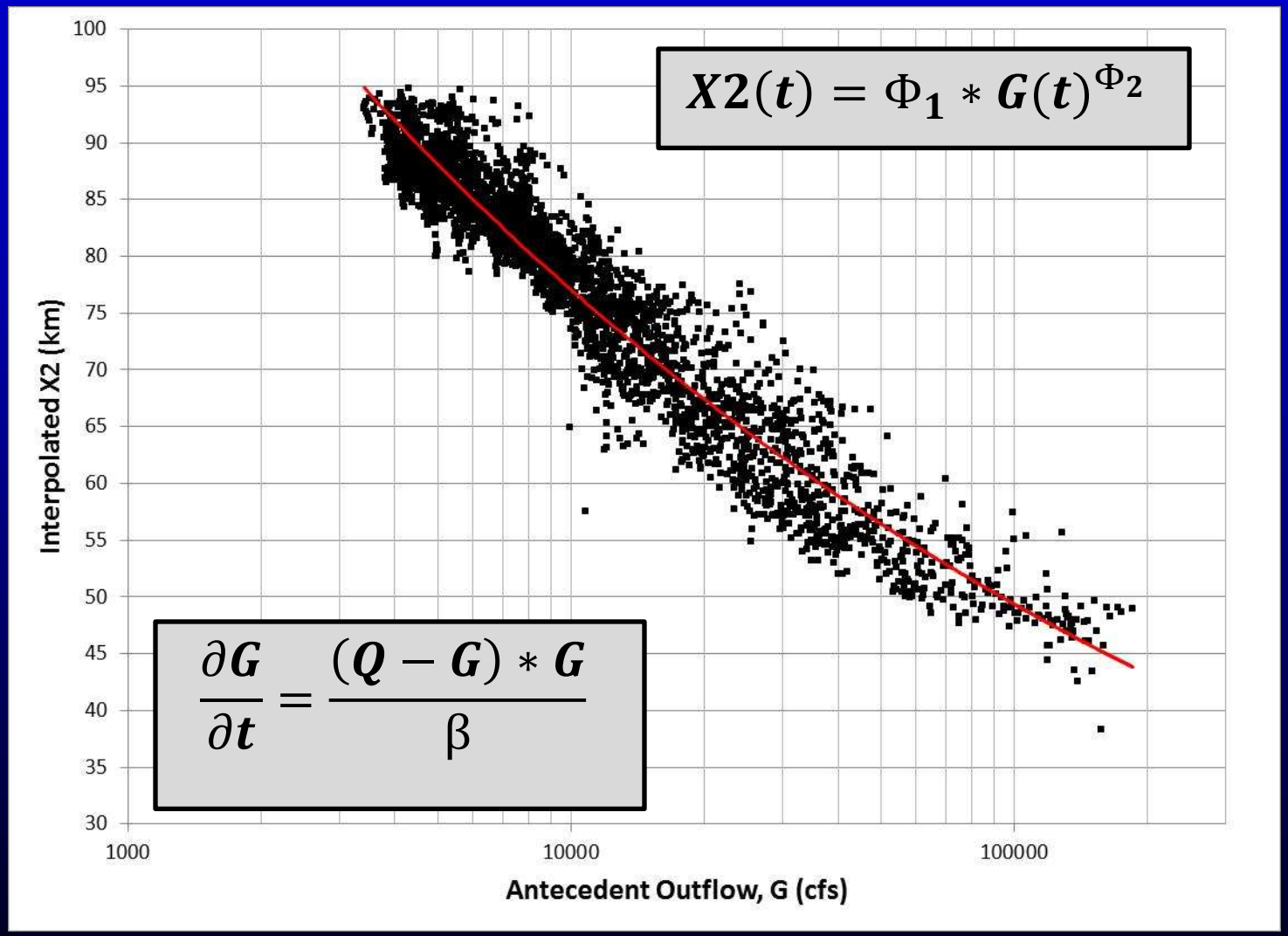
$$S = (S_o - S_b) * \exp\left[\tau * \left(\frac{X}{X2}\right)^{\frac{-1}{\Phi_2}}\right] + S_b$$

The DSG model requires specification of Delta outflow & five (5) model parameters:

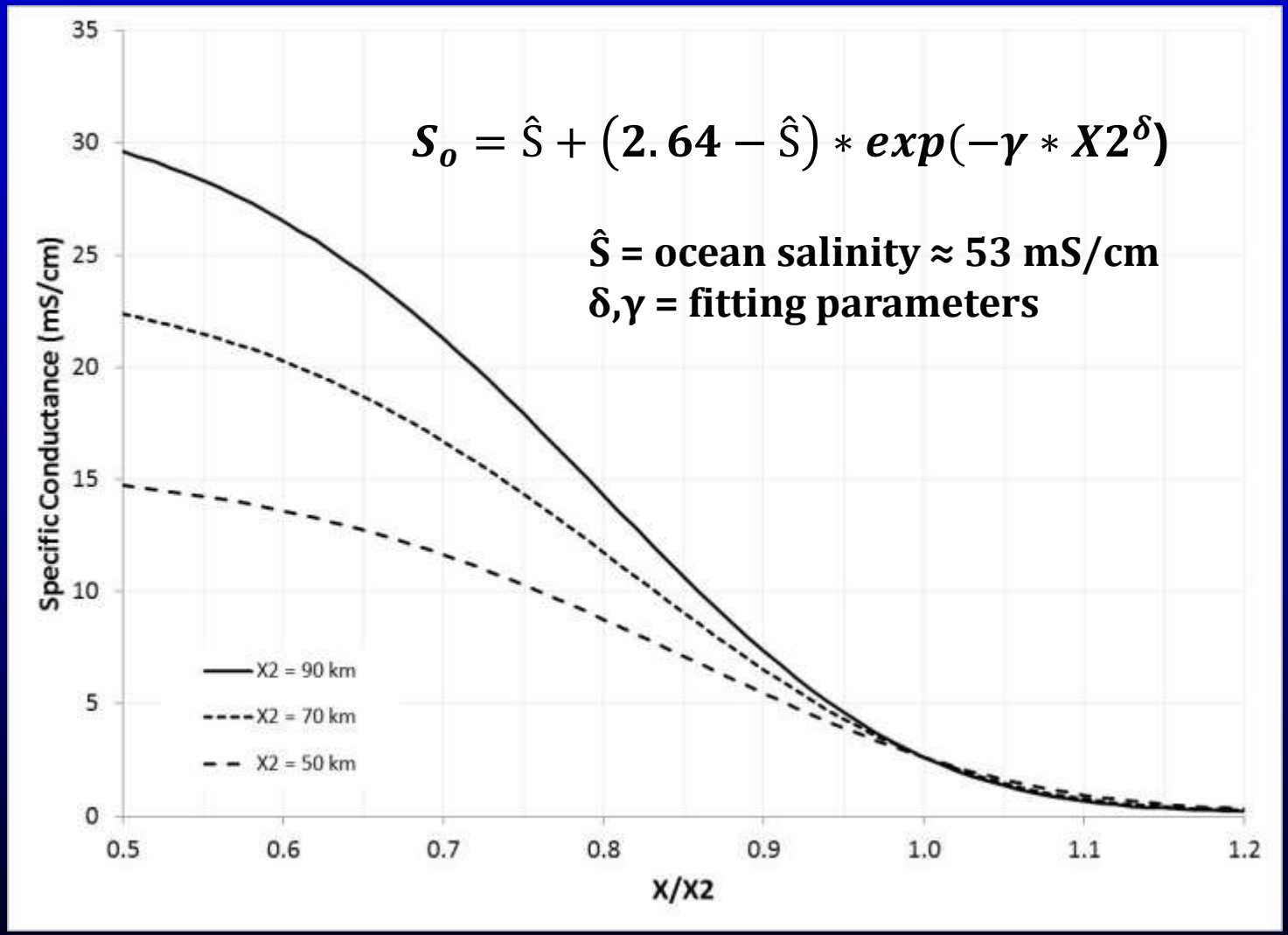
- **β: calculate antecedent outflow as a function of Delta outflow**
- **Φ_1 and Φ_2: calculate X2 as a function of antecedent outflow**
- **γ and δ: calculate S_o as a function of X2**

DSG Model Formulation (cont'd)

X2 vs. Antecedent Outflow



DSG Model Formulation (cont'd)



DSG Model Formulation (cont'd)

Normalized isohaline salinity

$$X = X2 * \left[\frac{\ln\left(\frac{S - S_b}{S_o - S_b}\right)}{\tau}\right]^{-\Phi_2}$$

$$\tau = \ln\left(\frac{2.64 - S_b}{S_o - S_b}\right)$$

Normalized index salinity

X = isohaline distance from Golden Gate

X2 = distance of 2 ppt bottom isohaline = f(G)

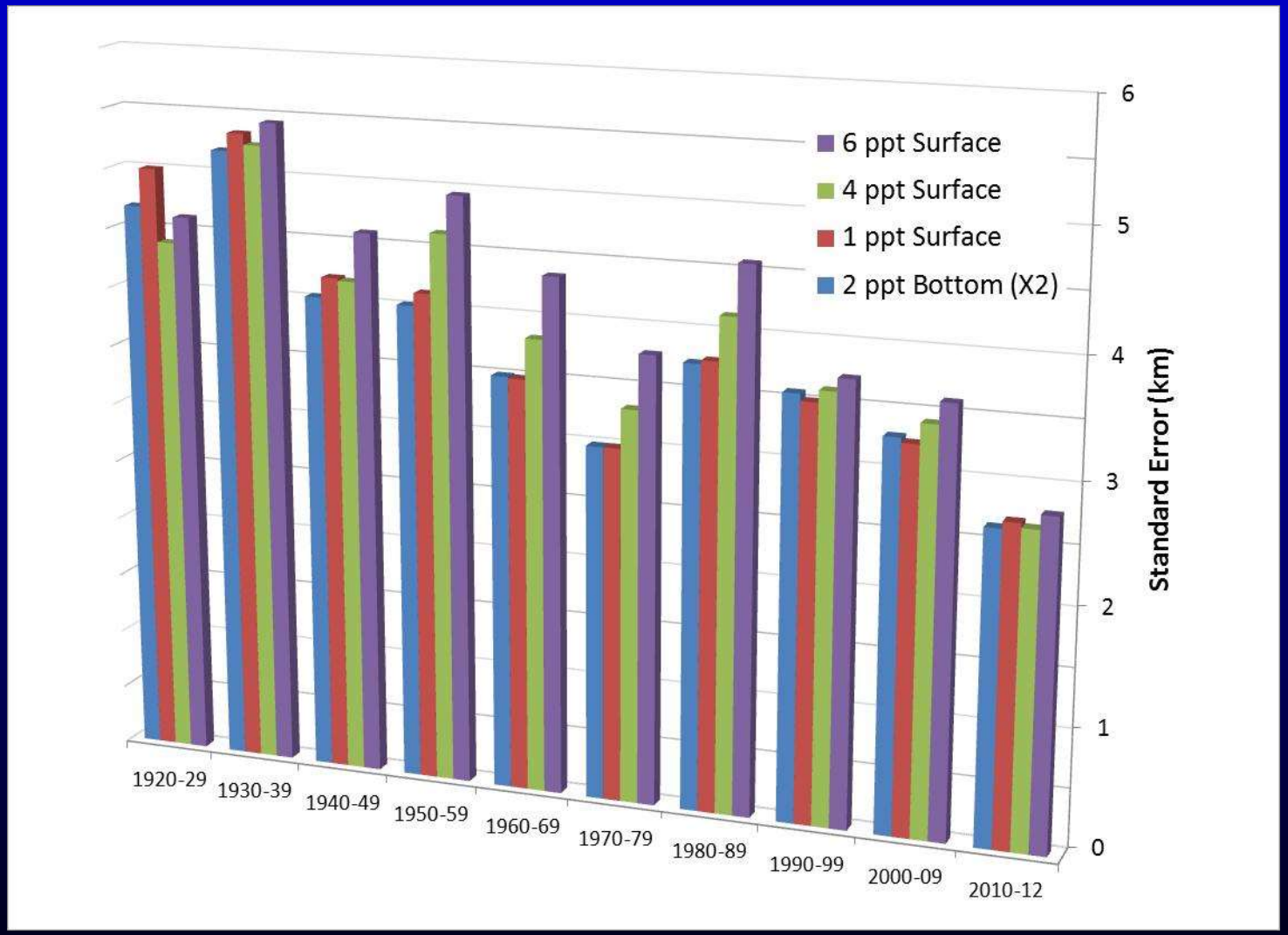
S = isohaline salinity (mS/cm)

S_b = upstream salinity

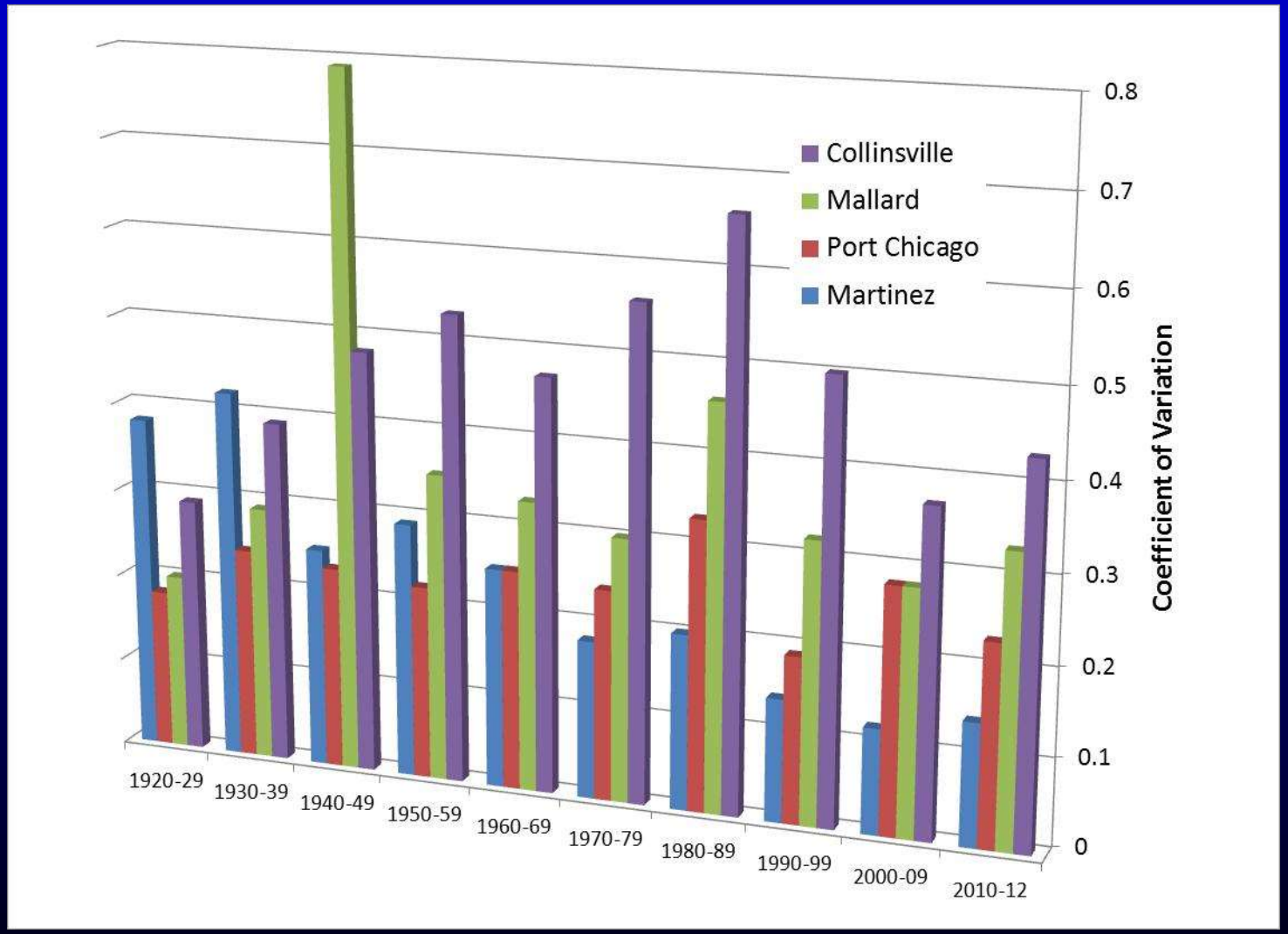
S_o = downstream salinity = f(X2)

Φ_2 = fitting parameter

Model Calibration/Validation



Model Calibration/Validation (cont'd)



The Delta Salinity Gradient (DSG) Model

Introduction

Formulation/Calibration/Validation

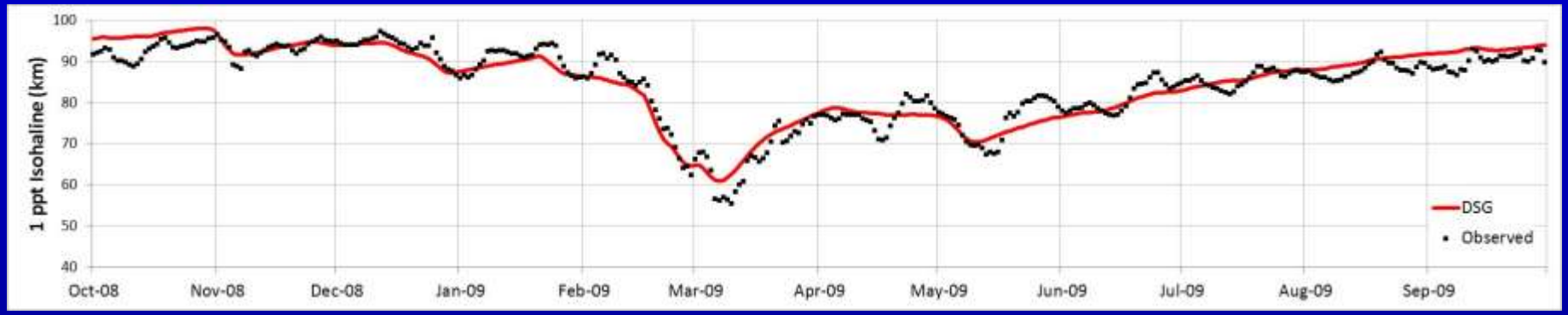
Perturbation Analysis & Possible Next Steps

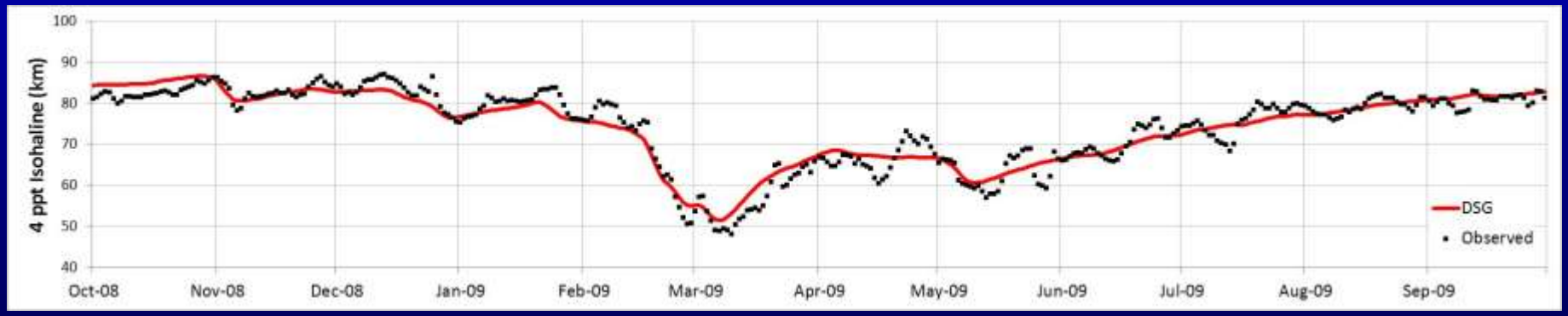
Perturbation Analysis

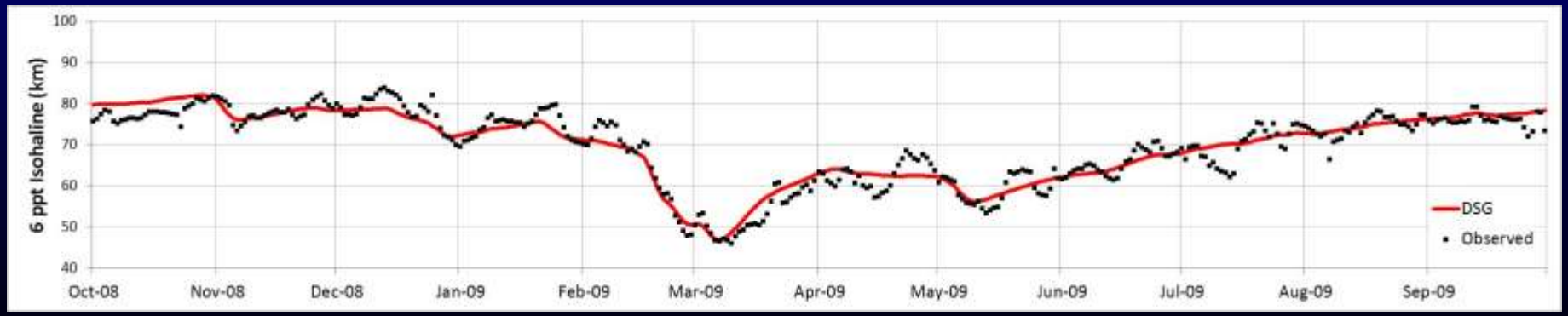
X (km)	Difference with Baseline (%)									
	β		Φ_1		Φ_2		γ		δ	
	-10%	+10%	-10%	+10%	-10%	+10%	-10%	+10%	-10%	+10%
54	0.4%	-0.4%	-27.8%	26.1%	55.4%	-47.9%	-5.4%	5.0%	-36.7%	40.9%
64	0.7%	-0.7%	-40.9%	43.4%	95.4%	-62.9%	-4.4%	4.0%	-31.4%	32.1%
75	1.5%	-1.4%	-58.2%	80.0%	185.1%	-77.0%	-2.8%	2.5%	-20.8%	18.9%
81	2.0%	-1.9%	-66.3%	113.2%	272.8%	-81.1%	-1.5%	1.4%	-11.6%	10.1%
92	2.9%	-2.8%	-64.2%	193.7%	526.6%	-69.9%	1.2%	-1.1%	12.0%	-6.4%

DSG Isohaline Position Estimates

with Calculated X2: Water Year 2009

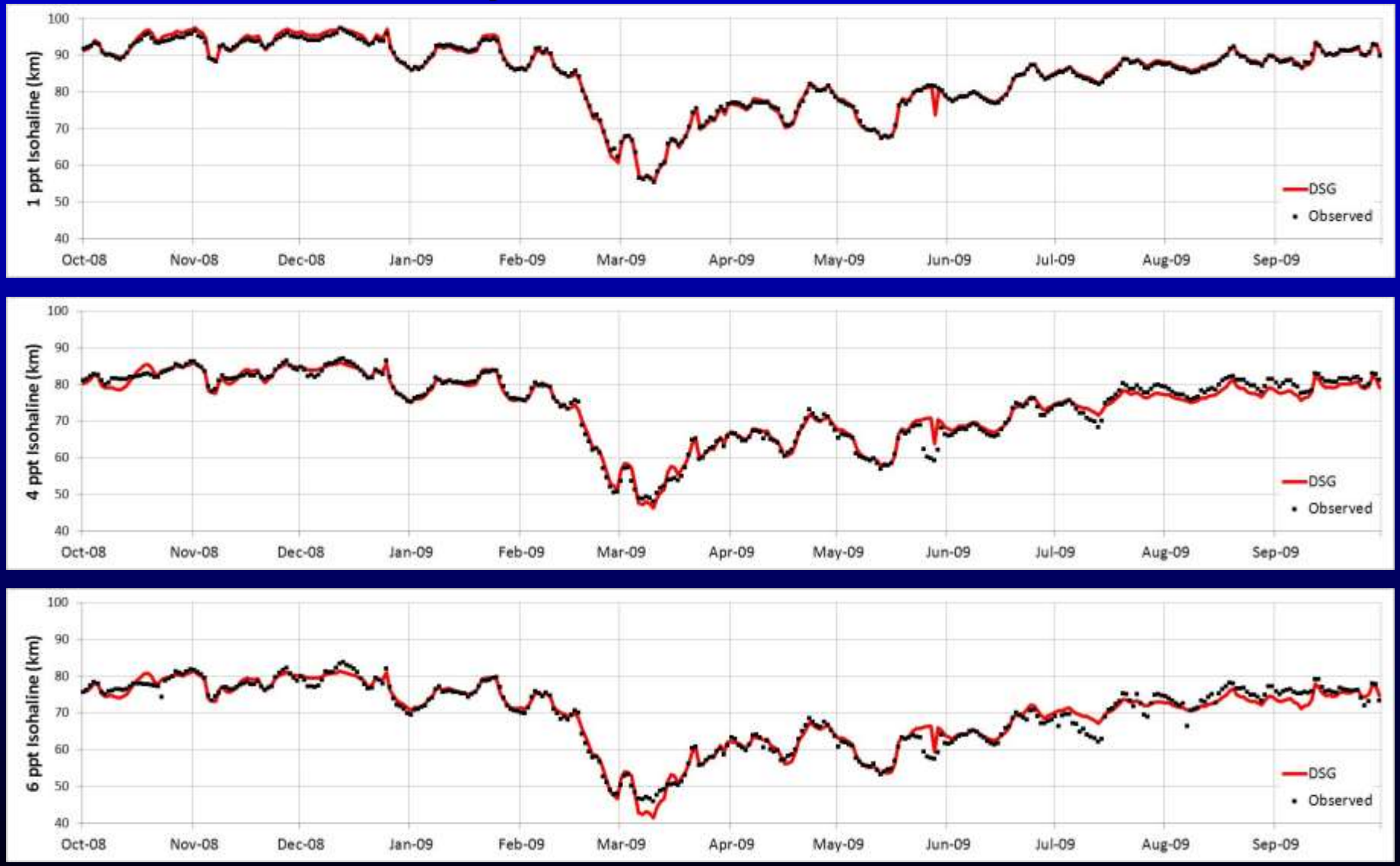






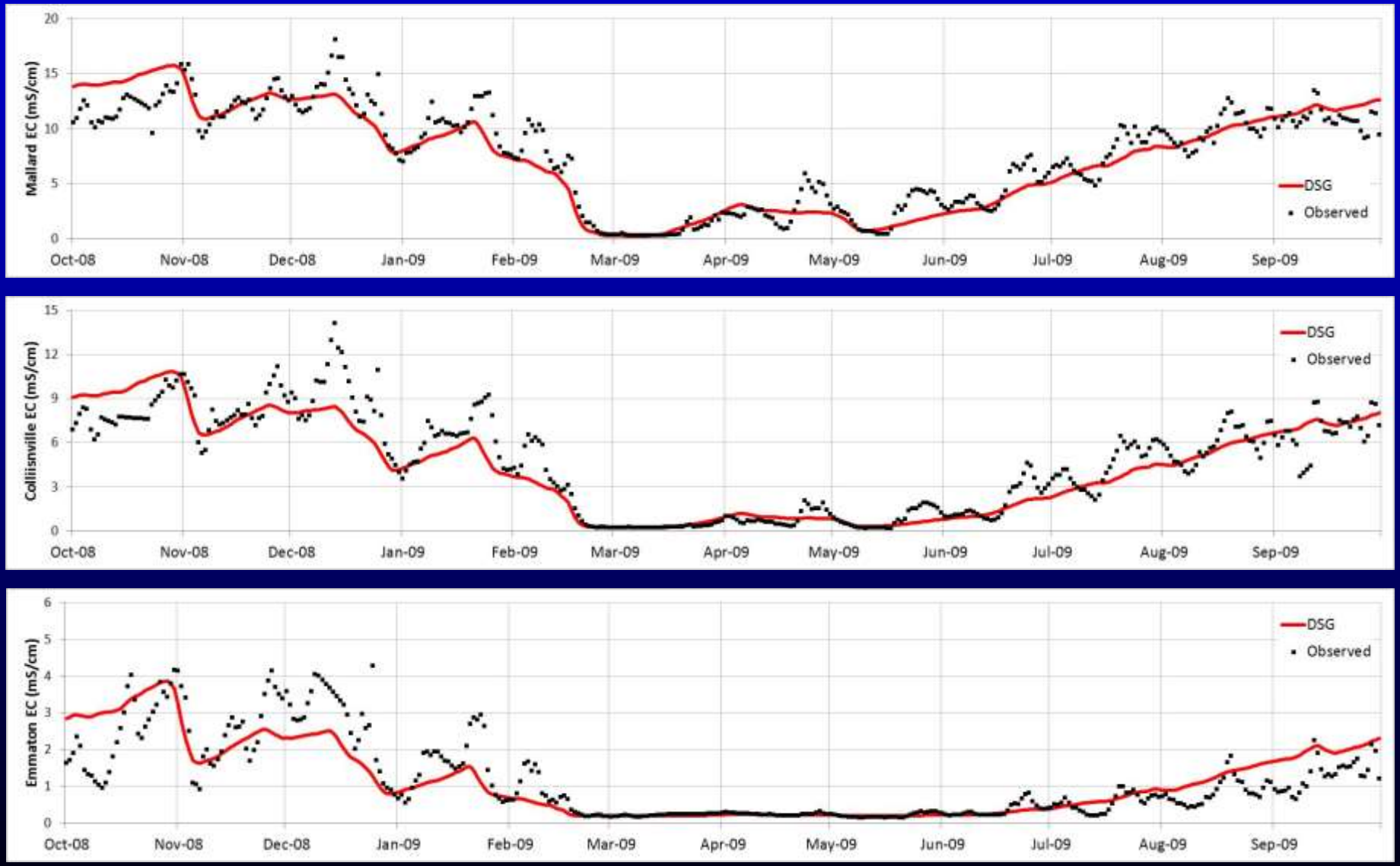
DSG Isohaline Position Estimates

with Interpolated X2: Water Year 2009



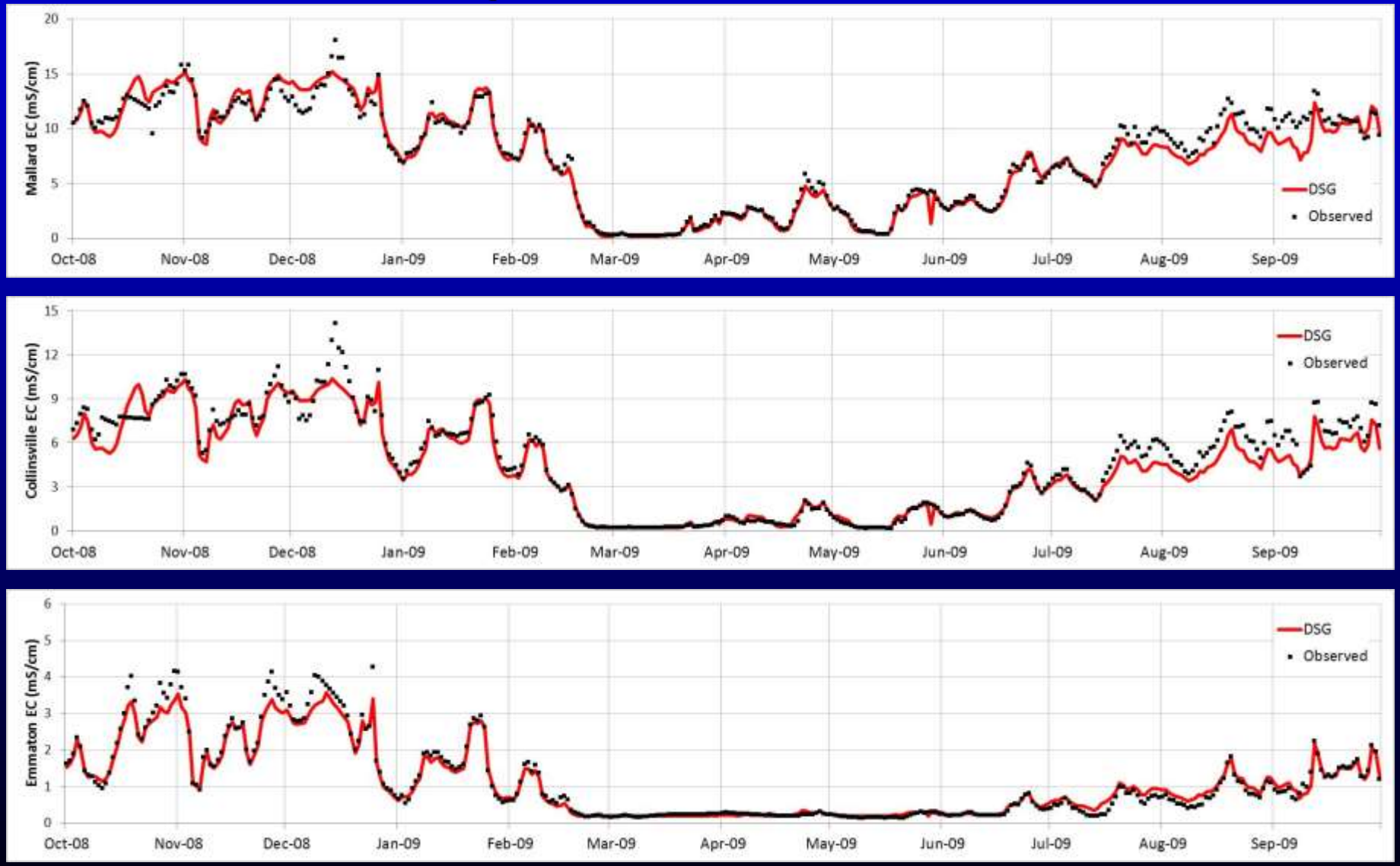
DSG Salinity Estimates

with Calculated X2: Water Year 2009



DSG Salinity Estimates

with Interpolated X2: Water Year 2009

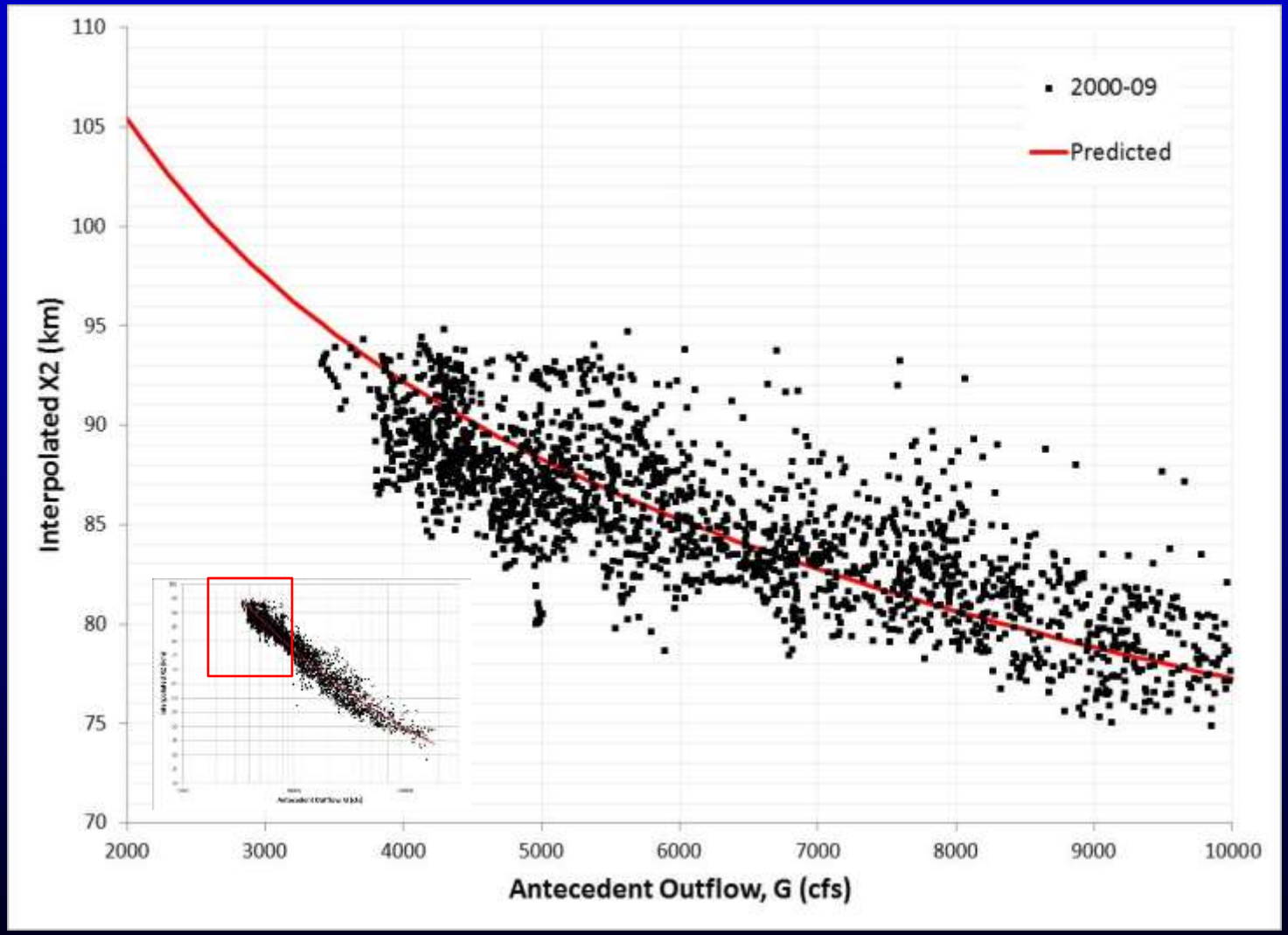


Possible Next Steps

- Re-calibrate existing X2 formulation
  - Include pre-Project data
  - Piece-wise fit
- Modify existing X2 formulation to increase degrees of freedom
  - Include a tidal term
  - Include a “QWEST” term

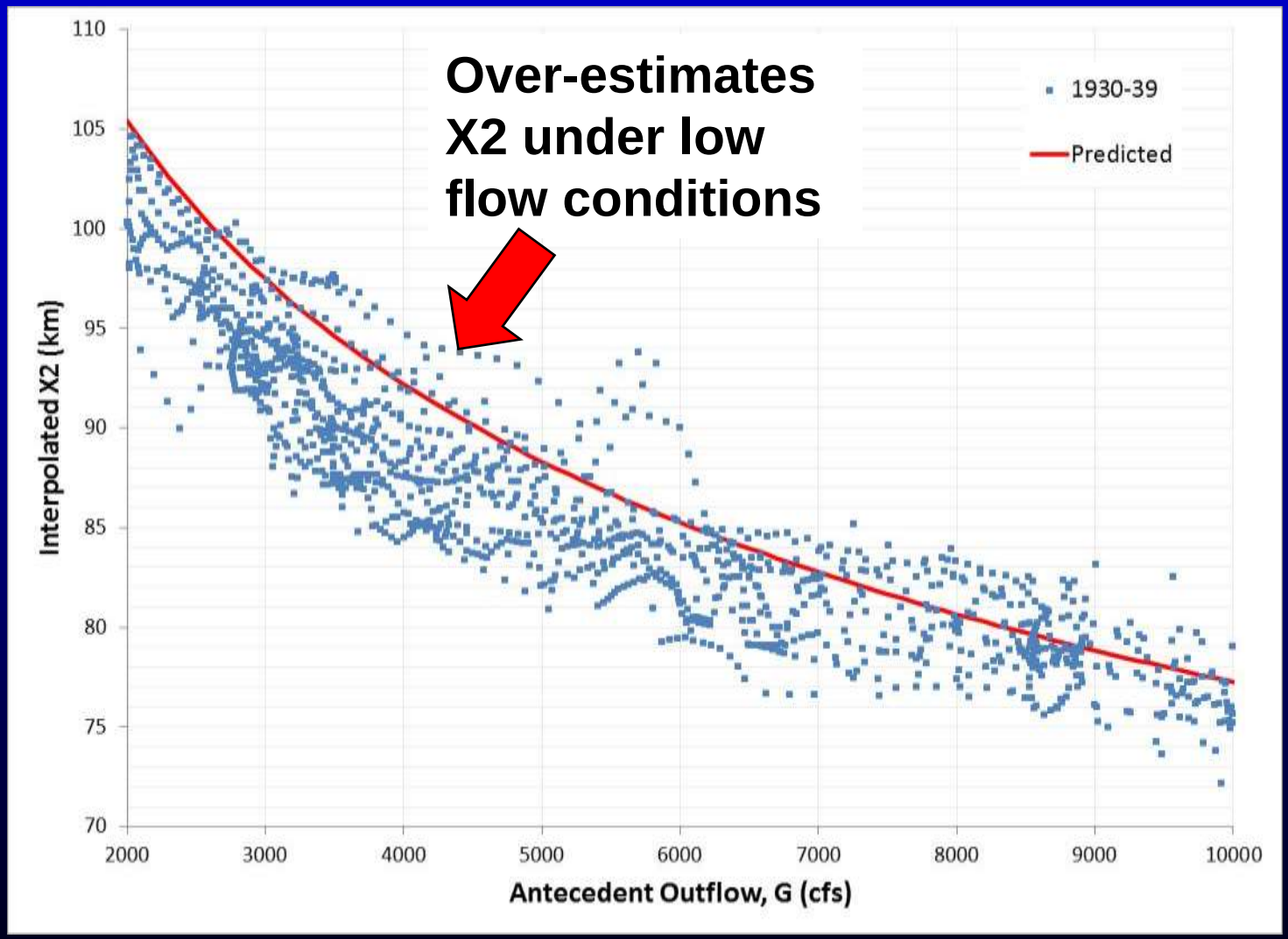
Possible X2 Re-calibration

Sacramento X2 vs. Antecedent Outflow 2000-09



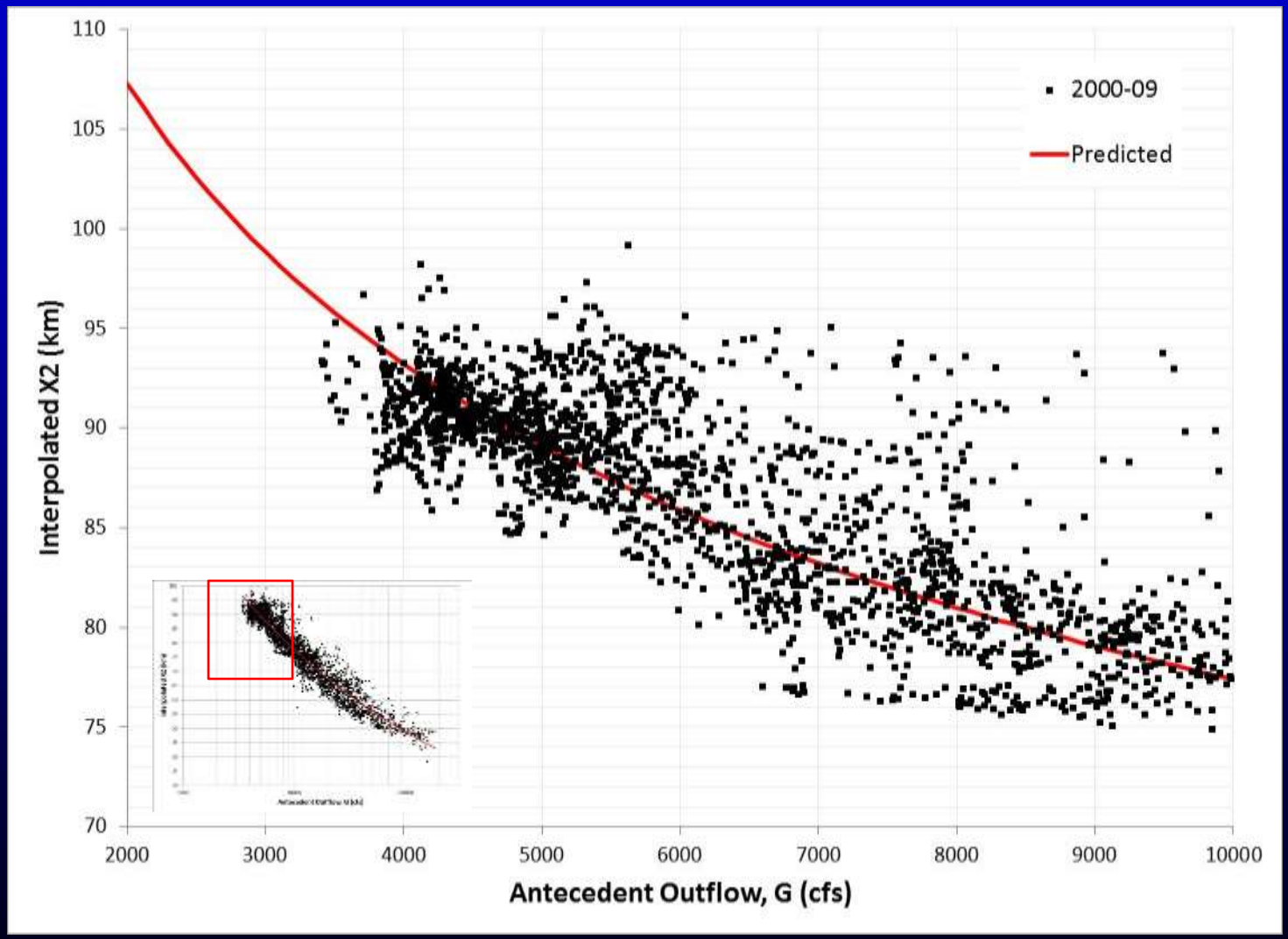
Possible X2 Re-calibration

Sacramento X2 vs. Antecedent Outflow 1930-39



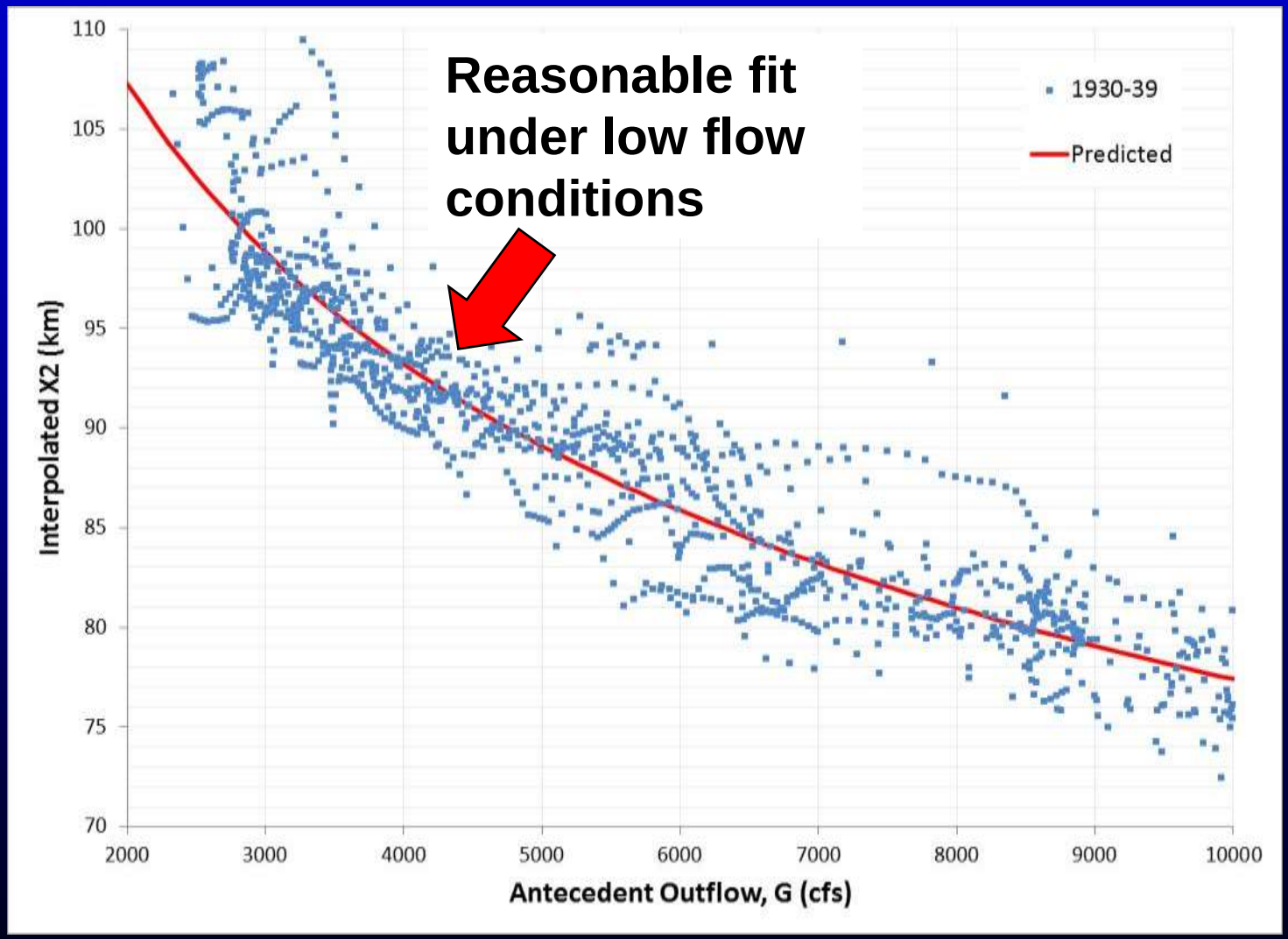
Possible X2 Re-calibration

San Joaquin X2 vs. Antecedent Outflow 2000-09



Possible X2 Re-calibration

San Joaquin X2 vs. Antecedent Outflow 1930-39



Possible Next Steps

- Re-calibrate existing X2 formulation
  - Include pre-Project data
  - Piece-wise fit
- Modify existing X2 formulation to increase degrees of freedom
  - Include a tidal term
  - Include a “QWEST” term
- **Explore use of artificial neural networks within DSG framework**

Paul Hutton, Ph.D., P.E.
phutton@mwdh2o.com