



U.S. Fish & Wildlife Service

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Loxahatchee National Wildlife Refuge

Total Phosphorus – 4-Box WASP Model



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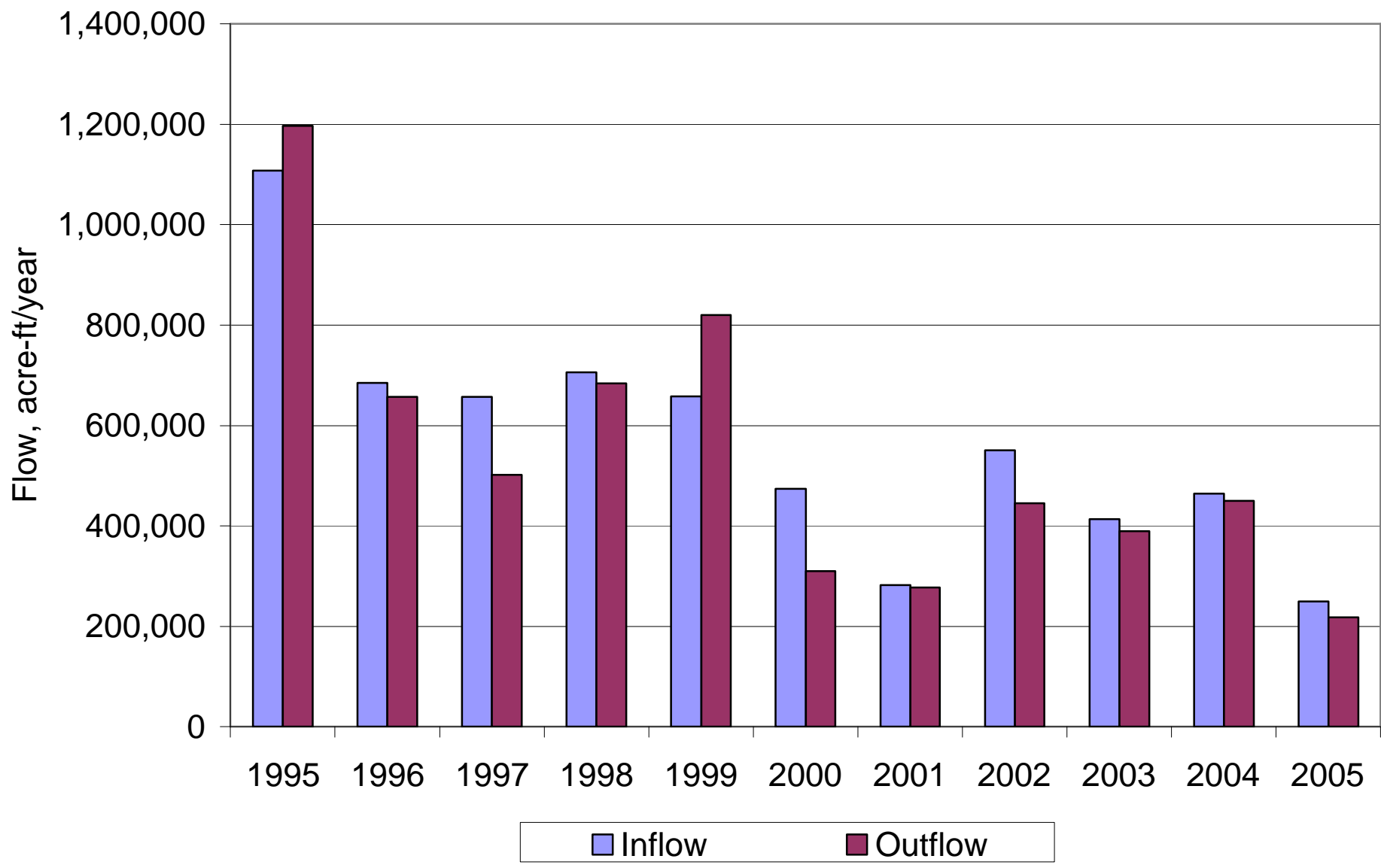
MODELING STRATEGY

- Build on other mass balance models
 - 2-box water balance model
 - Chloride model
 - Sulfate model
- Begin as simply as possible
 - Add complexity as needed
- Use WASP, at least as a first step, to reduce development time & enhance credibility

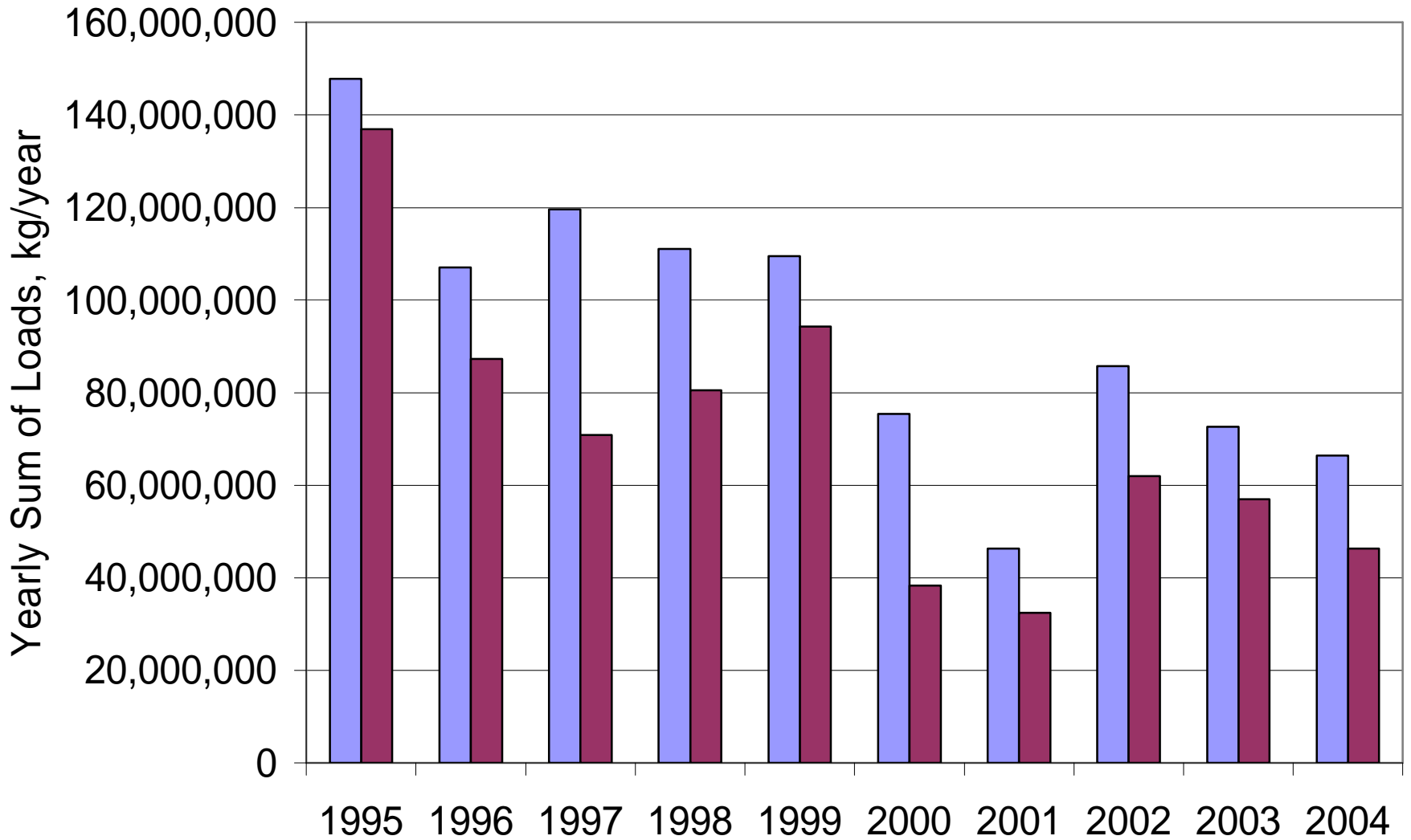
MASS BUDGETS

- Constituent inflow & outflow time series were interpolated as daily values
 - Needed for calculation of FWM concentrations of inflow
- As a first step, annual mass budgets were examined for
 - Water
 - Chloride
 - TP

Yearly Sum of Inflows and Outflows



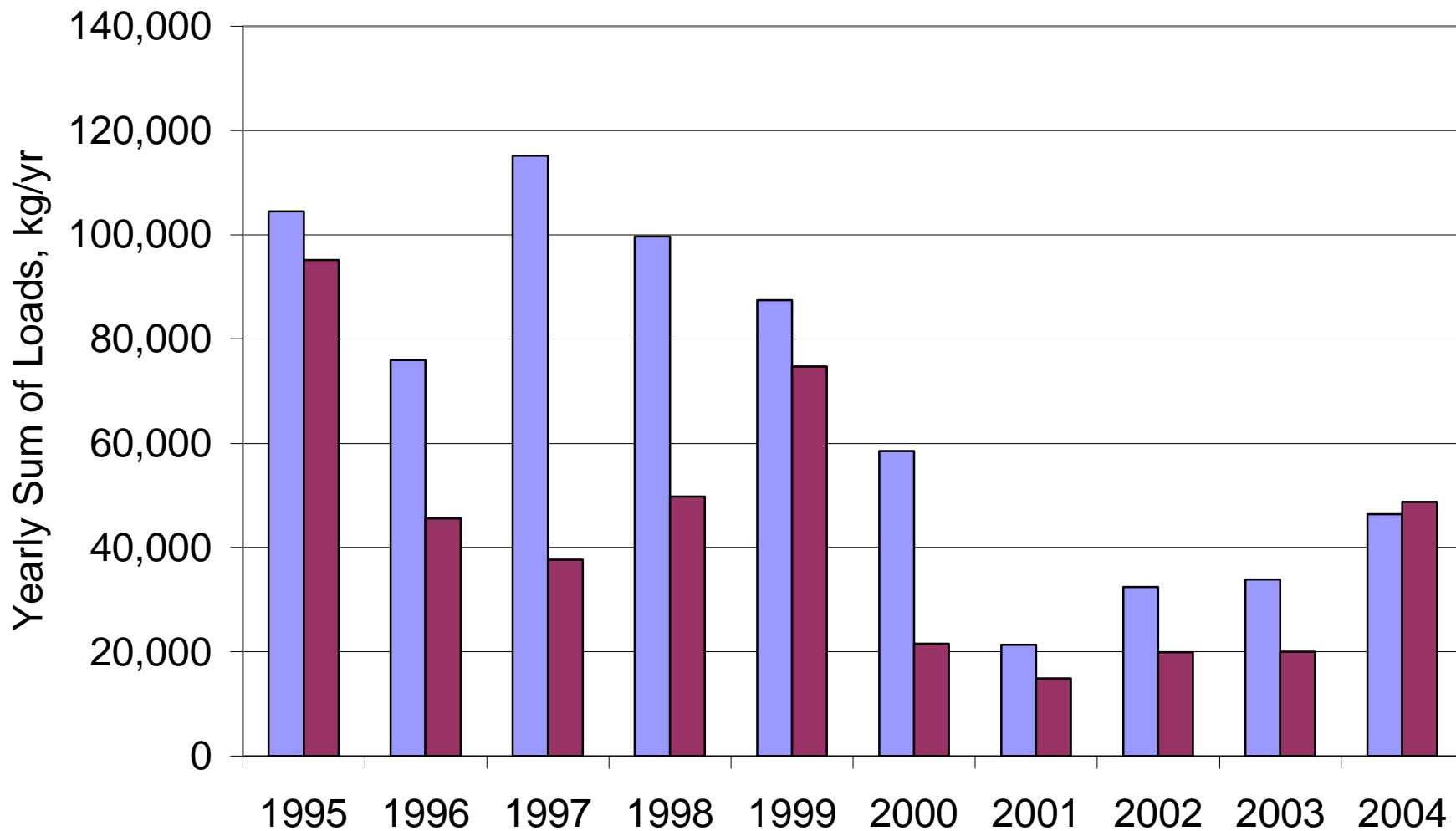
Chloride - Yearly Sum of Loads



Yearly Sum of Inflow Loads

Yearly Sum of Outflow Loads

Phosphorus - Yearly Sum of Loads



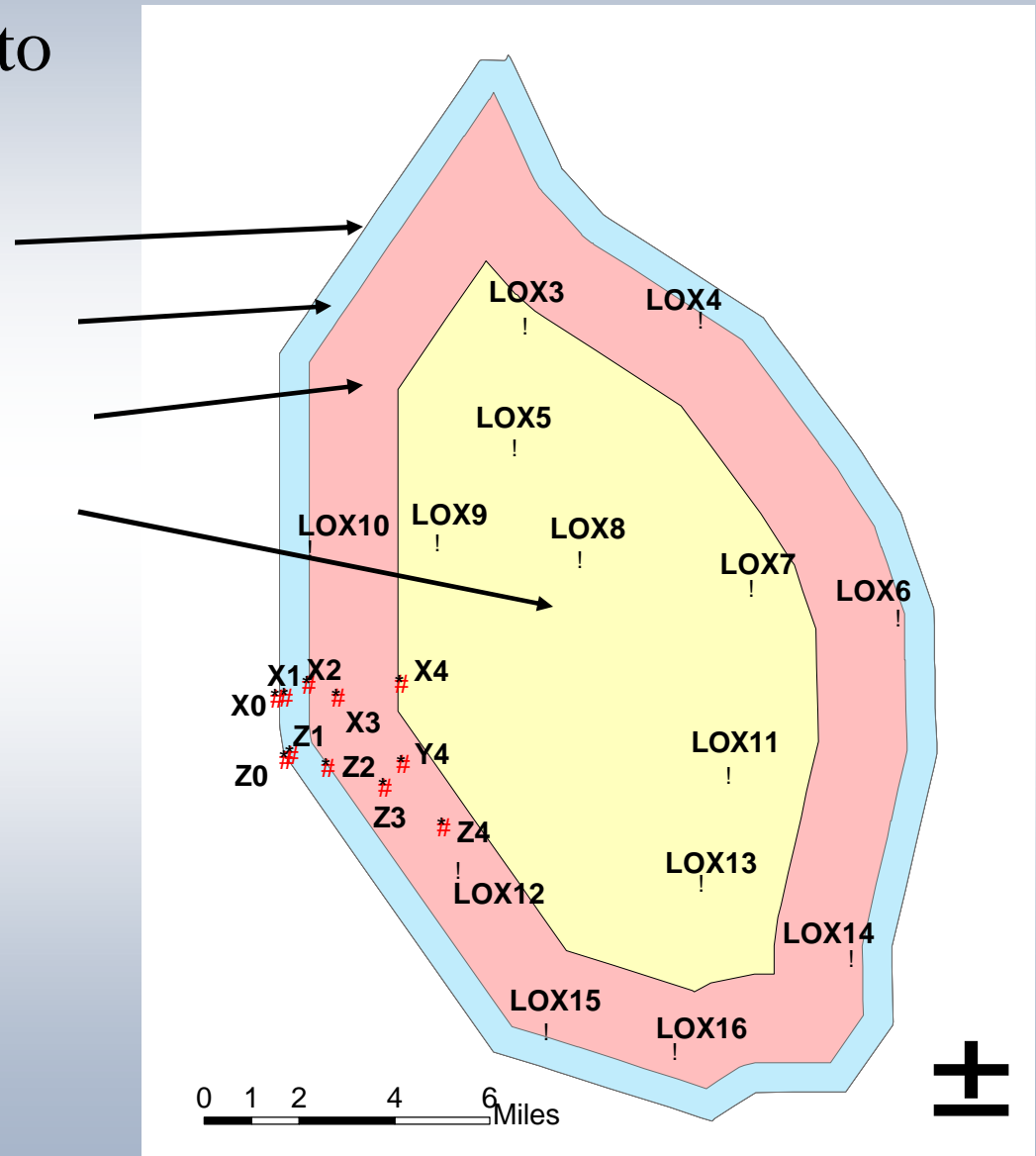
■ Yearly Sum of Inflow Loads

■ Yearly Sum of Outflow Loads

Phosphorus WASP Model

CONSTITUENT MODELING

- Divide the Refuge into four cells
 - Canal = 996 acres
 - Cell 1 = 22,072 acres
 - Cell 2 = 55,353 acres
 - Cell 3 = 60,901 acres
- Observed Data – aggregated monthly
 - XYZ
 - EVPA
 - Outflow Hydraulic Structures



WASP Setup

- Period of Study: 1/1/1995 to 12/31/2004
- Model Type: Eutrophication Model
 - Carbonaceous Biochemical Oxygen Demand (CBOD)
 - k-c* model (Kadlec and Knight, 1996)
- Time Step: 0.1 days (2.4 hours)
- 4 Compartments Setup
 - Same volumes as Cl & SO4 WASP models
 - Initial Conditions

Inputs

- Loads
 - Wet Deposition = 0.010 mg/L
 - Dry Deposition = 40 mg/m²-yr
 - kc* mass loading rate – Calibrated
- Exchanges – Same as Chloride WASP Model
 - Dispersion
- Flows
 - Inflows, Outflows, Canal Marsh Exchange Flow, Evapotranspiration (35% Transpired and 65% Evaporated), and Precipitation
 - Settling Rate – Calibrated
- Boundary Conditions

k-c* Model

- k-c* model developed by Kadlec and Knight

$$\frac{dhC}{dt} = -k(C - C^*) = -kC + kC^*$$

- Canal

- $c^* = 80 \mu\text{g/L}$ minimum concentration
- $k = 16.8 \text{ m/yr}$ apparent settling rate
- Areal Mass Load Rate, $kc^* = 1.3 \text{ g/m}^2\text{-yr}$

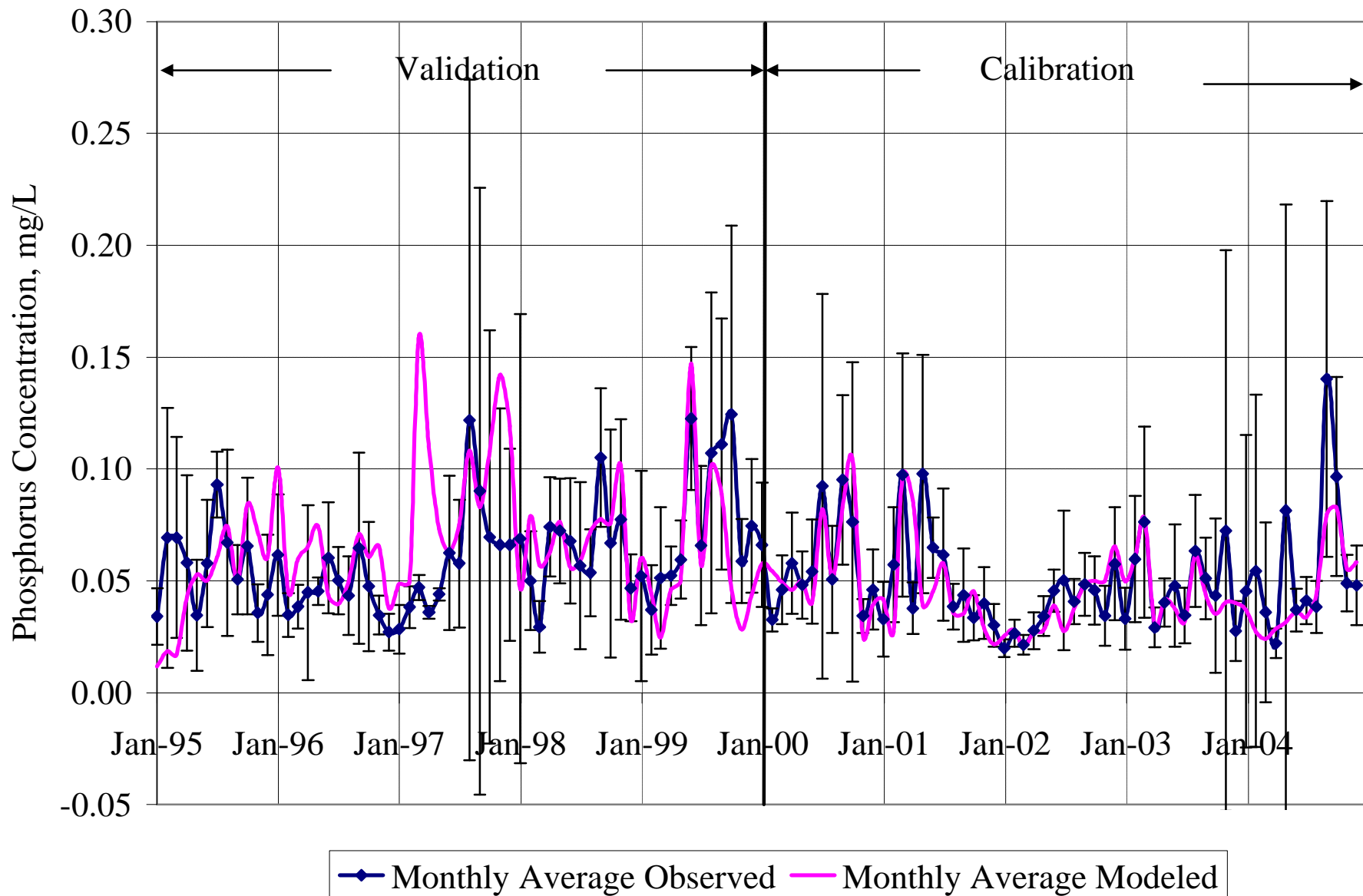
- Marsh

- $c^* = 8 \mu\text{g/L}$
- $k = 16.8 \text{ m/yr}$
- Areal Mass Load Rate , $kc^* = 0.13 \text{ g/m}^2\text{-yr}$

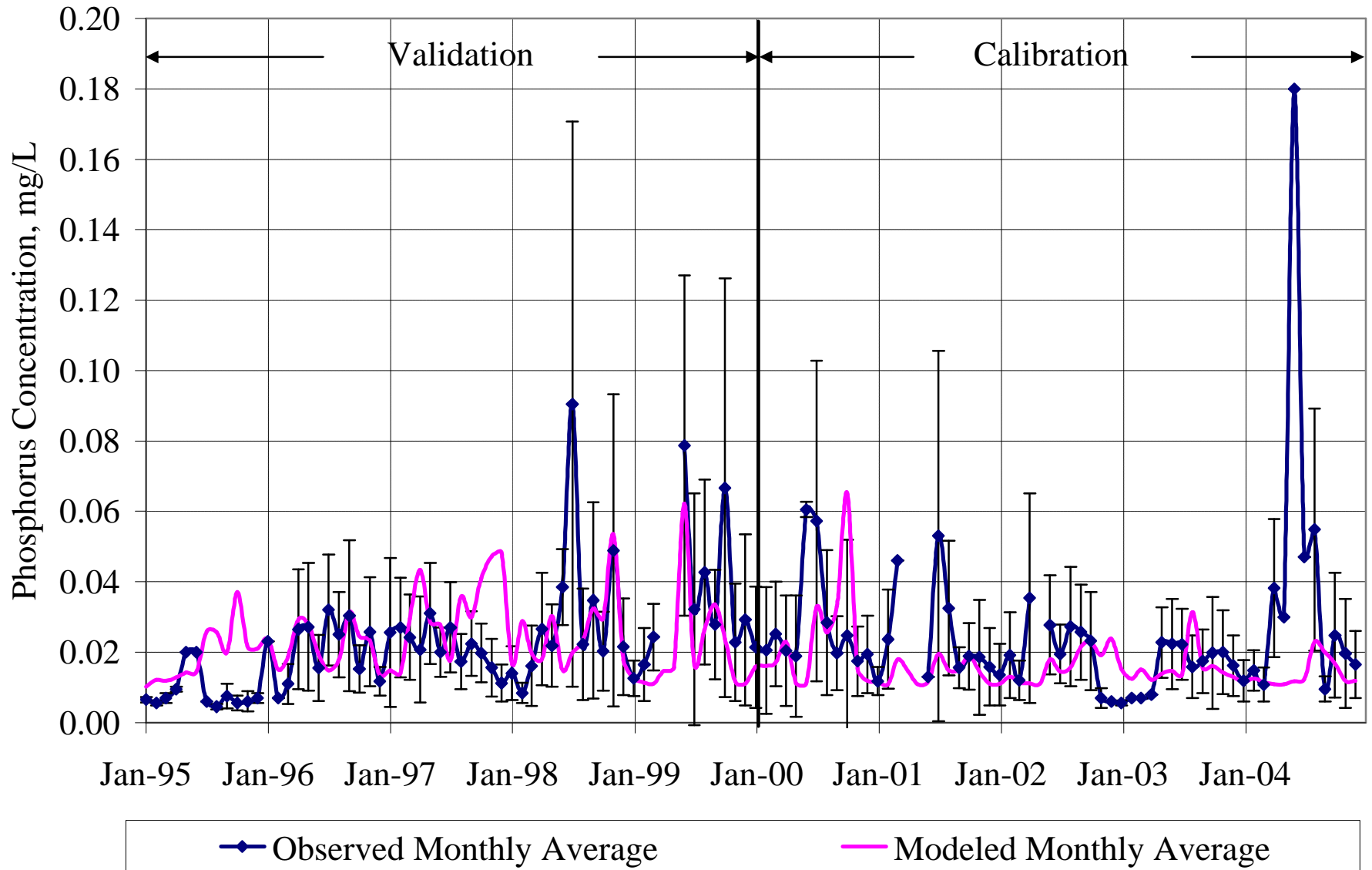
Calibration and Boundaries

- Calibration Parameters
 - Wet Deposition = 0.010 mg/L
 - Dry Deposition = 40 mg/m²-yr
 - k – Settling Rate = 16.8 m/yr
 - c* in canal = 80 µg/L
 - c* in marsh = 8 µg/L
- Phosphorus Concentration Boundaries
 - Canal – Inflow Concentrations (mg/L) were Estimated Daily Values

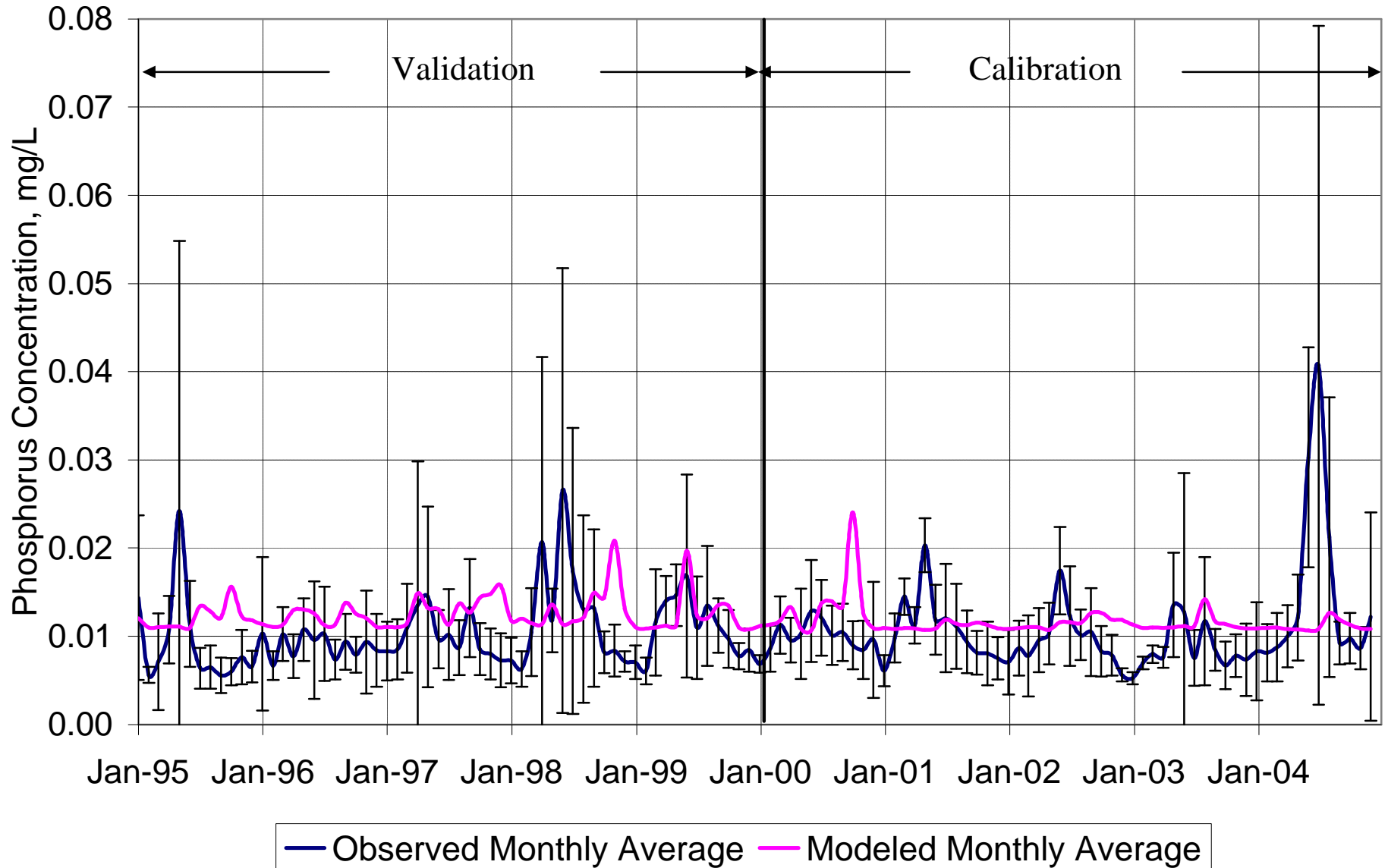
Phosphorus WASP Model - Canal



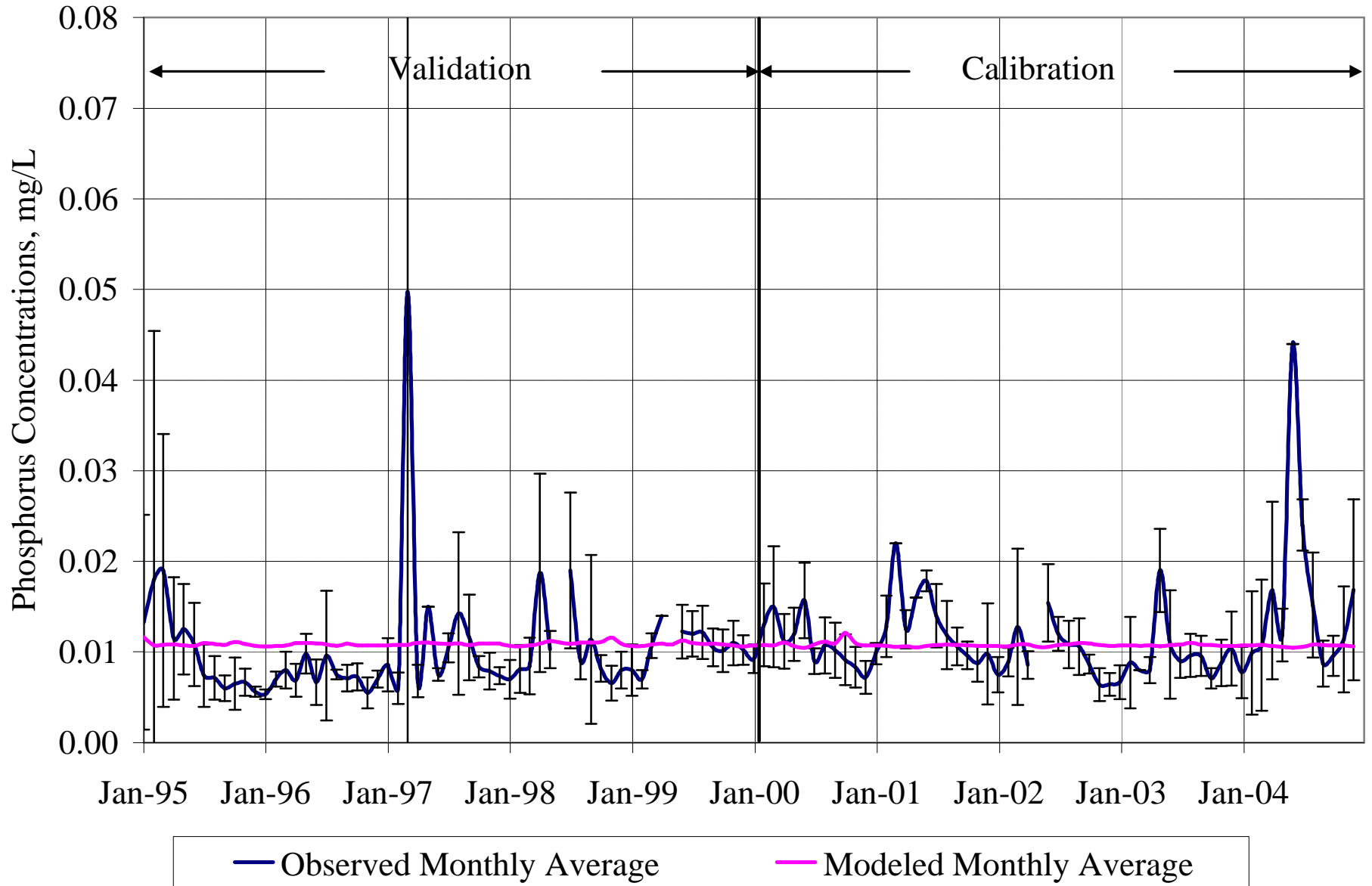
Phosphorus WASP Model - Cell 1



Phosphorus WASP Model - Cell 2



Phosphorus WASP Model - Cell 3



Phosphorus WASP Model Calibration Statistics

Statistical Parameter	Canal Calibration Statistics	Cell 1 Calibration Statistics	Cell 2 Calibration Statistics	Cell 3 Calibration Statistics	Marsh Calibration Statistics
Bias, mg/L	-0.0046	-0.0088	0.0009	-0.0011	-0.0088
RMSE, mg/L	0.182	0.0270	0.0060	0.0058	0.0270
R ² Value	0.4348	0.00001	0.0043	0.1088	0.0338
Nash Sutcliffe Efficiency	0.3580	-0.2422	-0.1741	-0.0630	-0.2422

Phosphorus WASP Model Validation Statistics

Statistical Parameter	Canal Validation Statistics	Cell 1 Validation Statistics	Cell 2 Validation Statistics	Cell 3 Validation Statistics	Marsh Validation Statistics
Bias, mg/L	0.0056	0.0004	0.0022	0.0006	0.0013
RMSE, mg/L	0.0313	0.0170	0.0051	0.0063	0.0125
R ² Value	0.1258	0.0736	0.0010	0.0016	0.2325
Nash Sutcliffe Efficiency	-0.7946	-0.0787	-0.5112	-0.0066	0.1368

Canal and Marsh Statistics for POR

Parameter	Canal	Marsh
Bias (ft)	0.0005	-0.0009
RMSE (ft)	0.0256	0.0137
R (Corel. Coef.)	0.2469	0.0950
Nash-Sutcliff Efficiency	-0.1817	0.0510

Phosphorus Conclusions

- Predictive of canal TP and annual outflow load
- Internal source in canal

Phosphorus Conclusions

- **Not reliable for interior marsh TP; not yet reliable for most management applications**
- **Captures the transients in the canal and cell 1 but did not in cells 2 and 3 (not unexpected)**
- **k-c* model is too simple to capture the transients in the interior – needs storage state variable**
- **Varied k and c* values between cells – not helpful in terms of calibration stats**

Phosphorus Future Developments

- **More complex simple model –**
 - **WASP phosphorus cycle (rather than CBOD), or**
 - **STELLA + DMSTA equations, or**
 - **DMSTA**
- **More cells**
- **Extend model to 2005 to 2006**
- **Support MIKE-FLOOD – ECO Lab modeling**