# Selenium Fate and Transport in Great Salt Lake Wetlands

Presented to the GSL Selenium Steering Committee
November 30, 2007

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**Nagendra Dev**

# Presentation Outline

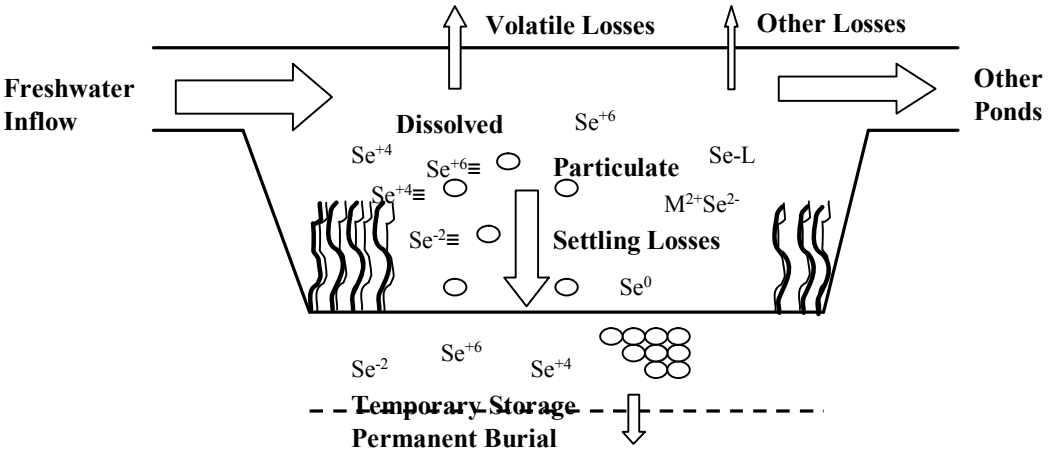
- Overview
- Algal-driven water chemistry
- Temporal selenium speciation
- Selenium Fate and Transport Modeling
- Conclusions

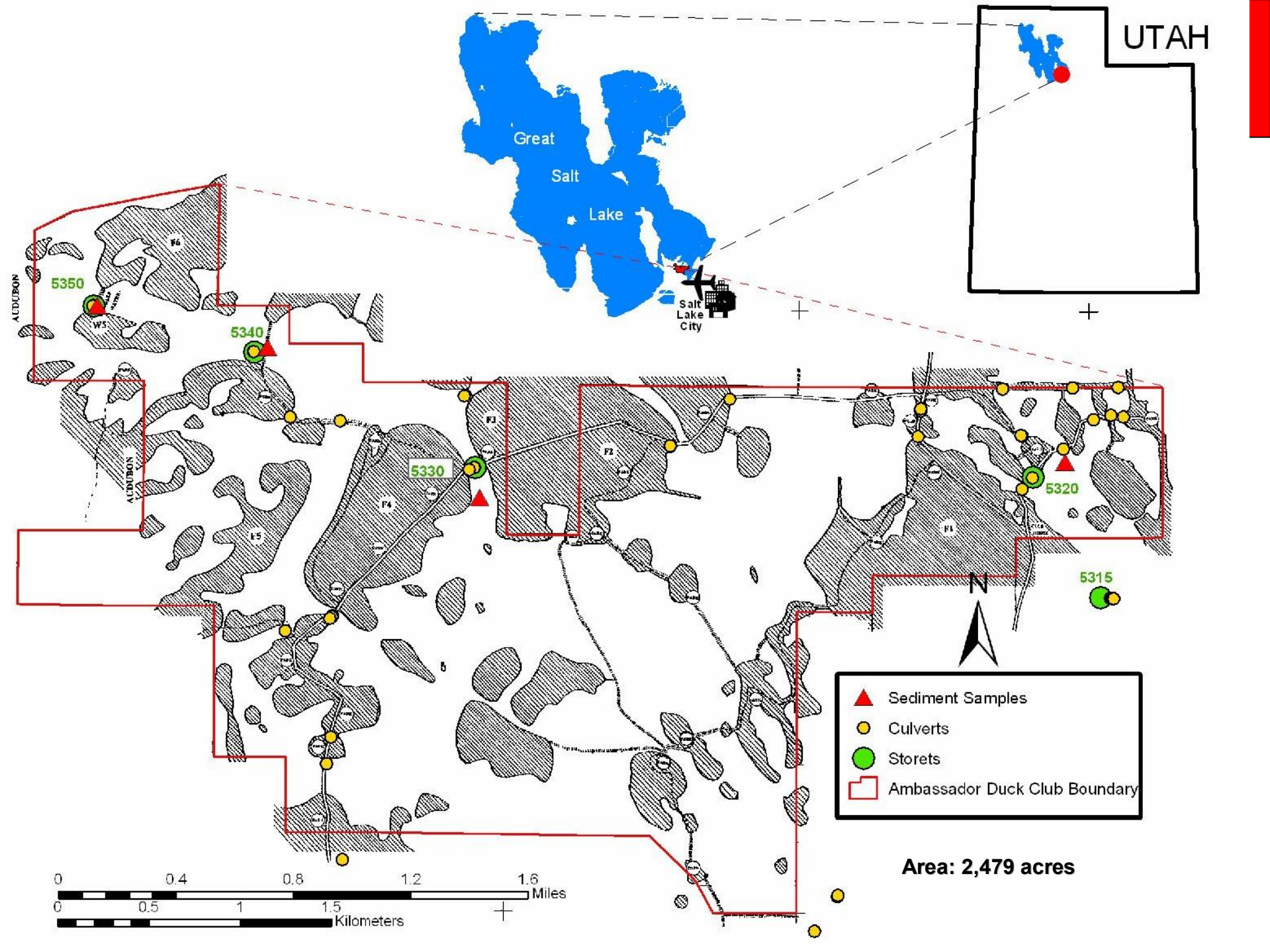
# Students Supported

- Rino Dicataldo – PhD
  - Diurnal variations/First pond mass balance
- Nagendra Dev – PhD
  - Se fate and transport through the entire wetland system
- Beau Uriona – MS
  - Se partitioning and salinity affects

# Research Goals

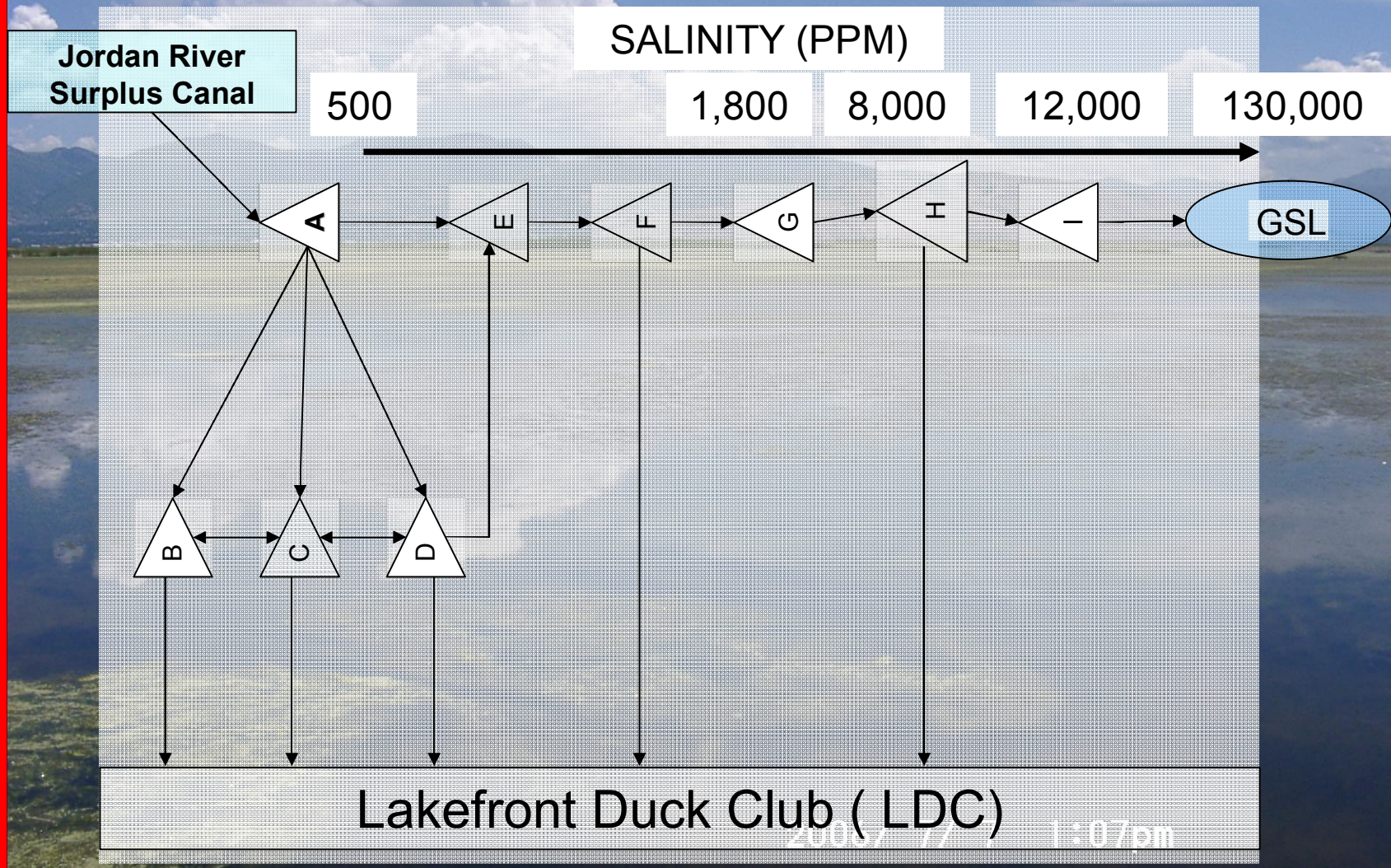
- Understand and quantify the fate and transport of selenium as it moves through wetlands adjacent to the GSL
- Estimate the selenium load that passes through the wetlands and is discharged to the GSL



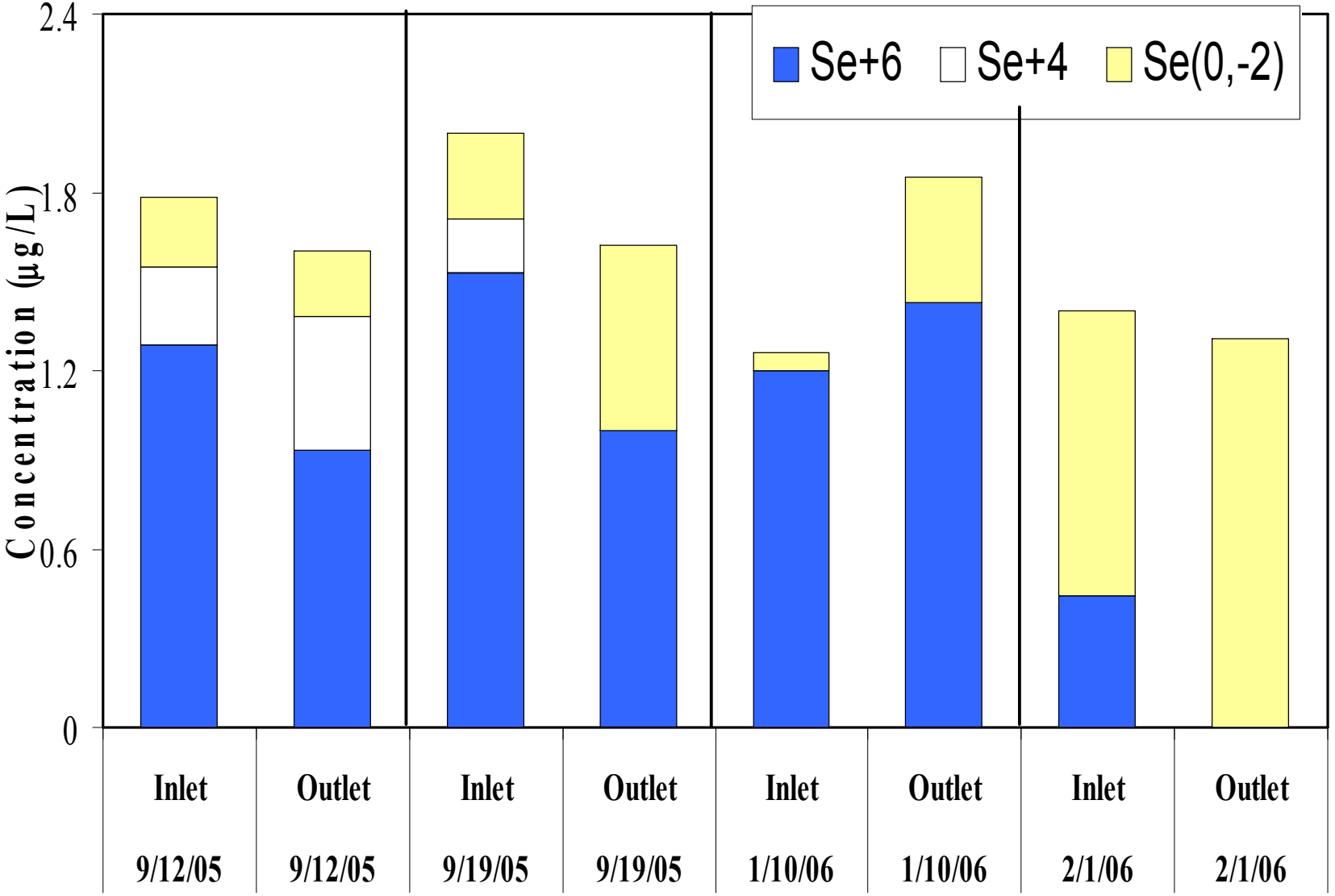

UTAH
Great
Salt
Lake
Salt
Lake
City
5350
5340
5330
5320
5315
N
Sediment Samples
Culverts
Storets
Ambassador Duck Club Boundary
Area: 2,479 acres
0
0.4
0.8
1.2
1.6
Miles
0
0.5
1
1.5
Kilometers

# Interconnected Wetland Ponds

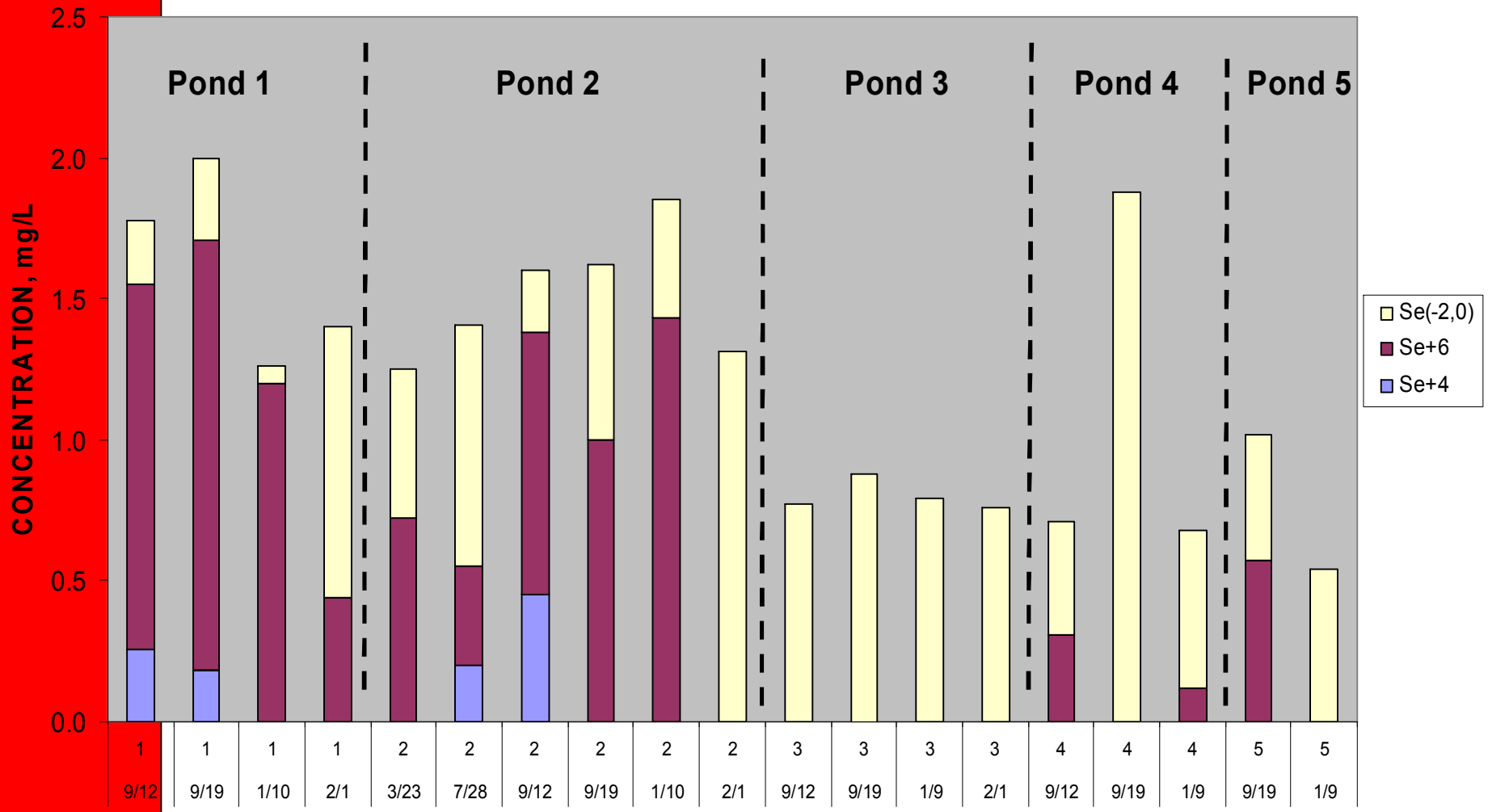
**Conditions change significantly as water flows from the SC to the GSL.**



# Selenium Fate – Pond A

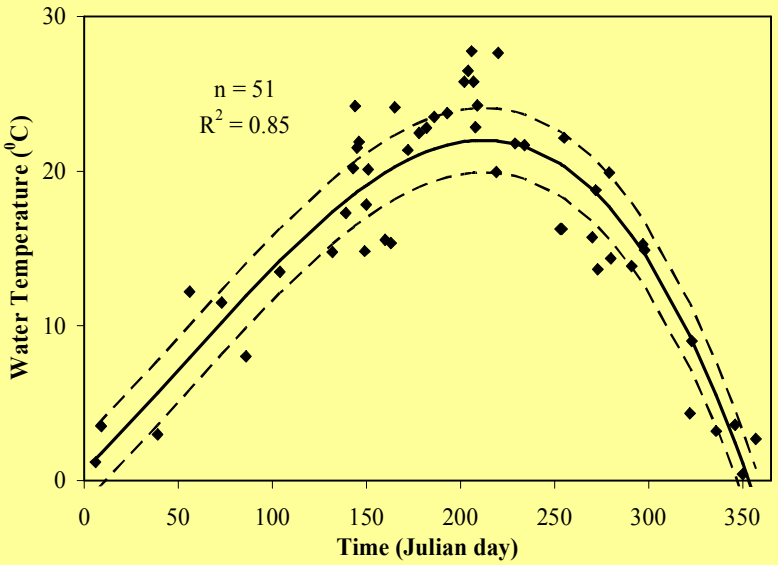


# ADC Selenium Concentrations

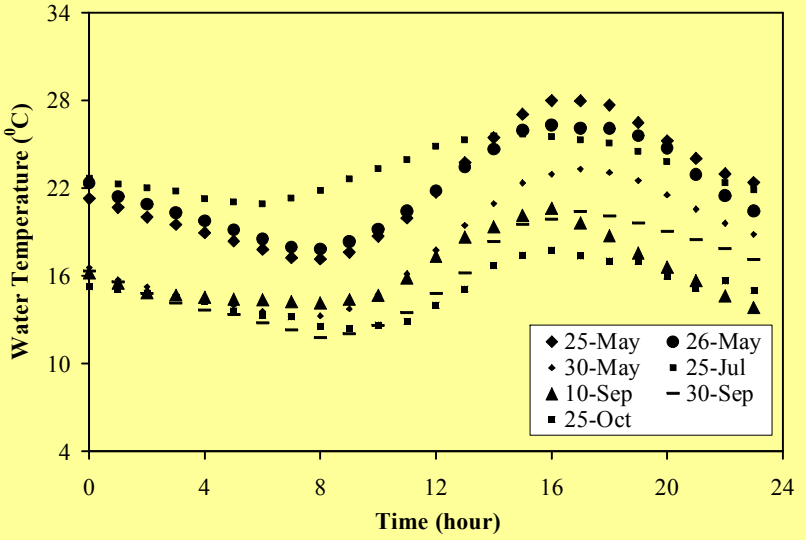


# Water Temperature

Seasonal Change
(0 – 30$^0$ C)

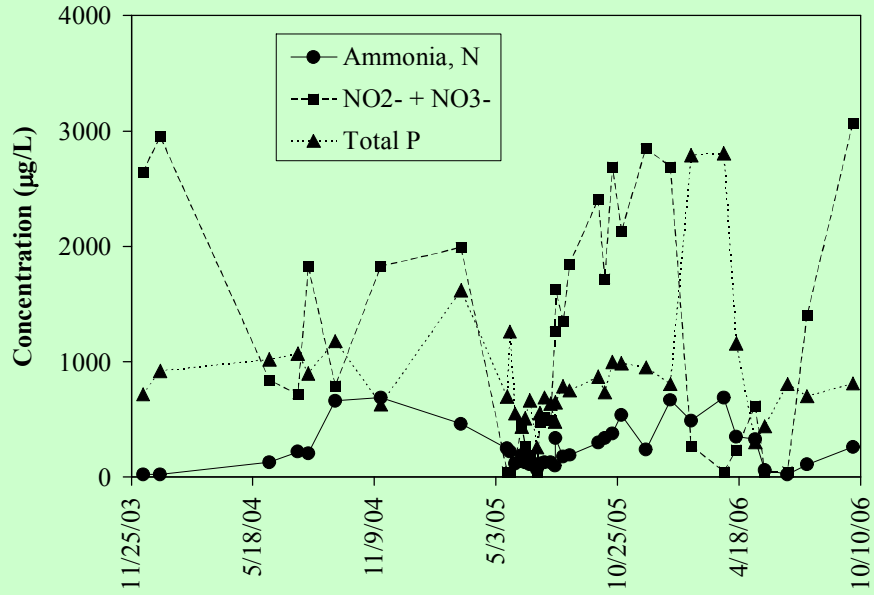


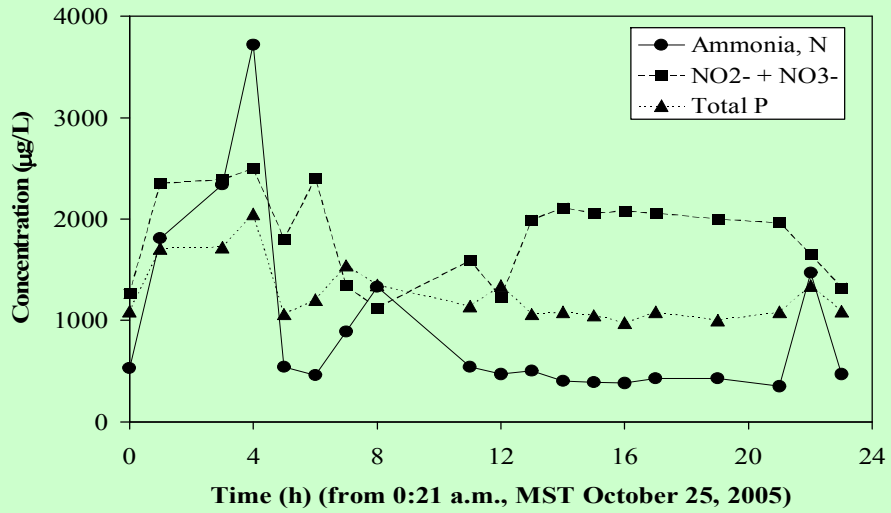

Daily Change
(0 – 11$^0$C)



# Nutrients

- Sufficient inflow of:
  - Nitrate (Nitrite)
  - Ammonia
  - Phosphorous
- Eutrophic System
  - Chlorophyll *a* > 10 μg/L
- Evidence of Nitrification



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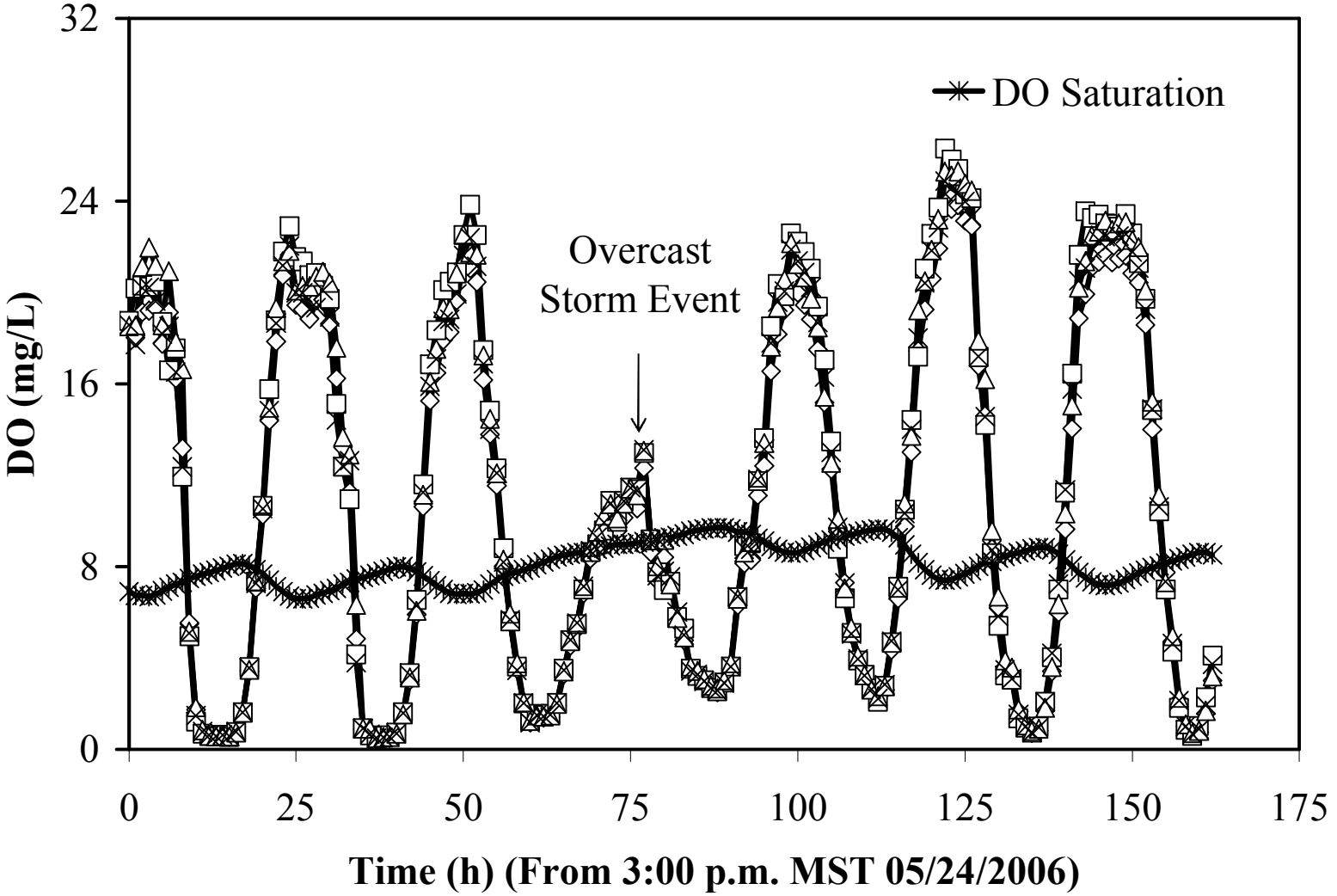
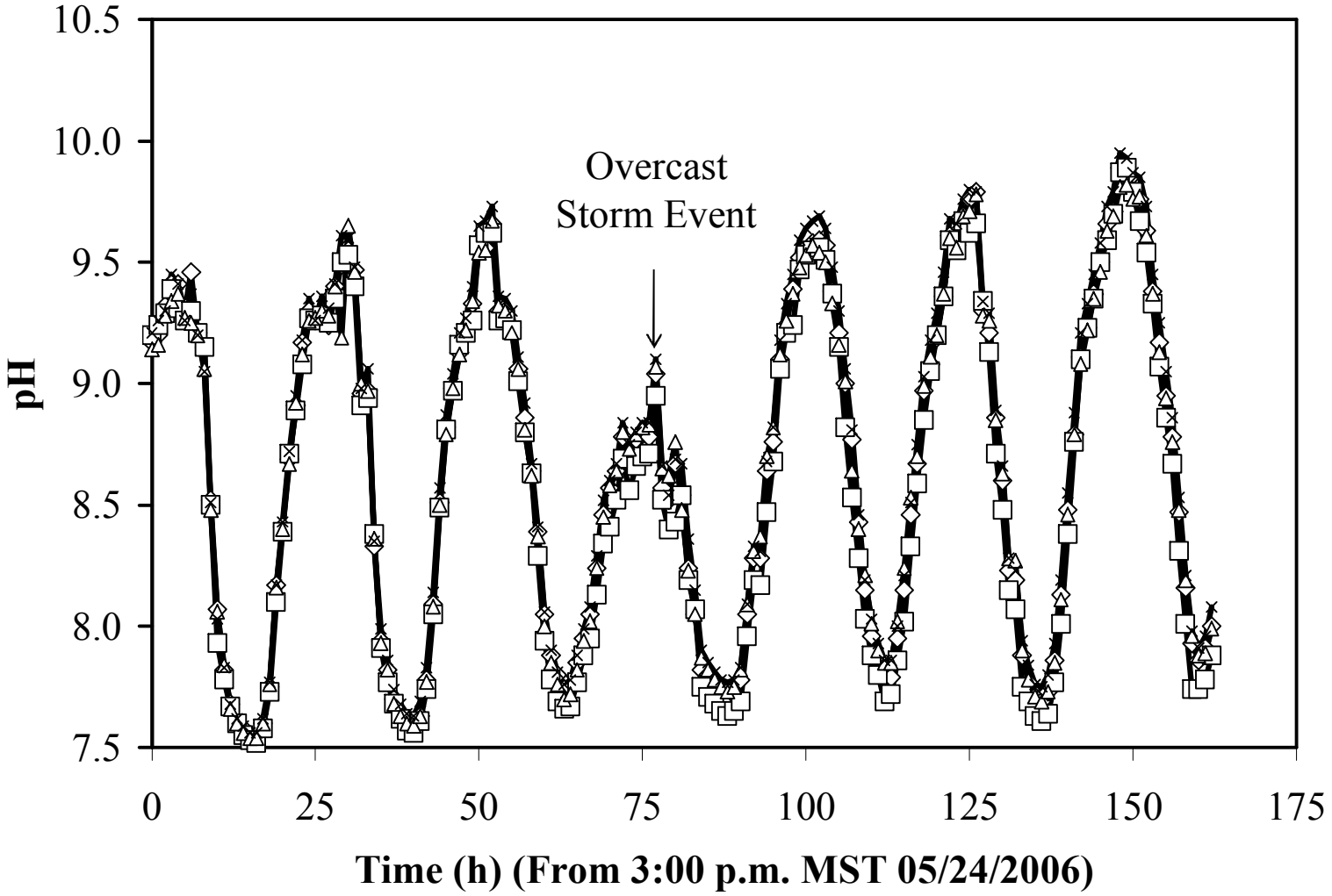
# DIURNAL PATTERNS DRIVEN BY ALGAL PRODUCTION

# DO Cycling



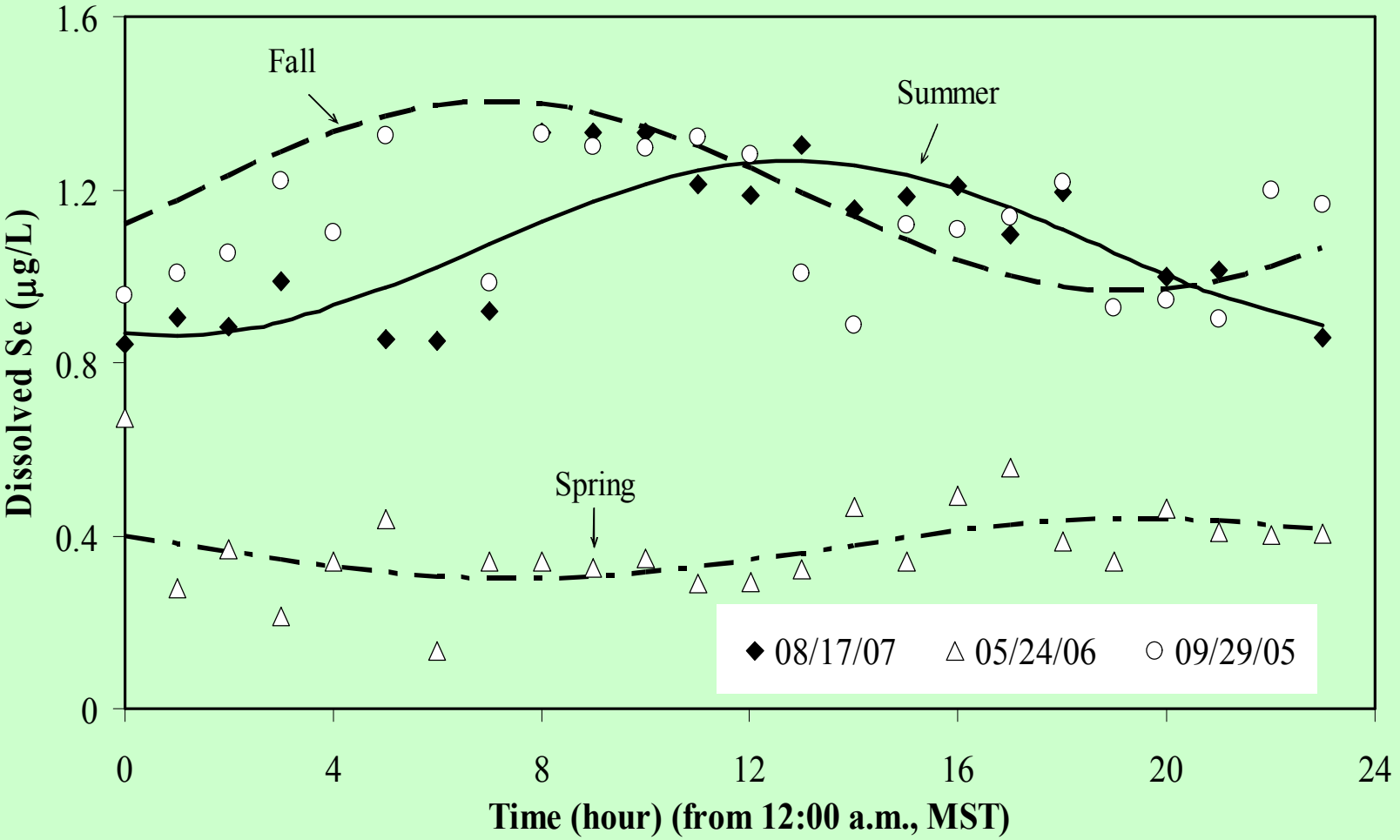

Site #5320 during Spring 2006 using 4 INSITU TROLLs 9000.

# Daily pH Cycle




Site #5320 during Spring 2006 using 4 INSITU TROLLs 9000.

# Diurnal Dissolved[1] Se Concentrations




Seasonal trend of dissolved Se in Pond A. The lines represent the sinusoidal curve fit.

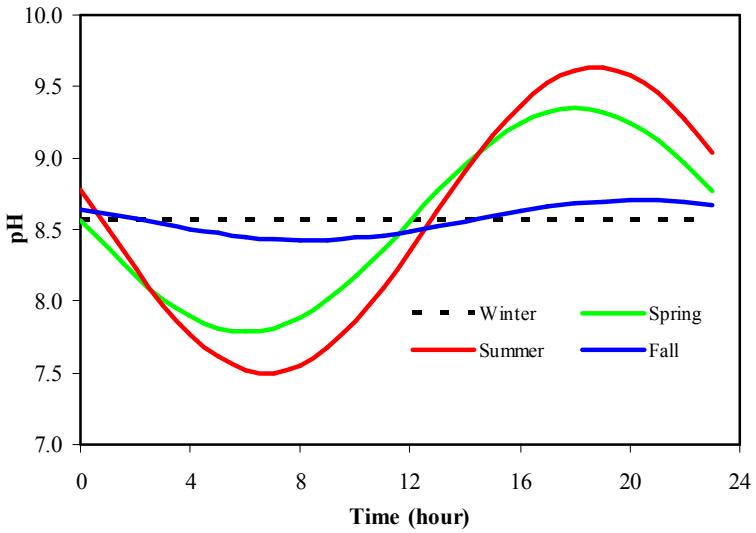
[1]Filtrate passing a 0.45 µm diameter filter.

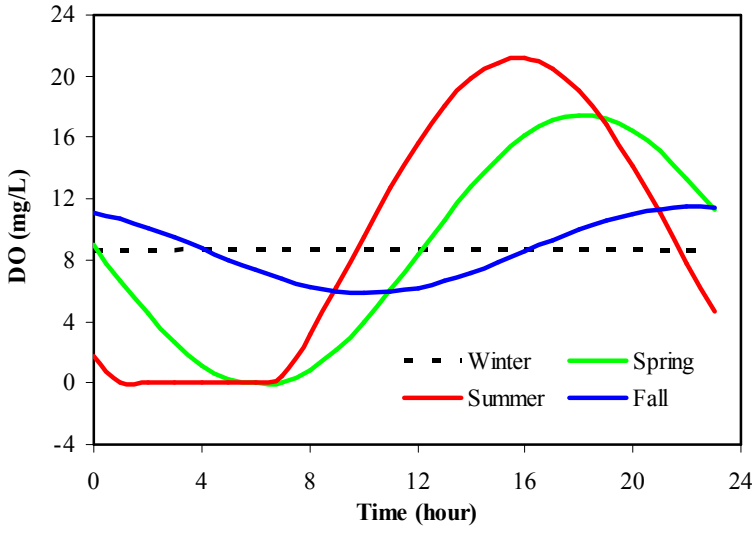
# EMPRICAL DO Model

$$DO(t) = P_{avg} + A_1 \cos(\varpi_0 t) + B_1 \sin(\varpi_0 t)$$

- 3 unknown parameters
  - Net average DO production by photosynthesis ($P_{avg}$ )
  - $A_1$
  - $B_1$
- $A_1$ and $B_1$ are related to the photoperiod and water temperature

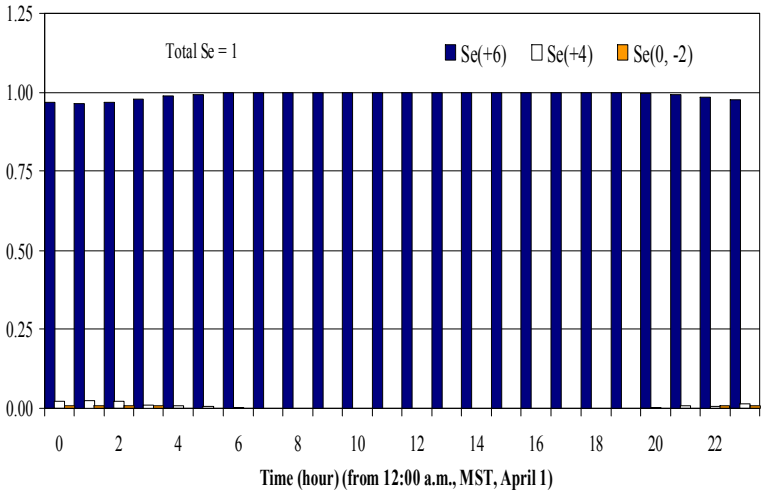
# Pond 1 Diurnal Forecast Models

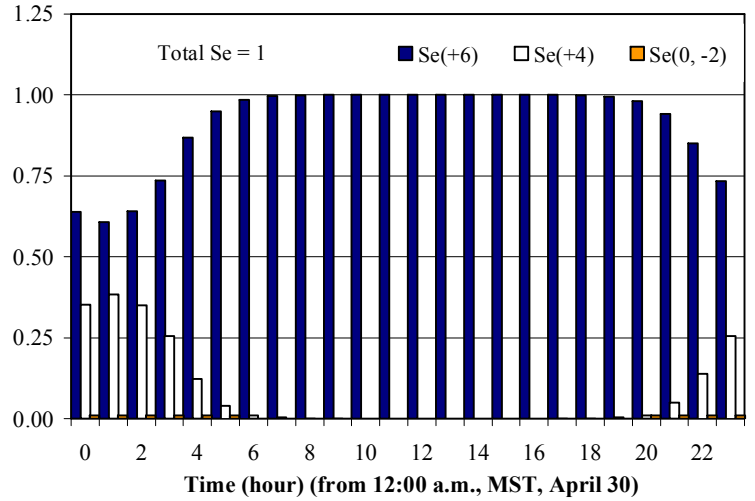


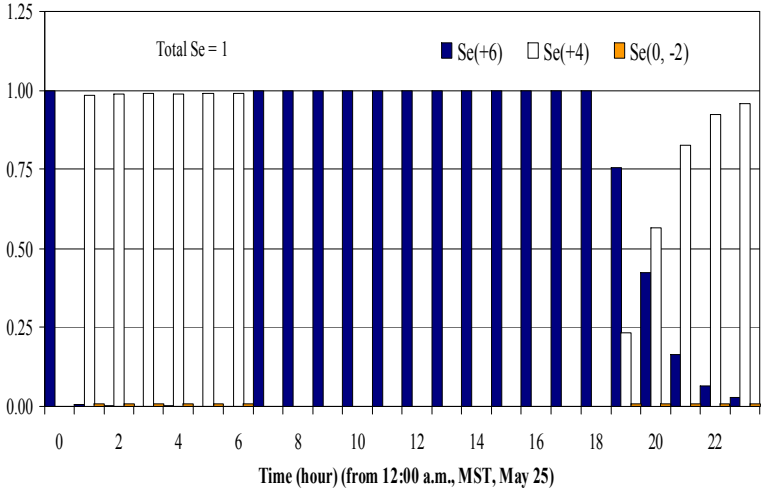




Winter = January 1; Spring = April 21; Summer = June 21; and Fall = October 21.

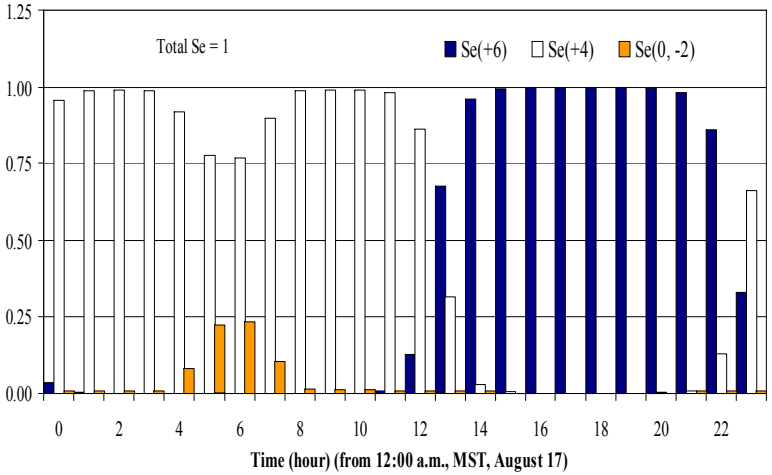
# Predicted Diurnal Selenium Speciation

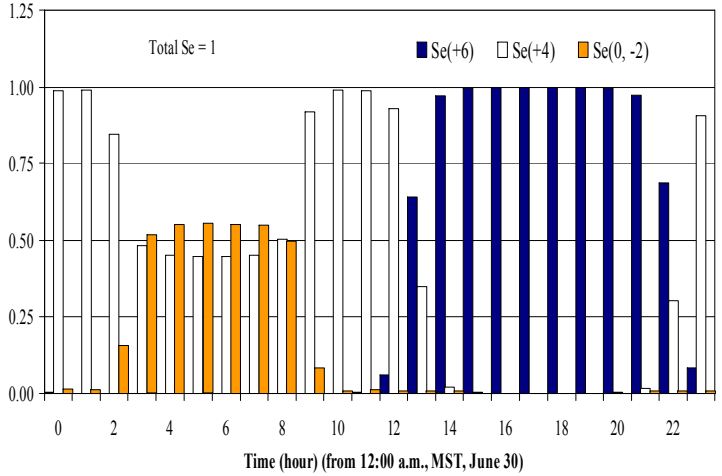


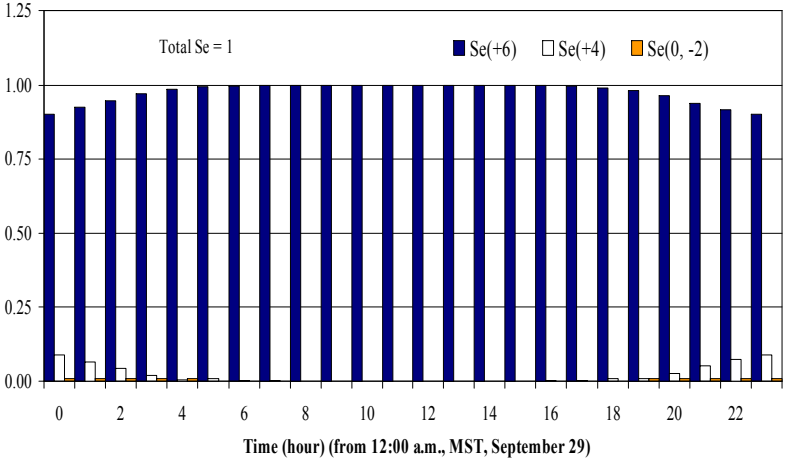



# Predicted Diurnal Selenium Speciation



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# FATE AND TRANSPORT MODELING

# Se Fate and Transport Models

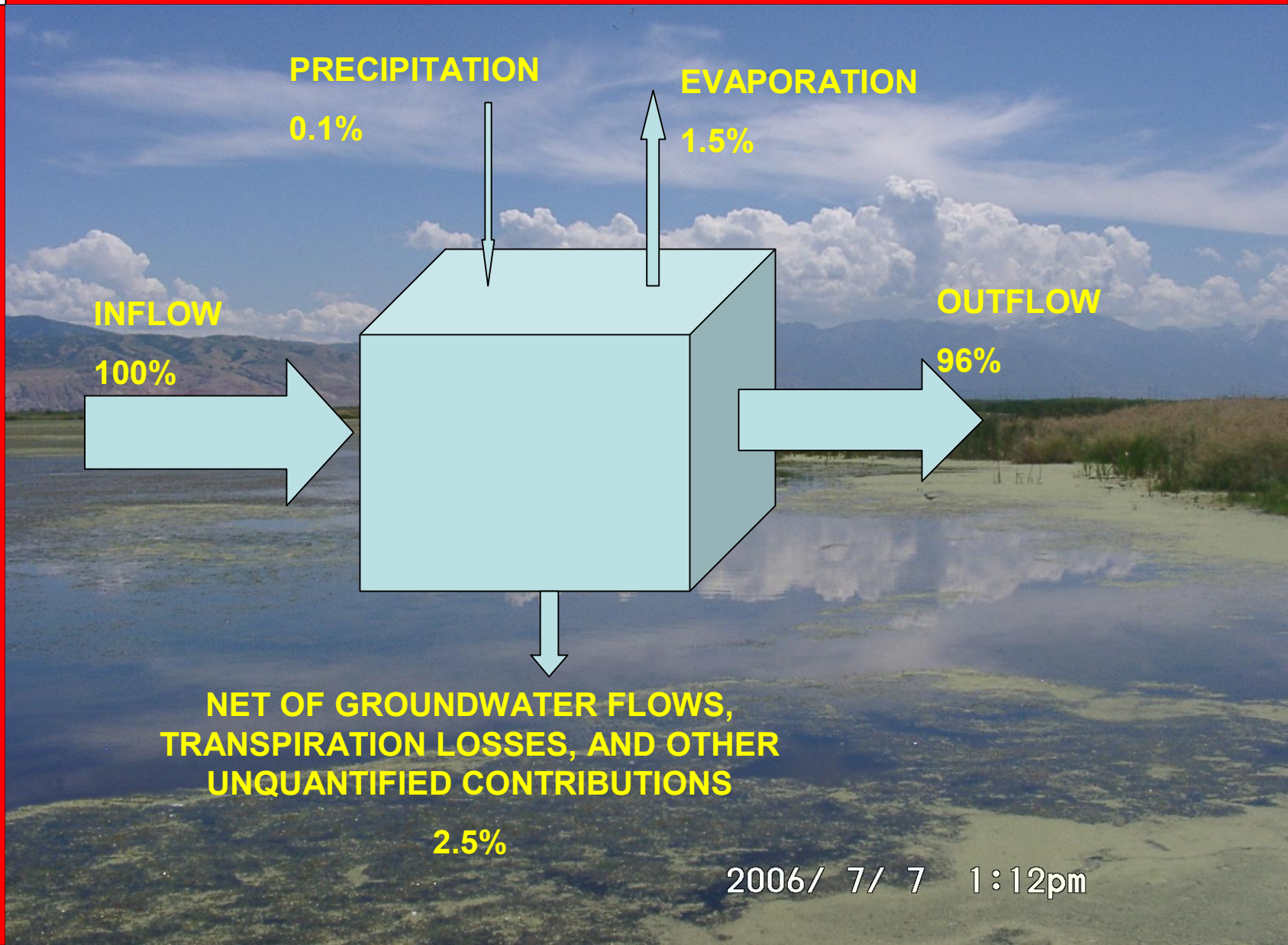
The Se fate and transport models consist of three distinct components:

1. Water Balance
2. Solids Mass Balance
3. Selenium Mass Balance

**Assumption:**

- Wetlands approximated to a completely mixed reactor

# Water Balance



# Solids Balance

- Sediment flux Pond A
  - $J_{SSe} = v_s$*(Particulate Se Concentration)
  - $v_s$ = 0.25 – 1.50 m/d (Stoke's Law)
  - Particulate Se Concentration = 0.2 μg/L
  - $J_{SSe} = 1.83x10^{-2}$ - $8.32x10^{-2}$ (gSe/($m^2$ yr))
  - Mass Transfer = 15.2 ± 11.4 (KgSe/yr)
- Sediment flux south arm GSL
  - $J_{SSe} = 1.58x10^{-1}$ & $1.19x10^{-3}$ (gSe/($m^2$ yr))
- Volatile Se Flux (Dissolved Se)
  - $JV_{Se} = v_v$*(volatile Se concentration in water – volatile Se concentration in air)
  - Measured Volatile Se concentration (Purge and Trap) in Pond A - average 0.8 ng/L
  - Volatile Se Flux Pond A = $3.2x10^{-4}$ – $9.4x10^{-4}$ (gSe/($m^2$ yr)

# Selenium Model Formulation

- Time-variable Se Model is necessary to understand short-term and long-term based fate and transport
- System drivers
  - Selenium loading to the wetlands
  - Solar energy (Photoperiod & cloud cover)
  - Water Temperature
  - Nutrient concentrations
  - Algal production
- Effects are shown by
  - Dissolved Oxygen
  - pH
  - Selenium speciation
- Short-term modeling (~ 1 day) to understand the system dynamics
- Long-term modeling (~1 yr) to understand seasonal pattern and broad impacts on the Great Salt Lake Se loading

# Se Partitioning – Water Column & Sediment

- **Particulate/Dissolved Se:**

  $Kd = c_P/c_W$

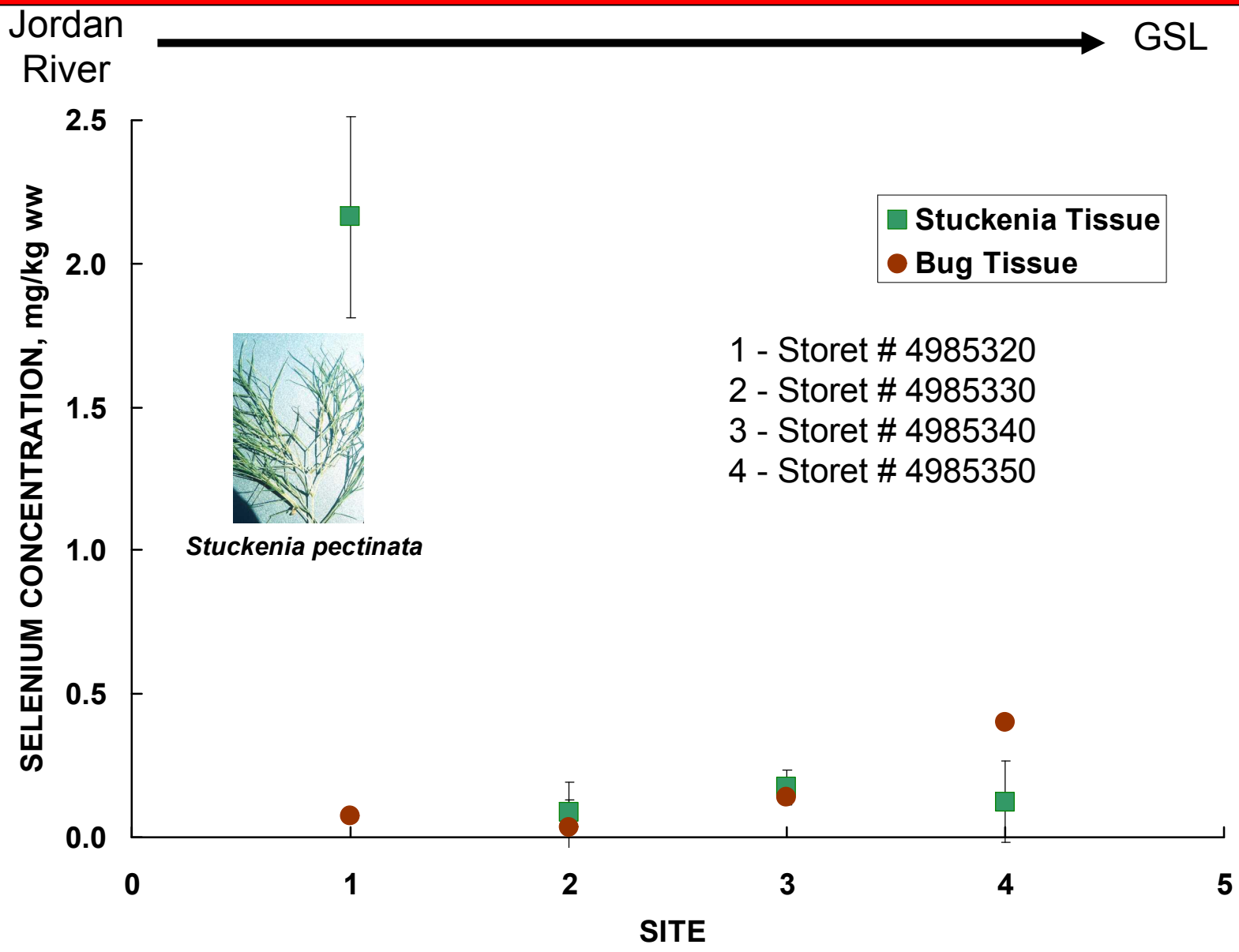
| Site | Kd Value, L/Kg | |
|---|---|---|
| 315 | 30±18 | (Inlet Pond A) |
| 320 | 53±15 | (Outlet Pond A) |

- **Sediment/Water Se**

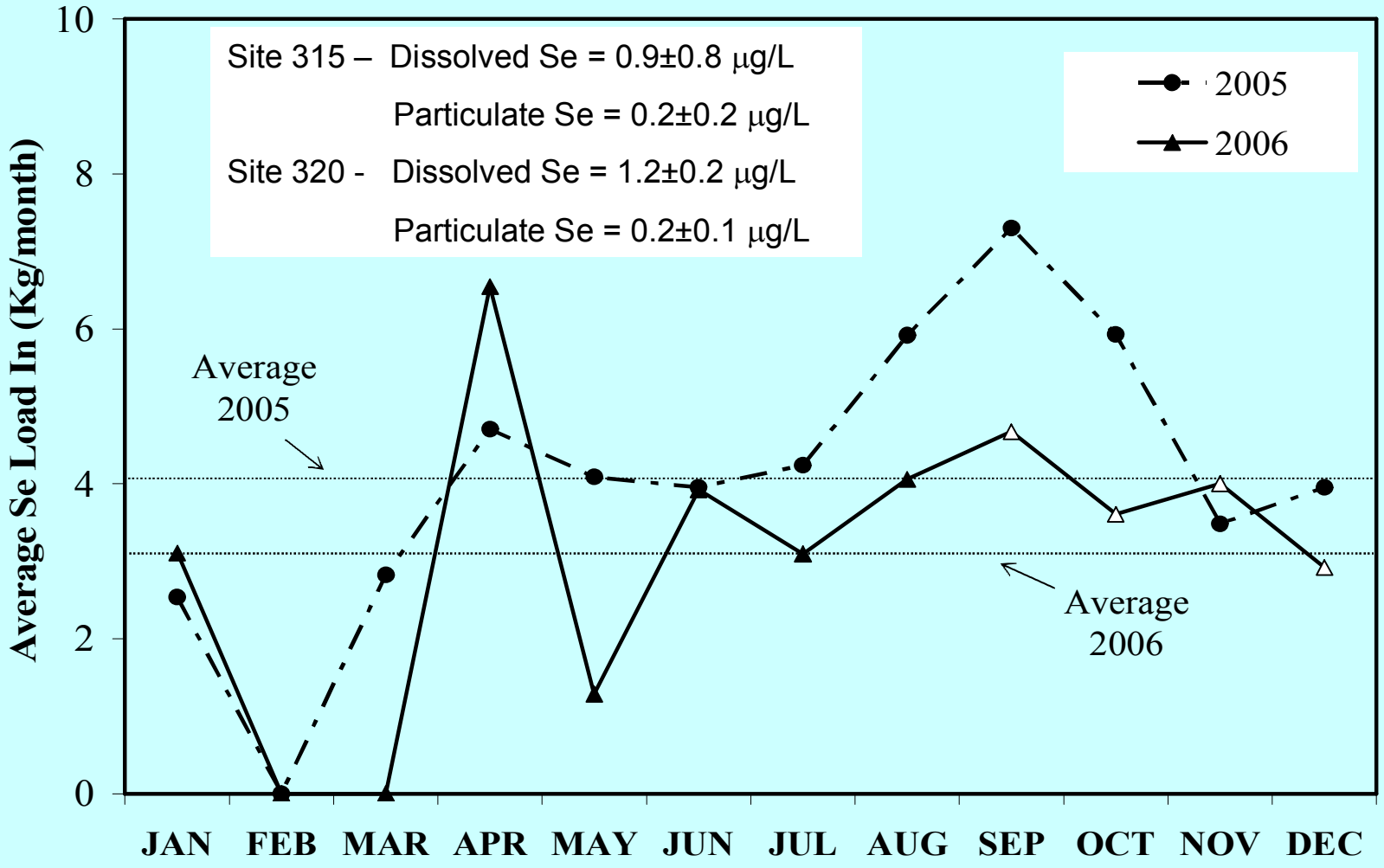
  $Kd = c_S/c_W$

| Site | Kd Value, L/Kg | |
|---|---|---|
| 315 | 861±182 | (Inlet Pond A) |
| 316 | 808±0 | (Outlet Pond A) |

# Selenium in Tissues

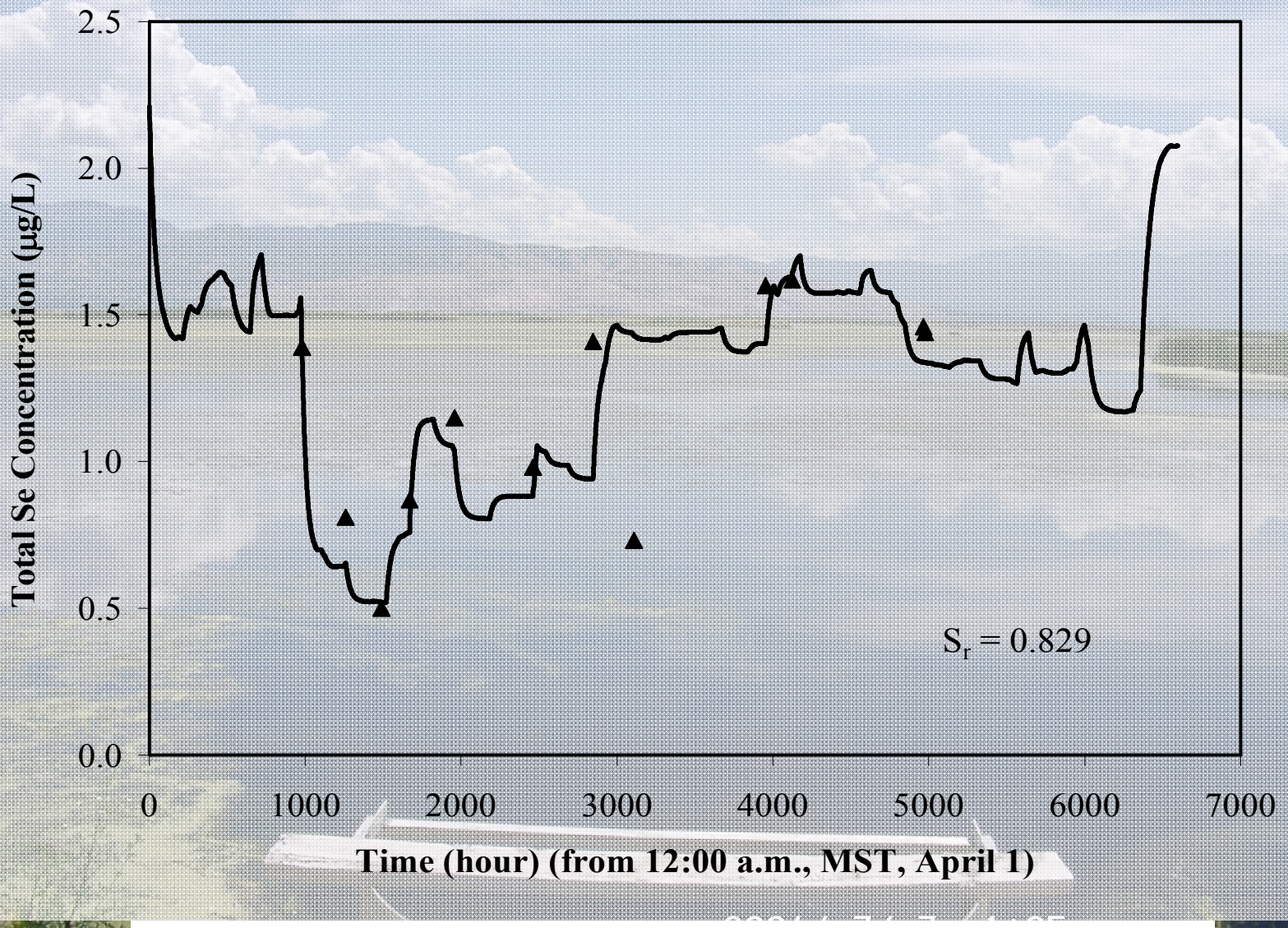


# Selenium Mass Balance



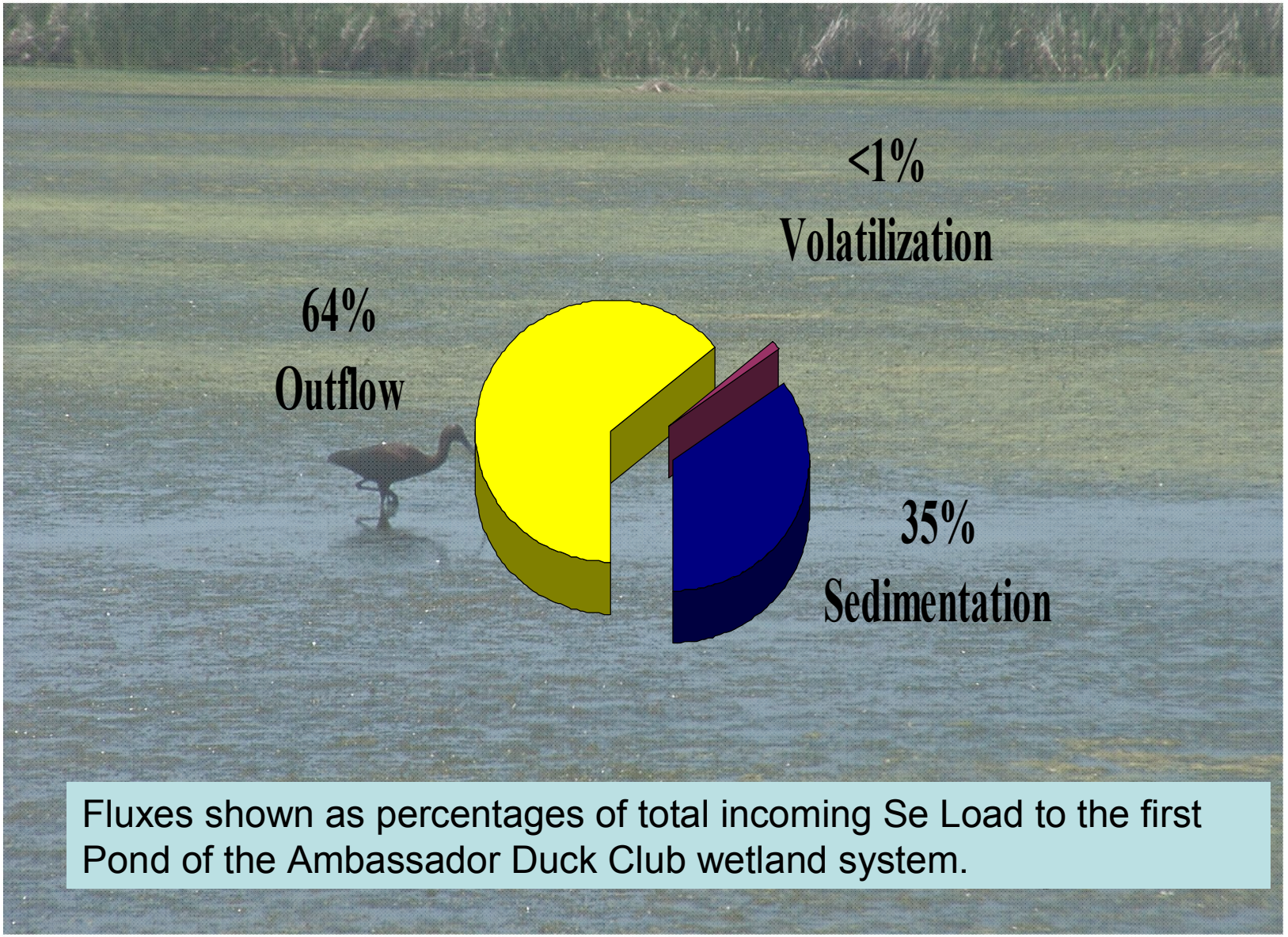

Average Se loads entering ADC during 2005 and 2006. Open symbols (Δ) represent estimated values from previous year.

# 1-Year Se Transport Prediction



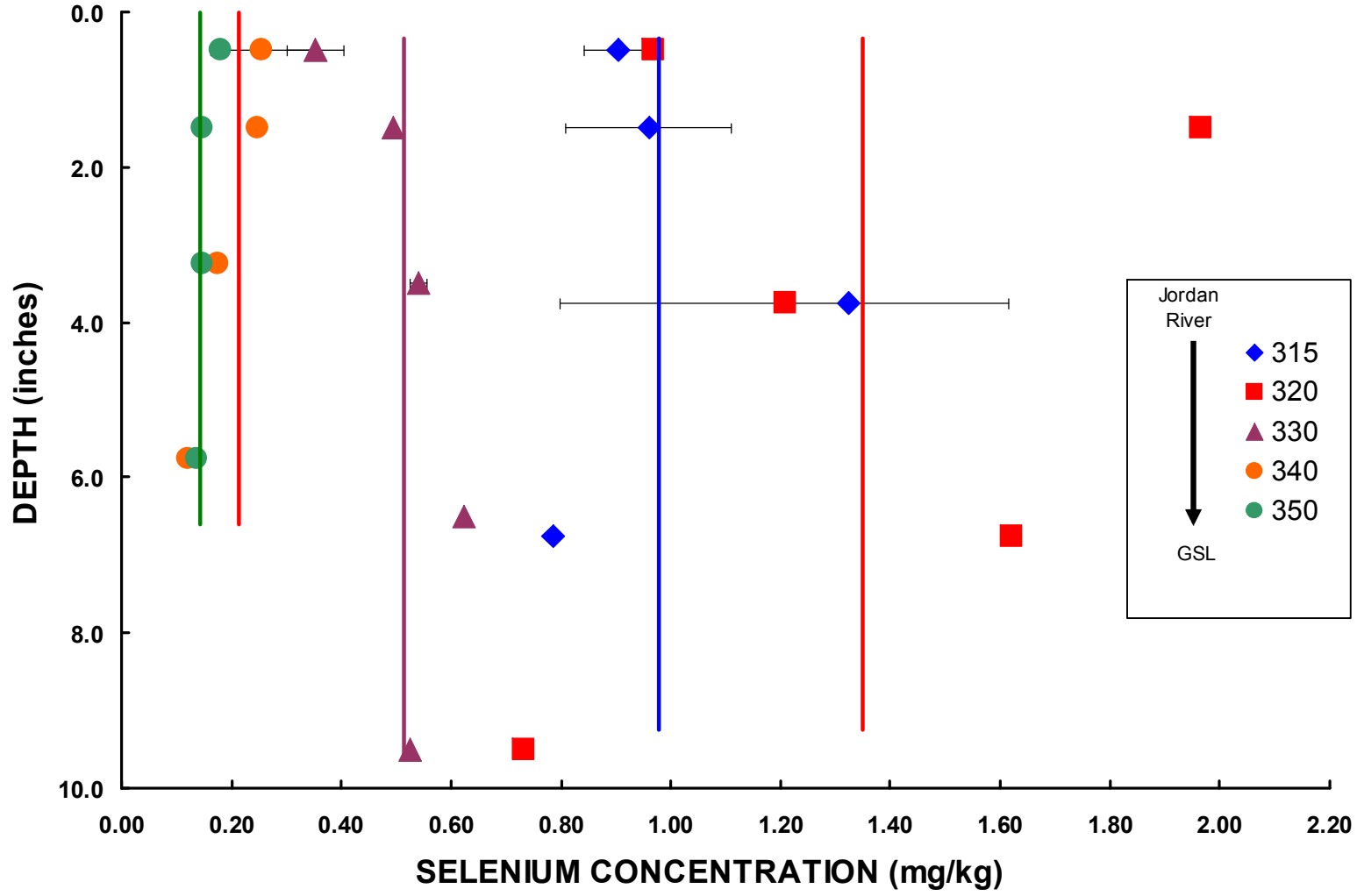

Se transport model in Pond A form April 1 to December 31.

# Estimated Selenium Fluxes




Fluxes shown as percentages of total incoming Se Load to the first Pond of the Ambassador Duck Club wetland system.

# Sediment Selenium Concentrations



# Status

- Research on diurnal cycling and first pond mass balance complete
  - Rino Dicataldo defended his PhD thesis earlier this week
- Selenium speciation work complete
  - Beau Uriona completed MS work
- Draft of multiple pond mass balance model is complete
  - Nagendra Dev should defend his PhD thesis in Spring 2008
- Draft final report will be submitted to DEQ in Dec 2007

# Conclusions

- Water temperature and photoperiod drive Selenium fate and transport
  - Algal production is driven by water temperature and photo period
  - Algal production drives diurnal DO cycles
  - Diurnal DO cycles drive pH and redox
  - pH and redox drive selenium speciation
- What happens to Selenium as it is transported through the GSL wetlands?
  - 35% lost by sedimentation (Pond A)
  - <1% lost by volatilization (Pond A)
- How much of the Se that enters the wetlands is discharged to the GSL?
  - 36% reduction of incoming Se Mass in Pond A
  - Significant reduction of Se concentration (>75%) as it goes through the entire ADC wetland system

# Acknowledgments

Utah Division of Water Quality (Dr. Miller, Dr. Moellmer, Mr. Baker, and Division staff)

US Environmental Protection Agency (Region 8)

Center for Water, Ecosystem, and Climate Science (Dr. William Johnson and Ximena Diaz (Ph.D. Student))

Ambassador Duck Club (Dick West and Dick Gilbert)

Central Davis Sewer District (Leland Myers)

Kennecott Environmental Laboratory (Lynn Hutchinson)