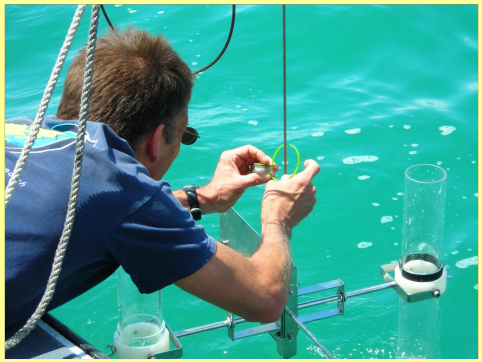
Estimation of selenium loads entering the south-arm of Great Salt Lake, Utah



David Naftz, USGS, Salt Lake City, UT

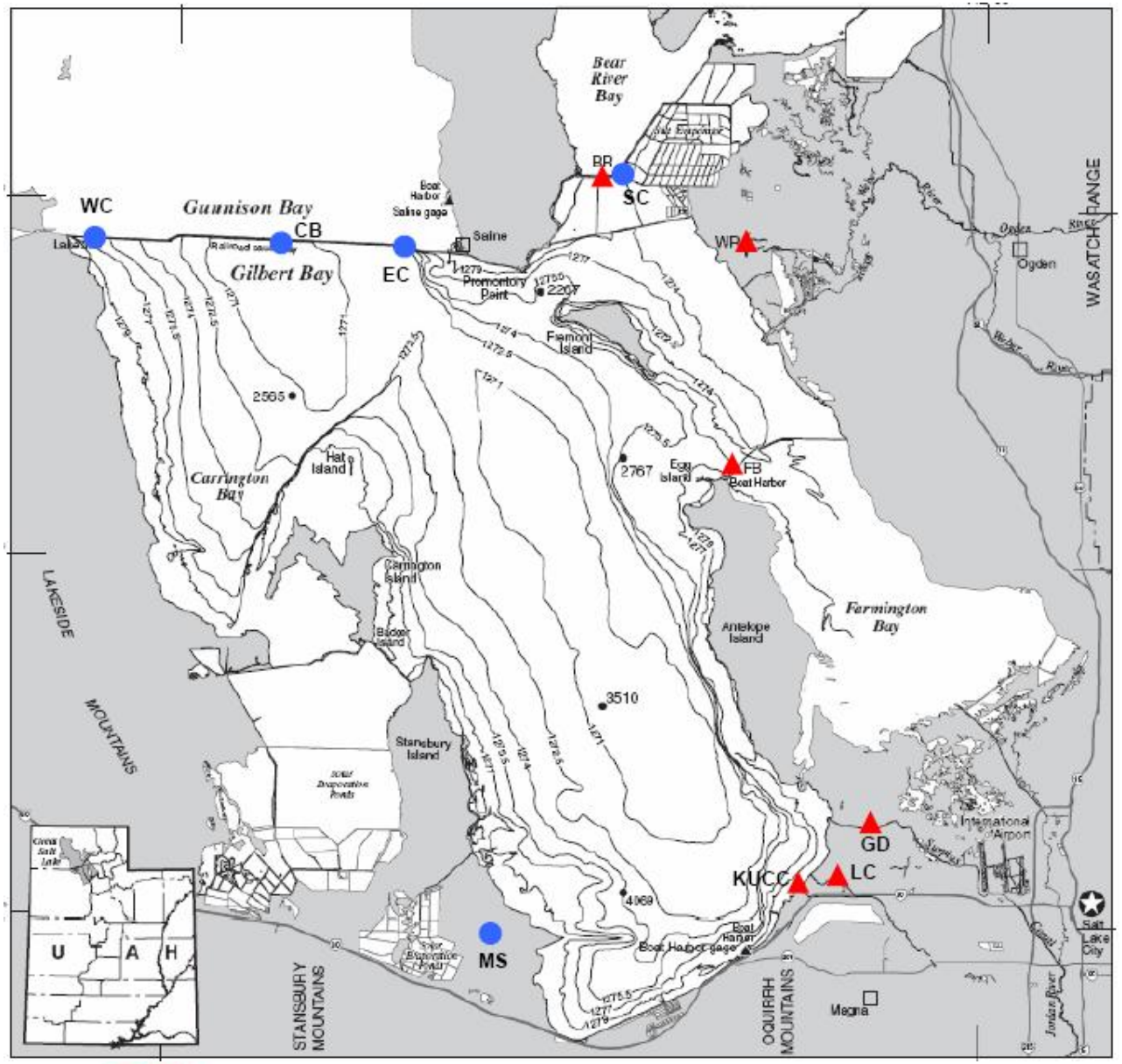
Bill Johnson, Univ. of Utah, Salt Lake City, UT

Kim Beisner, Univ. of Utah, Salt Lake City, UT

Ximena Diaz, Univ. of Utah, Salt Lake City, UT

TOPICS

- Period of record used
- LOADEST modeling results [total Se]
- Daily and cumulative Se loads
- Selenium species
- Historic vs. present day loads
- Lake modeling of input loads
- Continued work



Gage and misc. sampling sites

THE UNIVERSITY OF UTAH

Great Salt Lake Research Team

USGS

Period of record

Table 1. Streamflow-gaging stations with continuous records adjacent to Great Salt Lake, Utah, where stream discharge and water-quality samples were collected to simulate selenium loads.

[*, missing discharge record reconstructed with adjacent streamflow gages; #, estimated selenium concentrations added to LOADEST calibration file to obtain minimum sample size of 12]

Field ID	USGS station identification number	USGS station name	Number of selenium samples collected	Time period for which loads were simulated
BR	411403112200801	Bear River Bay Outflow at GSL Minerals Corp Bridge	17	03/21/06 thru 12/31/06*
WR	411316112132201	North Fork Weber River near West Warren, Utah	7#	05/11/06 thru 12/31/06
GD	10172630	Goggin Drain near Magna, Utah	17	05/03/06 thru 12/31/06
LC	10172640	Lee Creek near Magna, Utah	8#	05/18/06 thru 12/31/06
KUCC	10172650	Kennecott Drain near Magna, Utah	164	10/01/2005 thru 12/31/2006
FB	410401112134801	GSL Farmington Bay Outflow at Causeway Bridge	17	05/03/2006 thru 12/31/2006*

LOADEST model

Table 3. Regression models considered during the automated selection option in LOADEST (Runkel et al., 2004).

[a_0 thru a_6, model determined regression coefficients; ln, natural log; Q, discharge; dtime, decimal time; pi, 3.141593]

Model number	Regression model
1	$a_0 + a_1 \ln Q$
2	$a_0 + a_1 \ln Q + a_2 \ln Q^2$
3	$a_0 + a_1 \ln Q + a_2 dtime$
4	$a_0 + a_1 \ln Q + a_2 \sin(2\pi dtime) + a_3 \cos(2\pi dtime)$
5	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 dtime$
6	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime)$
7	$a_0 + a_1 \ln Q + a_2 \sin(2\pi dtime) + a_3 \cos(2\pi dtime) + a_4 dtime$
8	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime) + a_5 dtime$
9	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime) + a_5 dtime + a_6 dtime^2$

Lee Creek discharge record

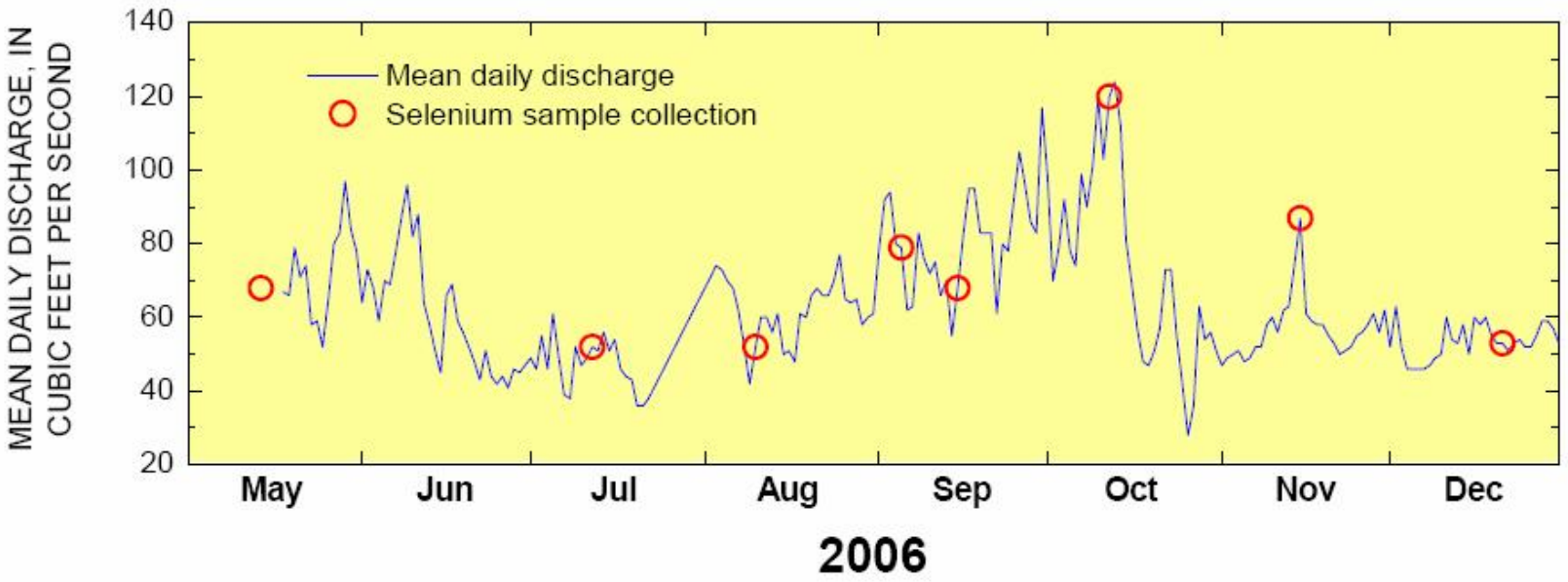


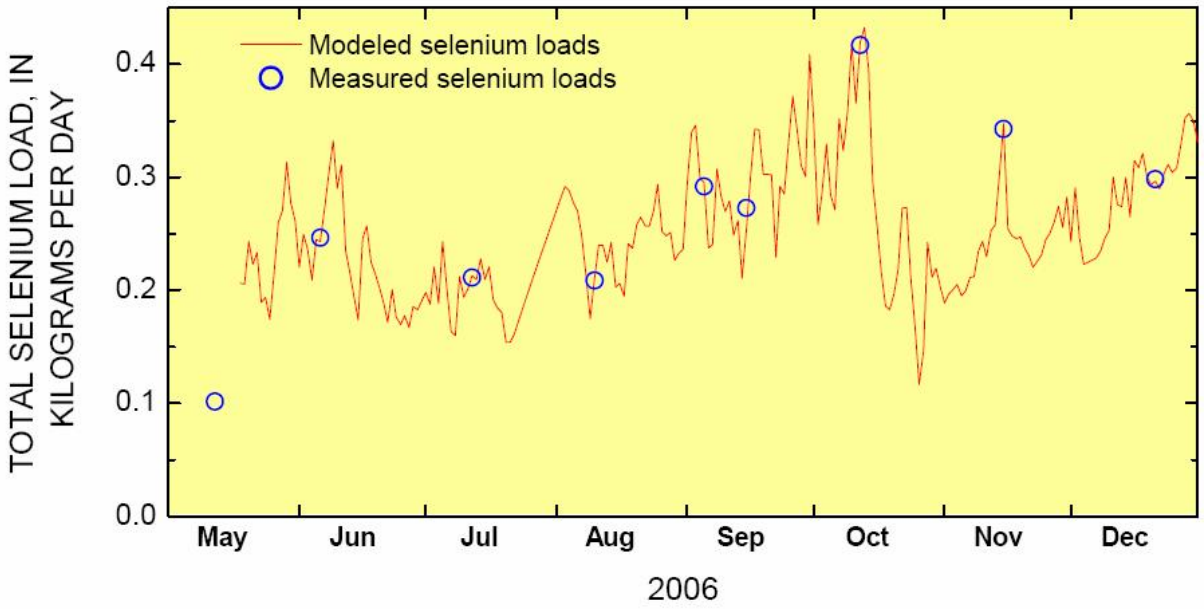
Figure 2. Stream discharge and dates when selenium samples were collected at the Lee Creek gaging station.

Modeled vs. measured Se load

$$Ln(Load) = a0 + a1\ LnQ + a2\ Sin(2\ pi\ dtime) + a3\ Cos(2\ pi\ dtime) + a4\ dtime$$

a0	a1	a2	a3	a4
-1.3417	0.8949	-0.5053	-0.0088	2.5773

Lee Creek



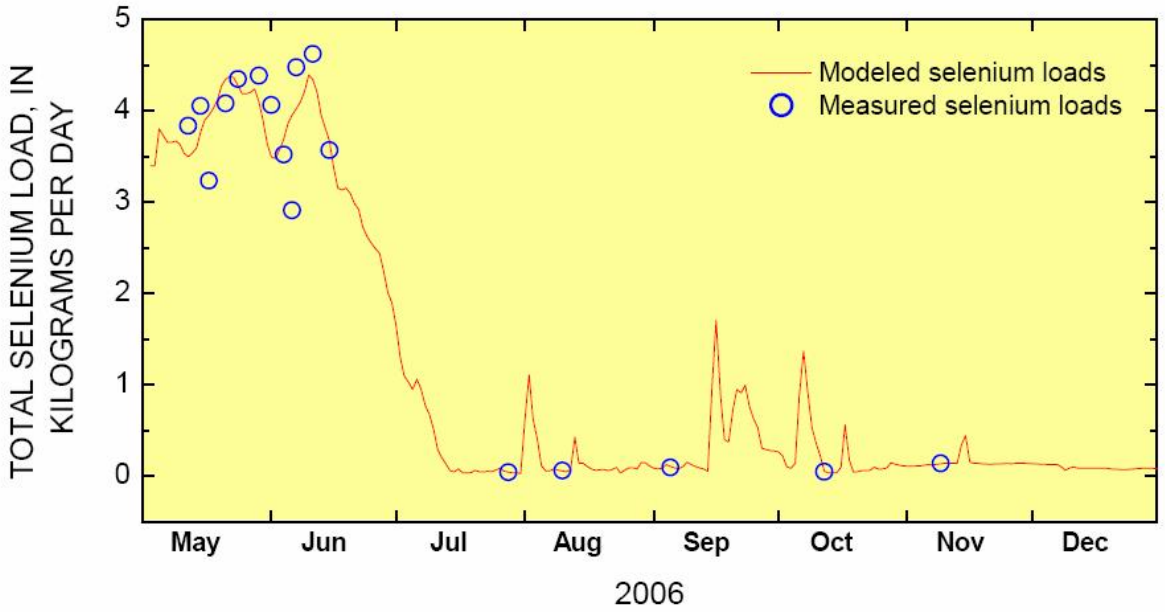
= 57 kg Se

Modeled vs. measured Se load

$$Ln(Load) = a0 + a1\ LnQ + a2\ LnQ^2$$

a0	a1	a2
-0.4524	0.9607	-0.0531

Goggn Drain



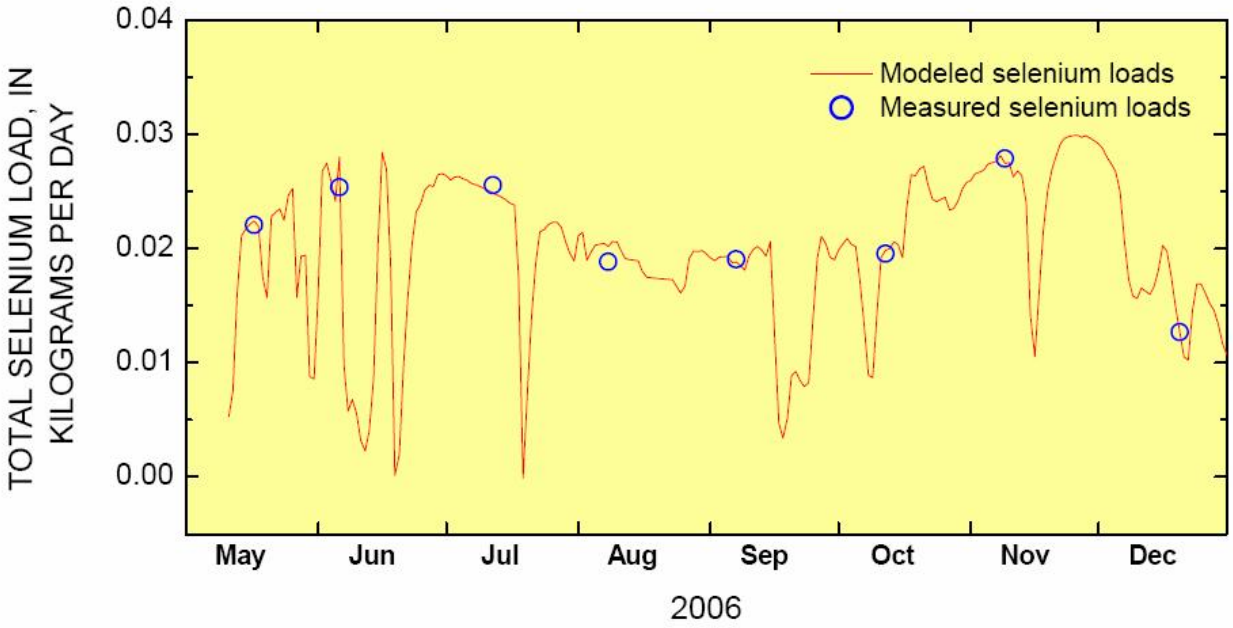
= 202 kg Se

Modeled vs. measured Se load

$$\ln(\text{Load}) = a0 + a1\ \text{LnQ} + a2\ \text{LnQ}^2 + a3\ \sin(2\pi\ \text{dtime}) + a4\ \cos(2\pi\ \text{dtime}) + a5\ \text{dtime} + a6\ \text{dtime}^2$$

a0	a1	a2	a3	a4	a5	a6
-0.6244	0.3294	-1.8479	-0.3229	-3.3118	1.6912	-47.4137

Weber River



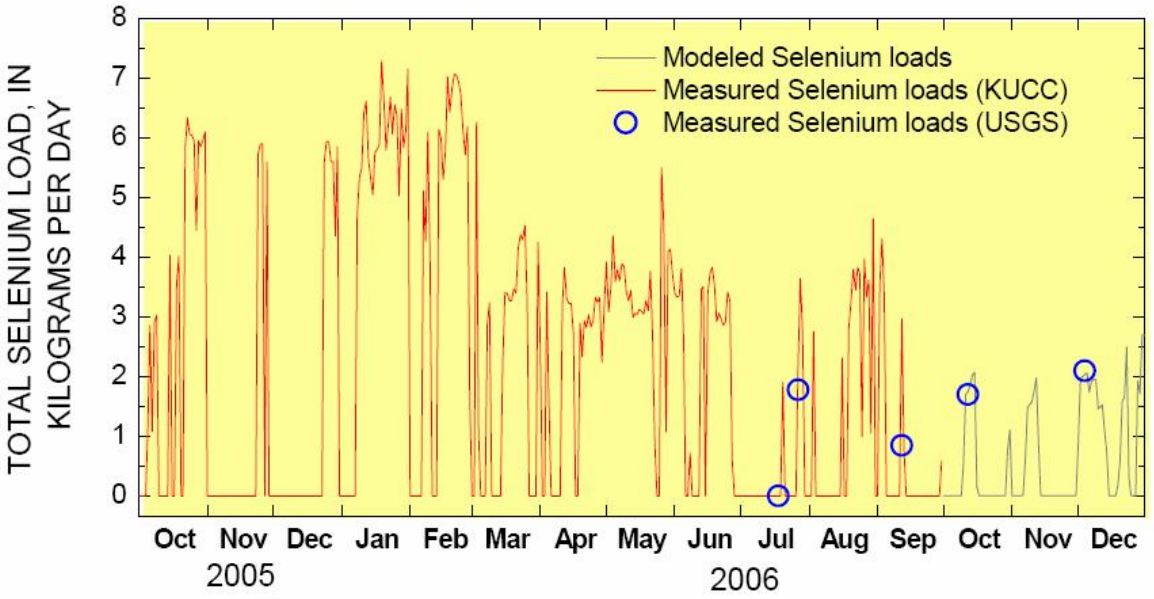
= 4.5 kg Se

Modeled vs. measured Se load

$$Ln(Load) = a0 + a1\ LnQ + a2\ LnQ^2 + a3\ Sin(2\ pi\ dtime) + a4\ Cos(2\ pi\ dtime)$$

a0	a1	a2	a3	a4
-2.1992	1.4053	-0.0967	-0.2658	0.2300

KUCC drain



= 231 kg Se

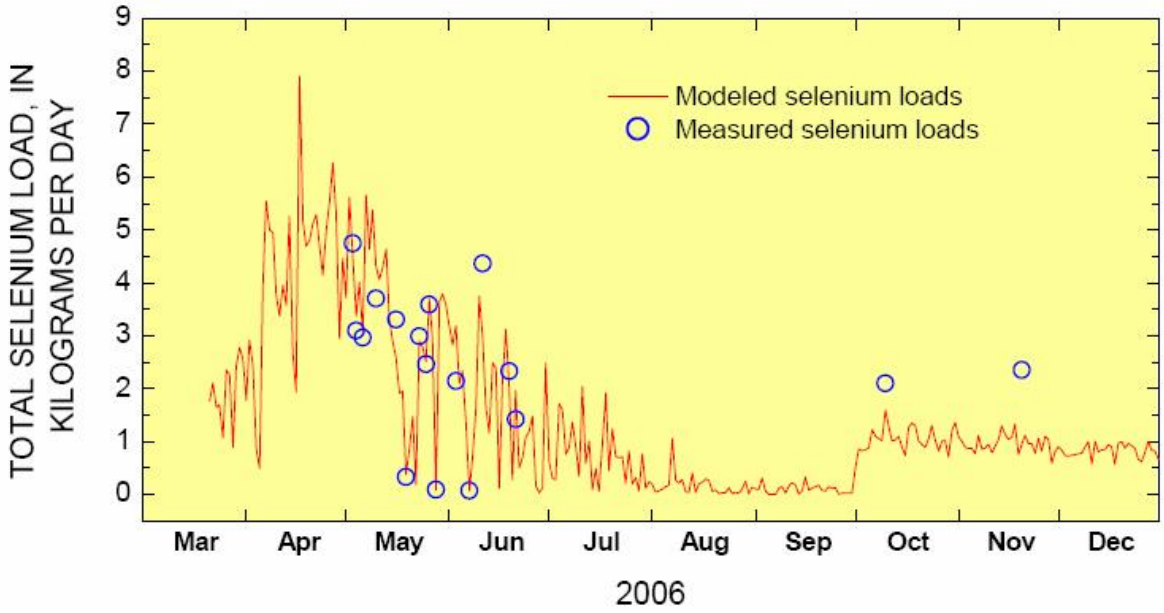
Modeled vs. measured Se load

$$Ln(Load) = a0 + a1\ LnQ + a2\ Sin(2\ pi\ dtime) + a3\ Cos(2\ pi\ dtime)$$

Model Coefficients

a0	a1	a2	a3
-0.7112	0.9865	0.0027	0.5521

Bear River



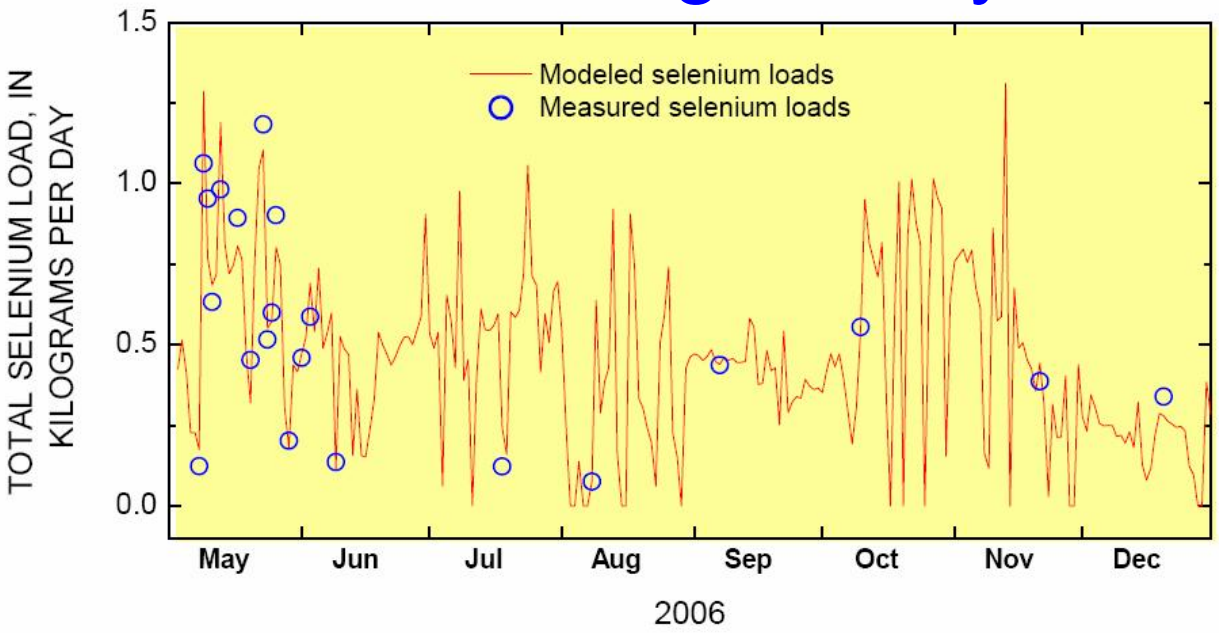
= 197 kg Se

Modeled vs. measured Se load

$$Ln(Load) = a0 + a1\ LnQ + a2\ dtime$$

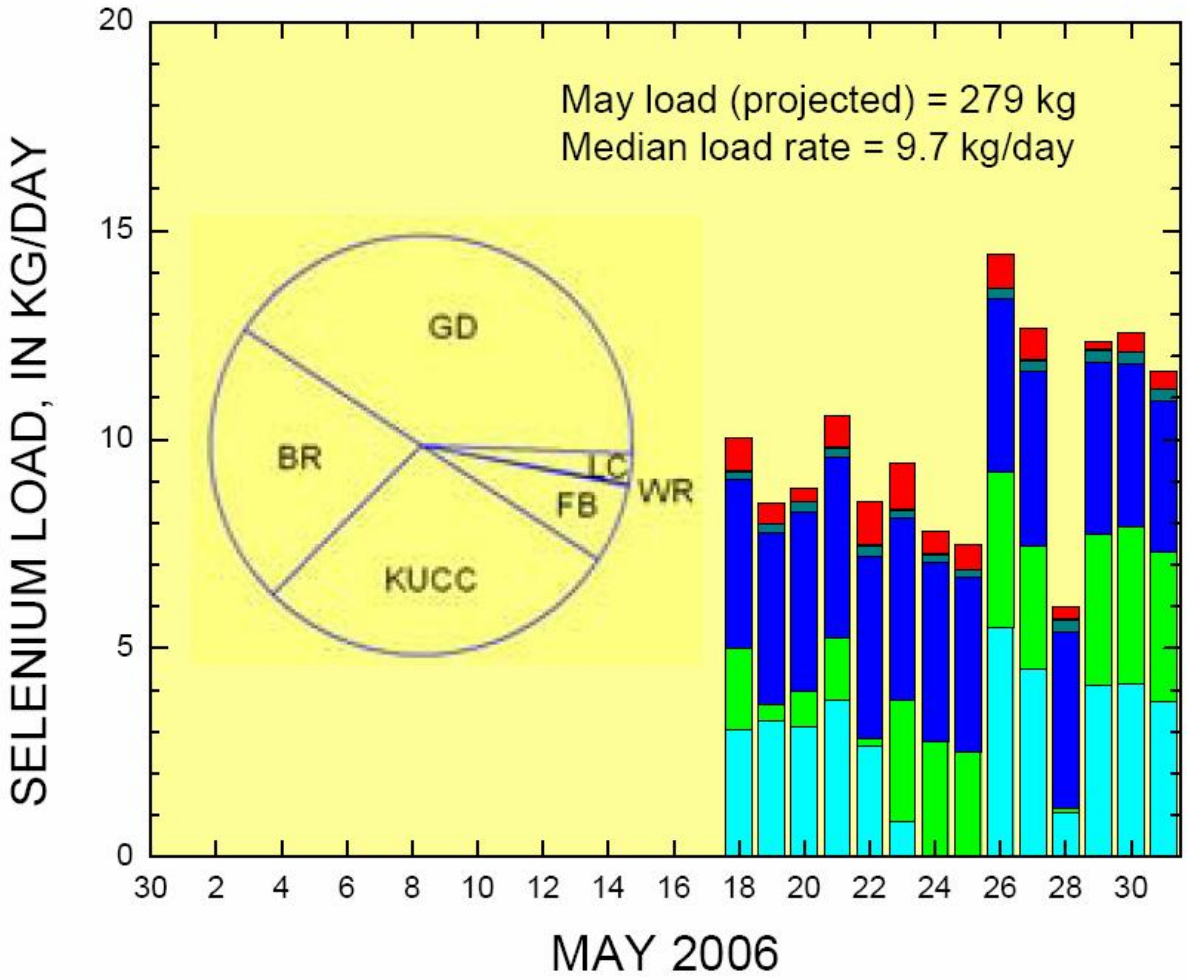
a0	a1	a2
-1.2739	1.0984	-0.8612

Farmington Bay



= 100 kg Se

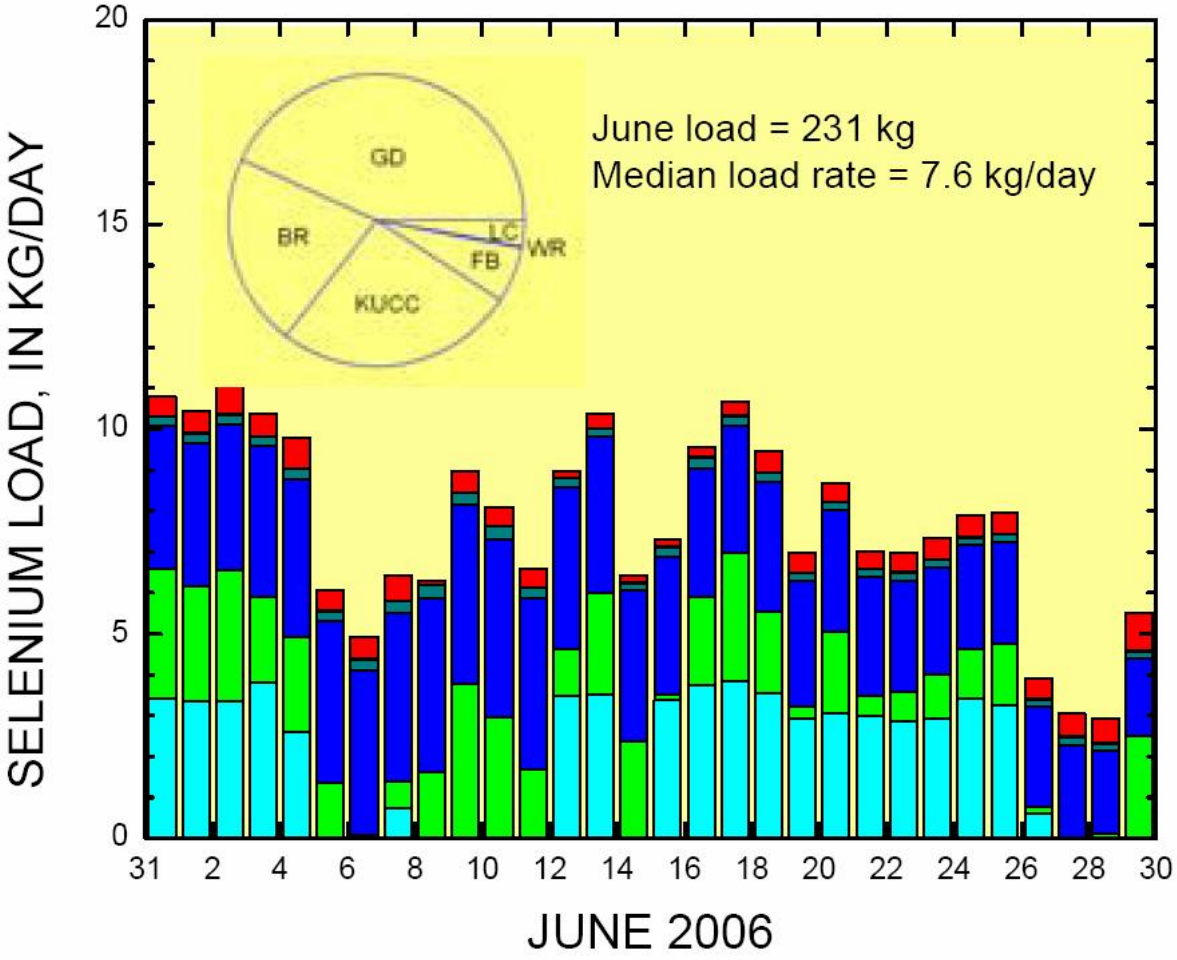
Daily Se loads—MAY 2006



EXPLANATION

Farm. Bay	**(FB)**
Weber River	**(WR)**
Lee Creek	**(LC)**
Goggin Drain	**(GD)**
Bear River	**(BR)**
KUCC Outfall	**(KUCC)**

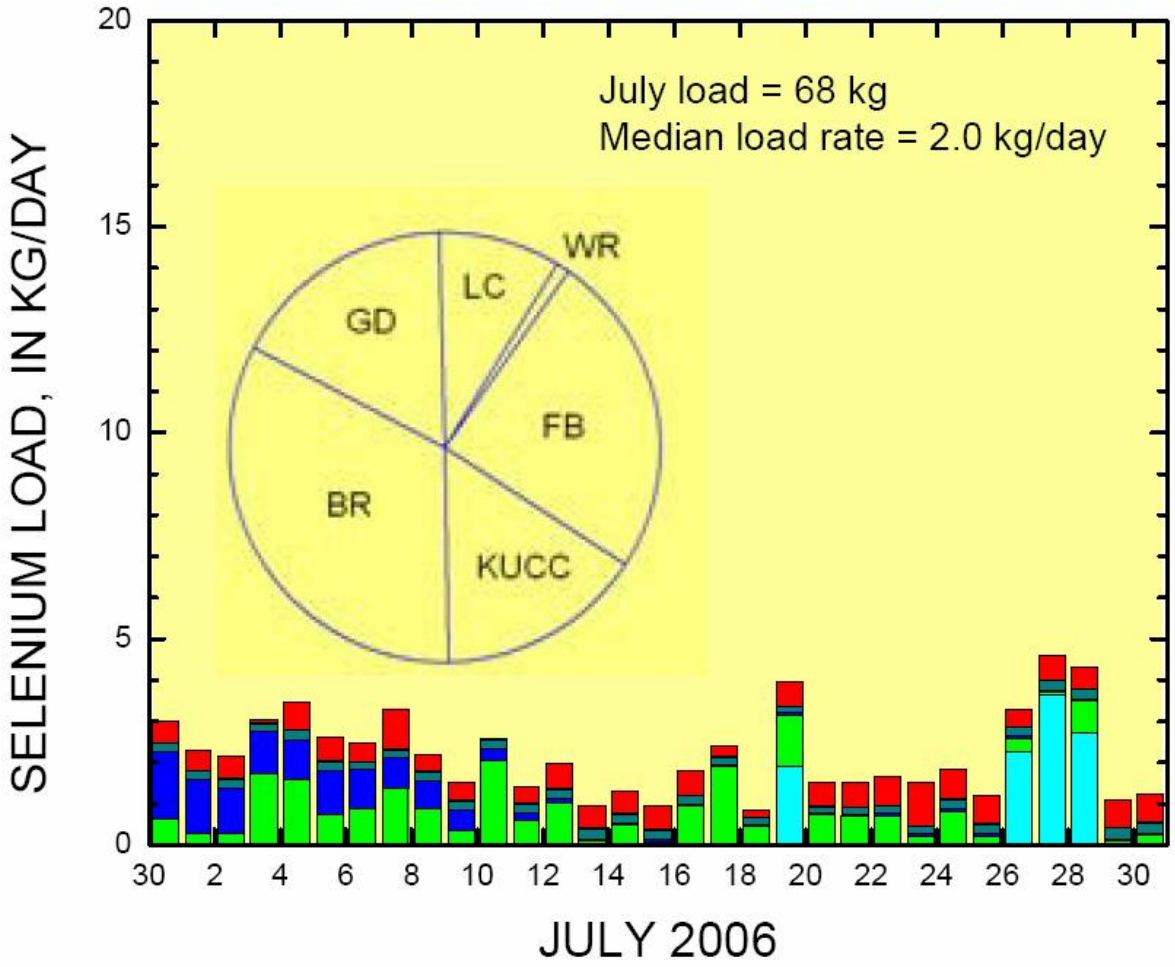
Daily Se loads—JUNE 2006



EXPLANATION

Farm. Bay	**(FB)**
Weber River	**(WR)**
Lee Creek	**(LC)**
Goggin Drain	**(GD)**
Bear River	**(BR)**
KUCC Outfall	**(KUCC)**

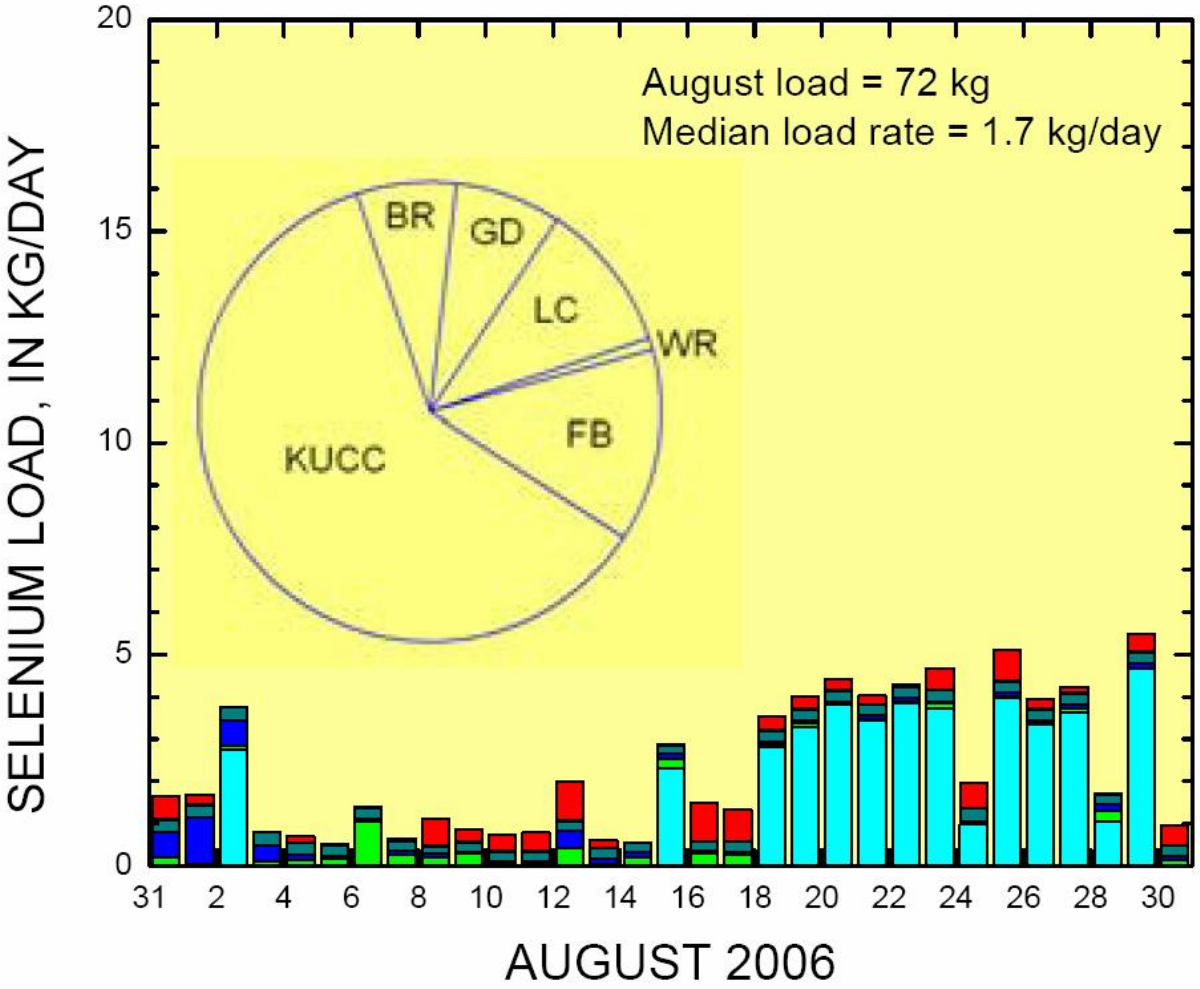
Daily Se loads—JULY 2006



EXPLANATION

Farm. Bay	**(FB)**
Weber River	**(WR)**
Lee Creek	**(LC)**
Goggin Drain	**(GD)**
Bear River	**(BR)**
KUCC Outfall	**(KUCC)**

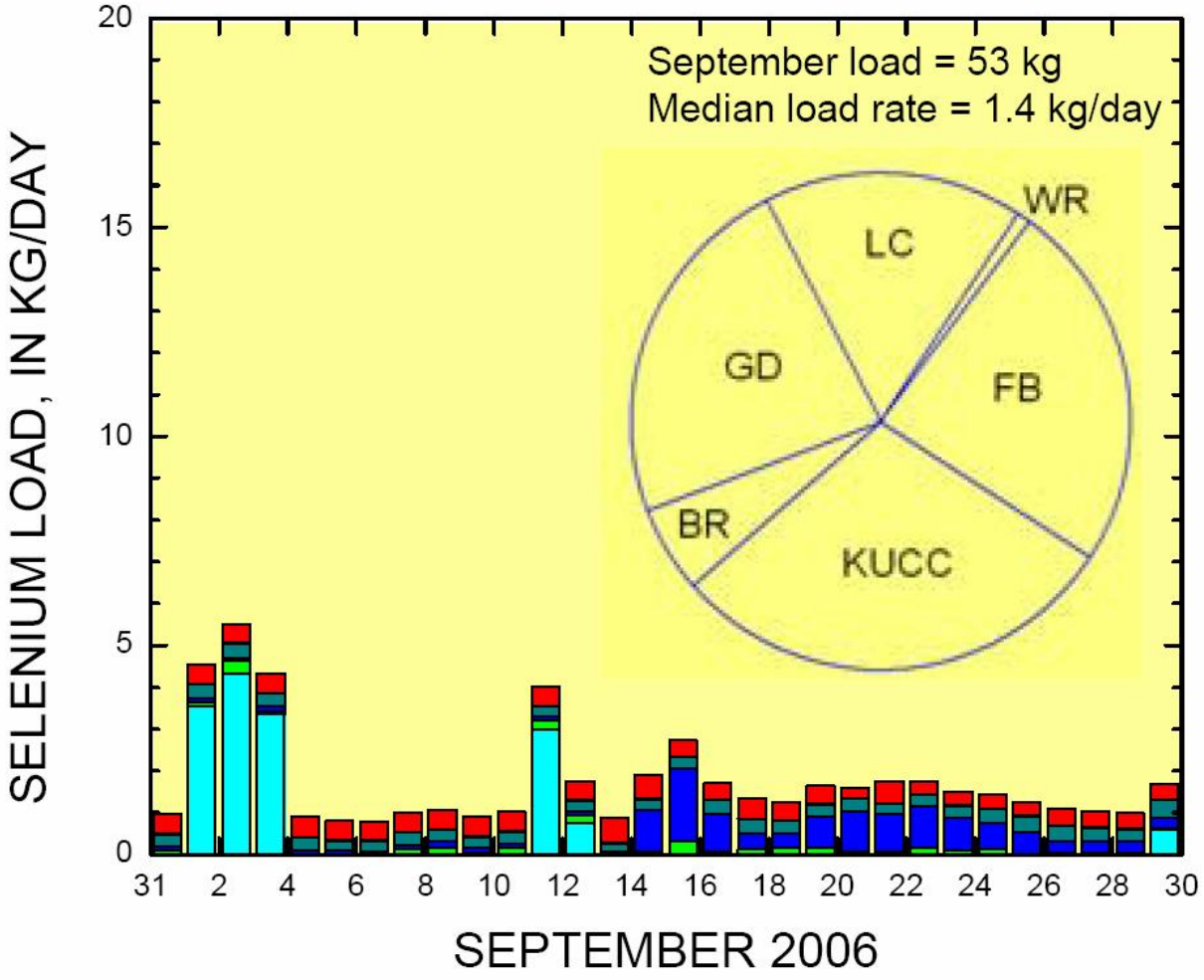
Daily Se loads—AUGUST 2006



EXPLANATION

Farm. Bay	**(FB)**
Weber River	**(WR)**
Lee Creek	**(LC)**
Goggin Drain	**(GD)**
Bear River	**(BR)**
KUCC Outfall	**(KUCC)**

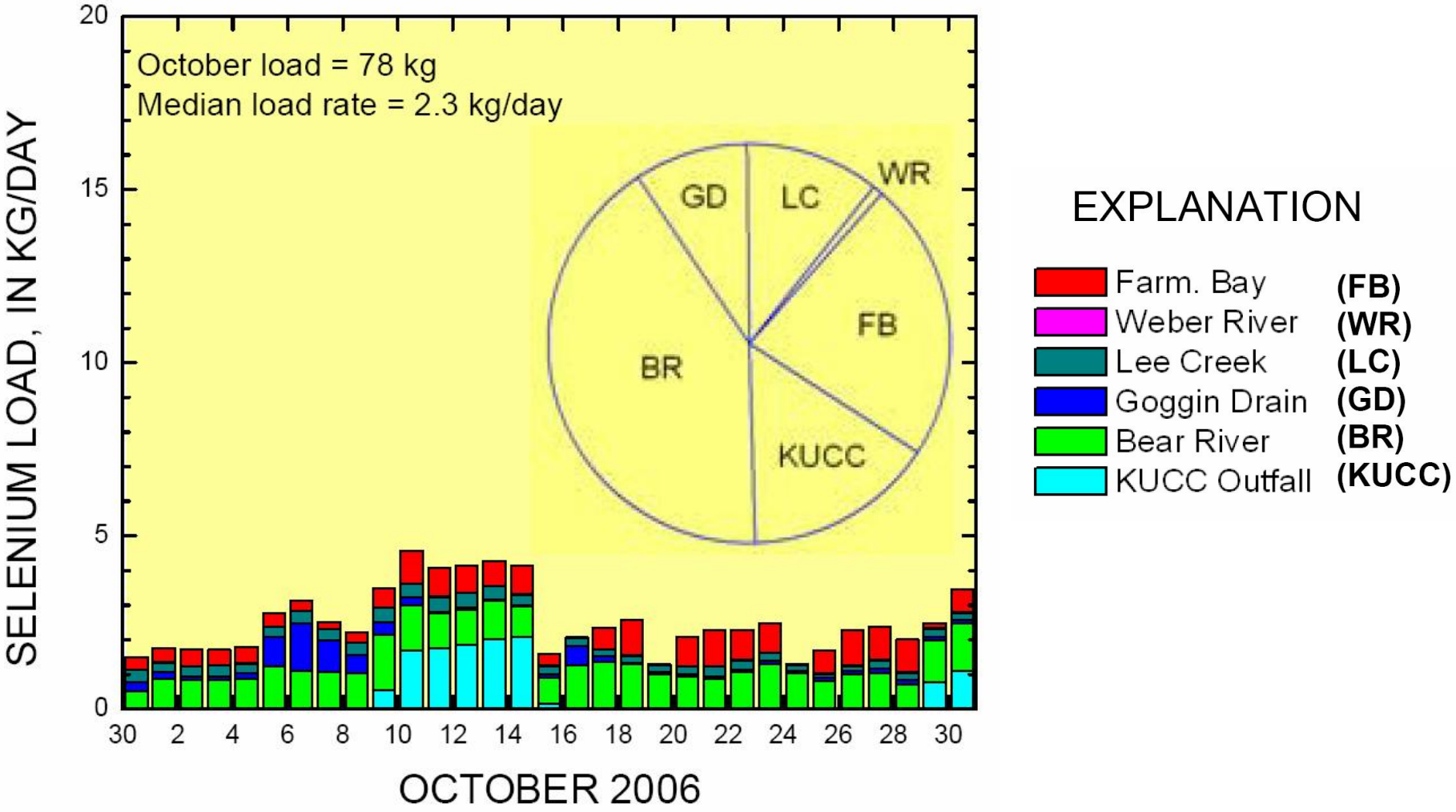
Daily Se loads—SEP 2006



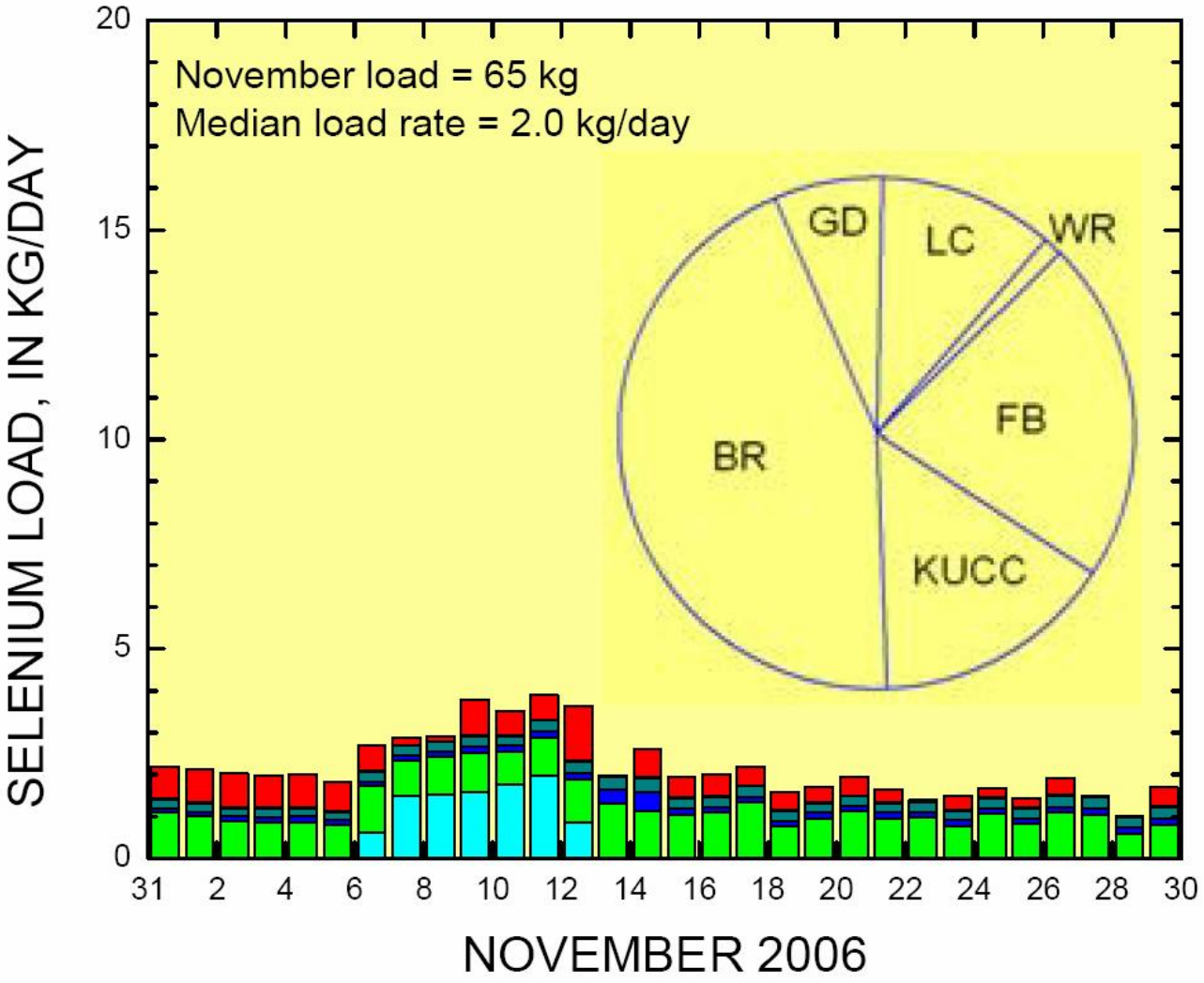
EXPLANATION

Farm. Bay	**(FB)**
Weber River	**(WR)**
Lee Creek	**(LC)**
Goggin Drain	**(GD)**
Bear River	**(BR)**
KUCC Outfall	**(KUCC)**

Daily Se loads—OCT 2006



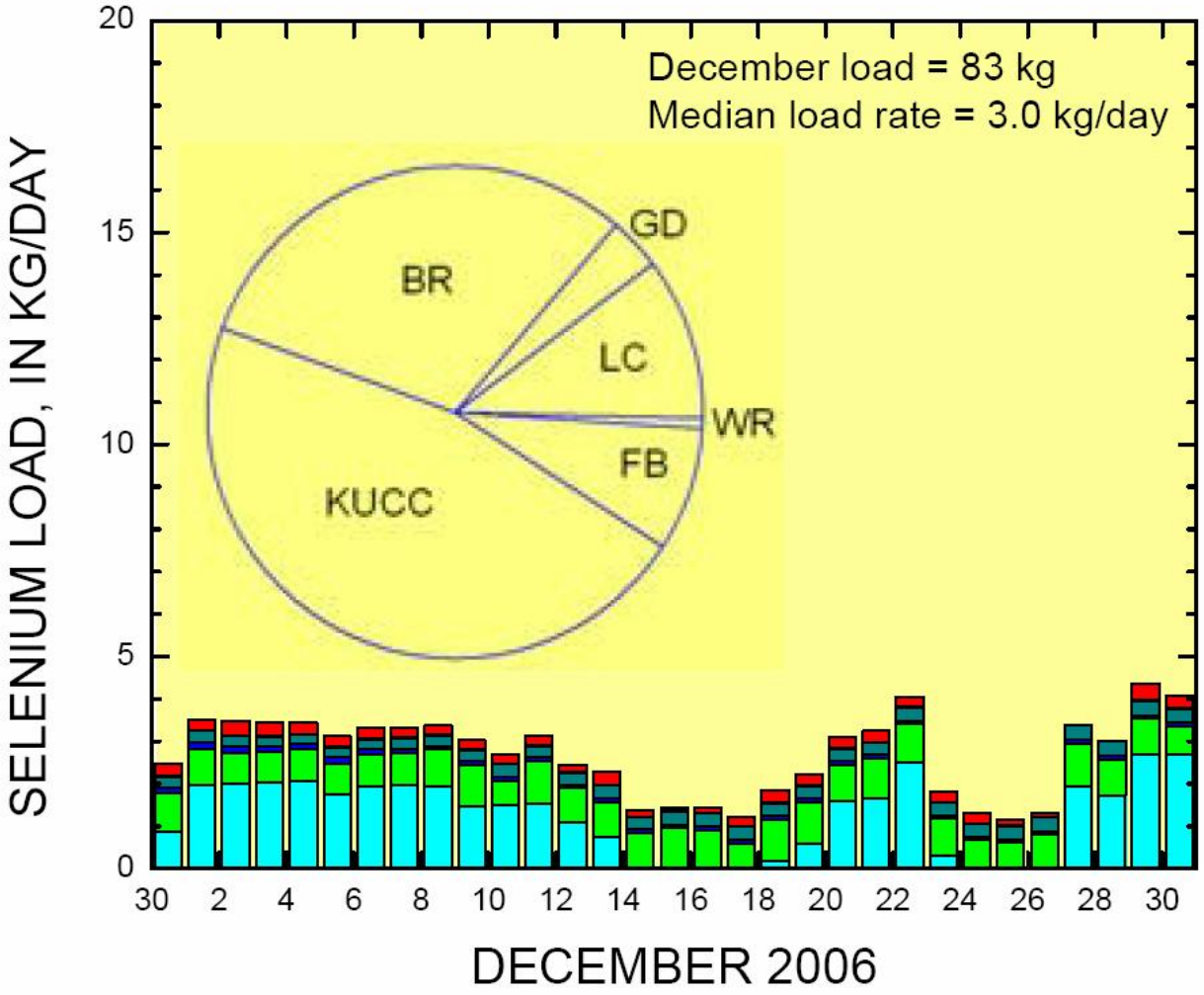
Daily Se loads—NOV 2006



EXPLANATION

Farm. Bay	**(FB)**
Weber River	**(WR)**
Lee Creek	**(LC)**
Goggin Drain	**(GD)**
Bear River	**(BR)**
KUCC Outfall	**(KUCC)**

Daily Se loads—DEC 2006

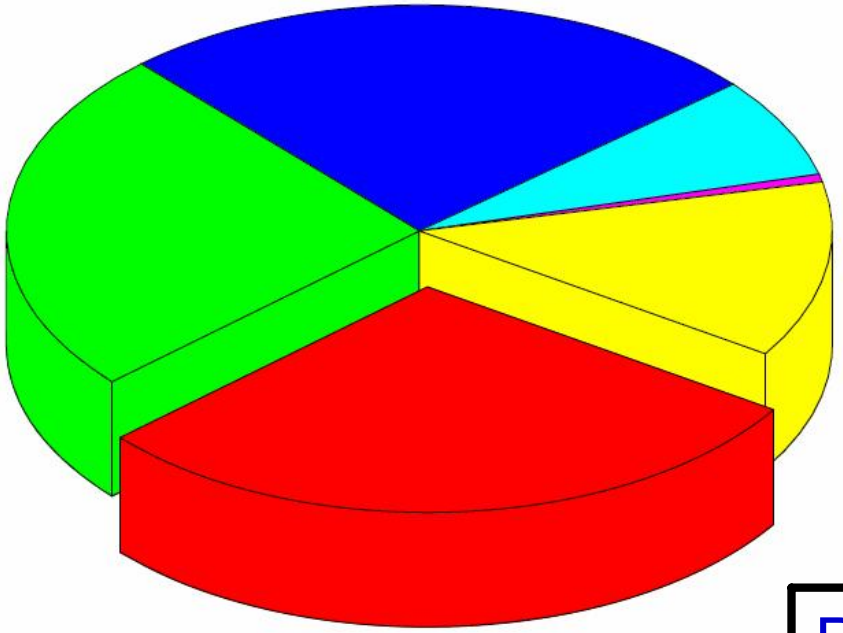


EXPLANATION

Farm. Bay	**(FB)**
Weber River	**(WR)**
Lee Creek	**(LC)**
Goggin Drain	**(GD)**
Bear River	**(BR)**
KUCC Outfall	**(KUCC)**

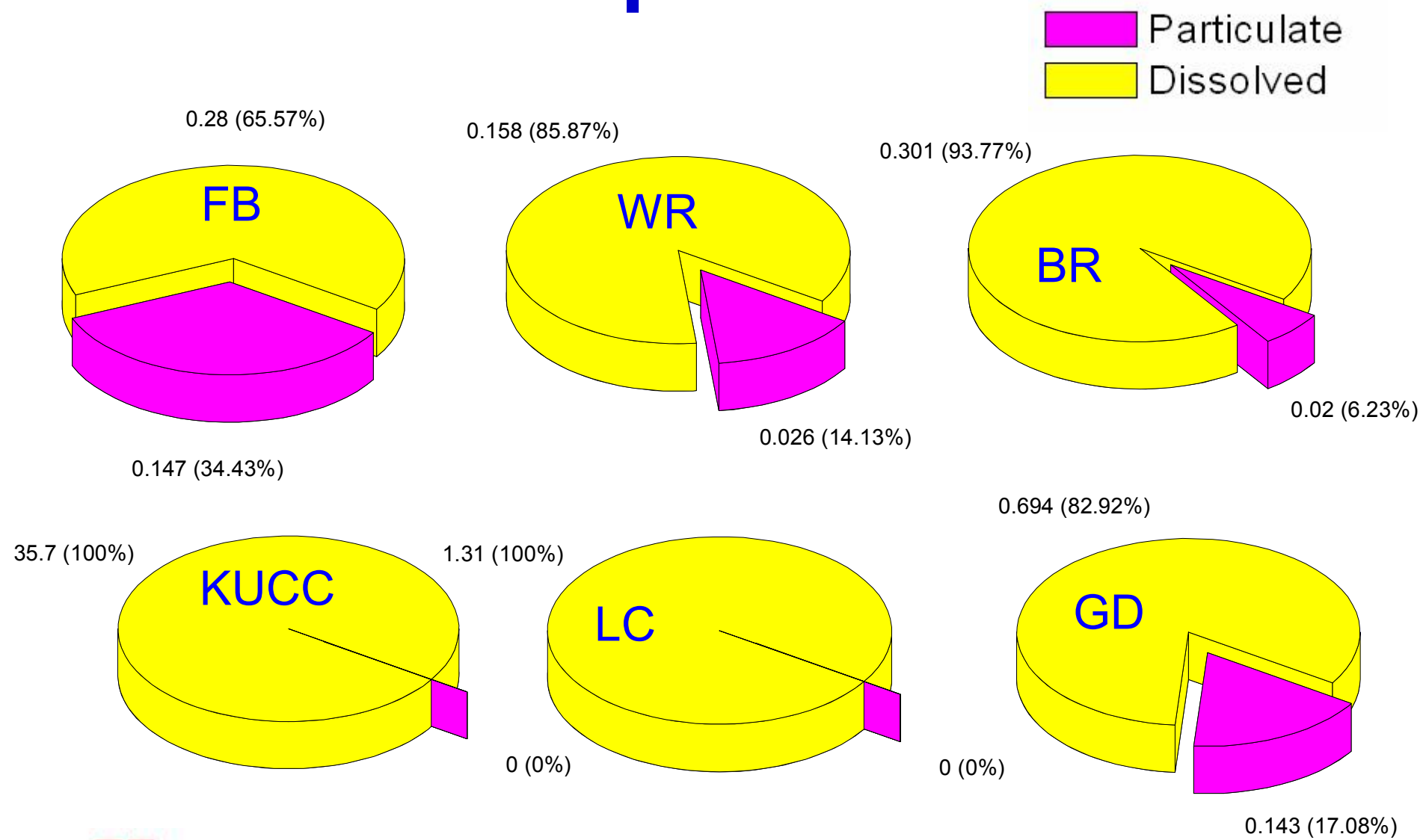
Total Se loads—mid MAY thru DEC 2006

Net N. Arm input
= 0.3 kg/day???

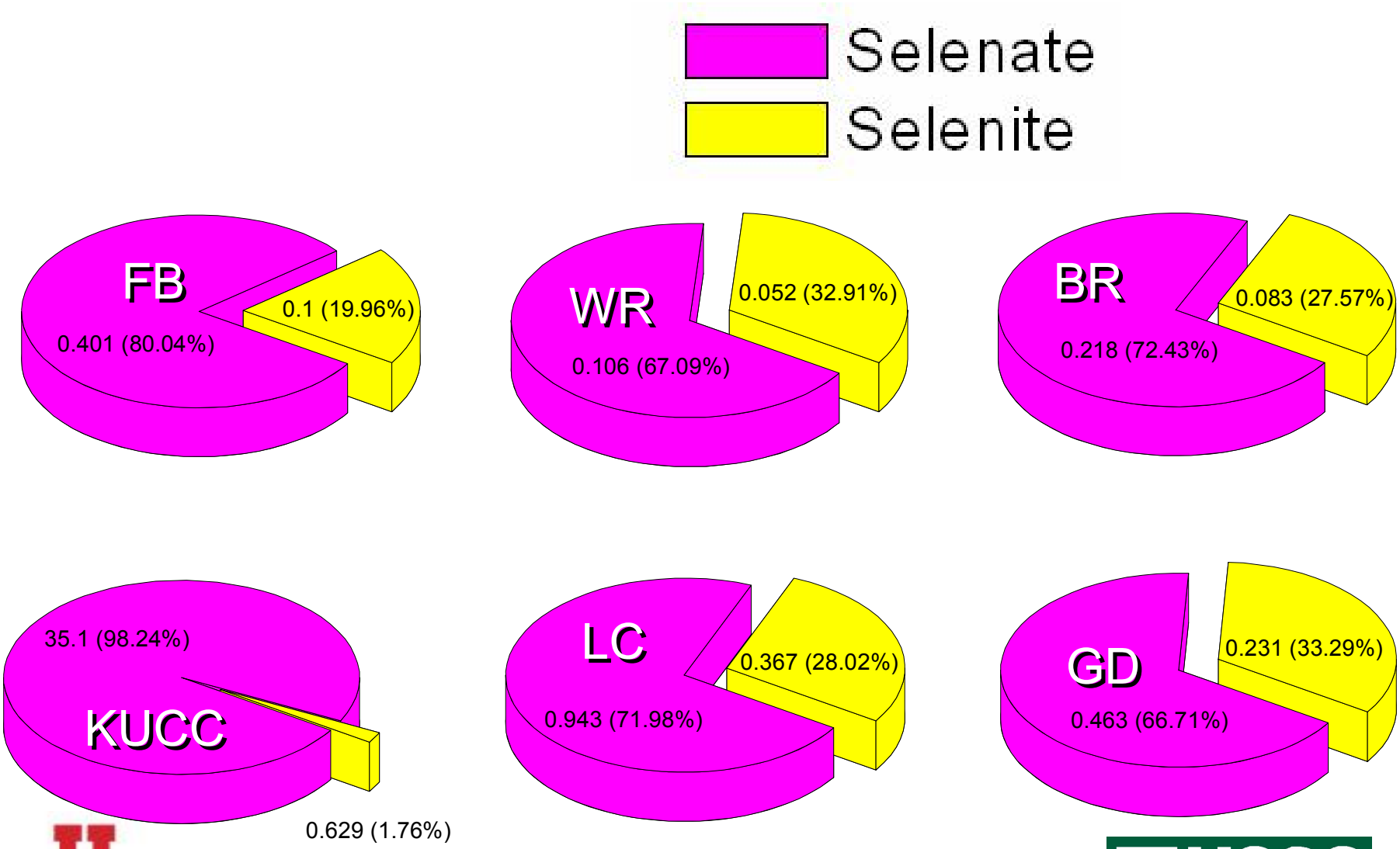


Projected annual load = 1,500 kg/d

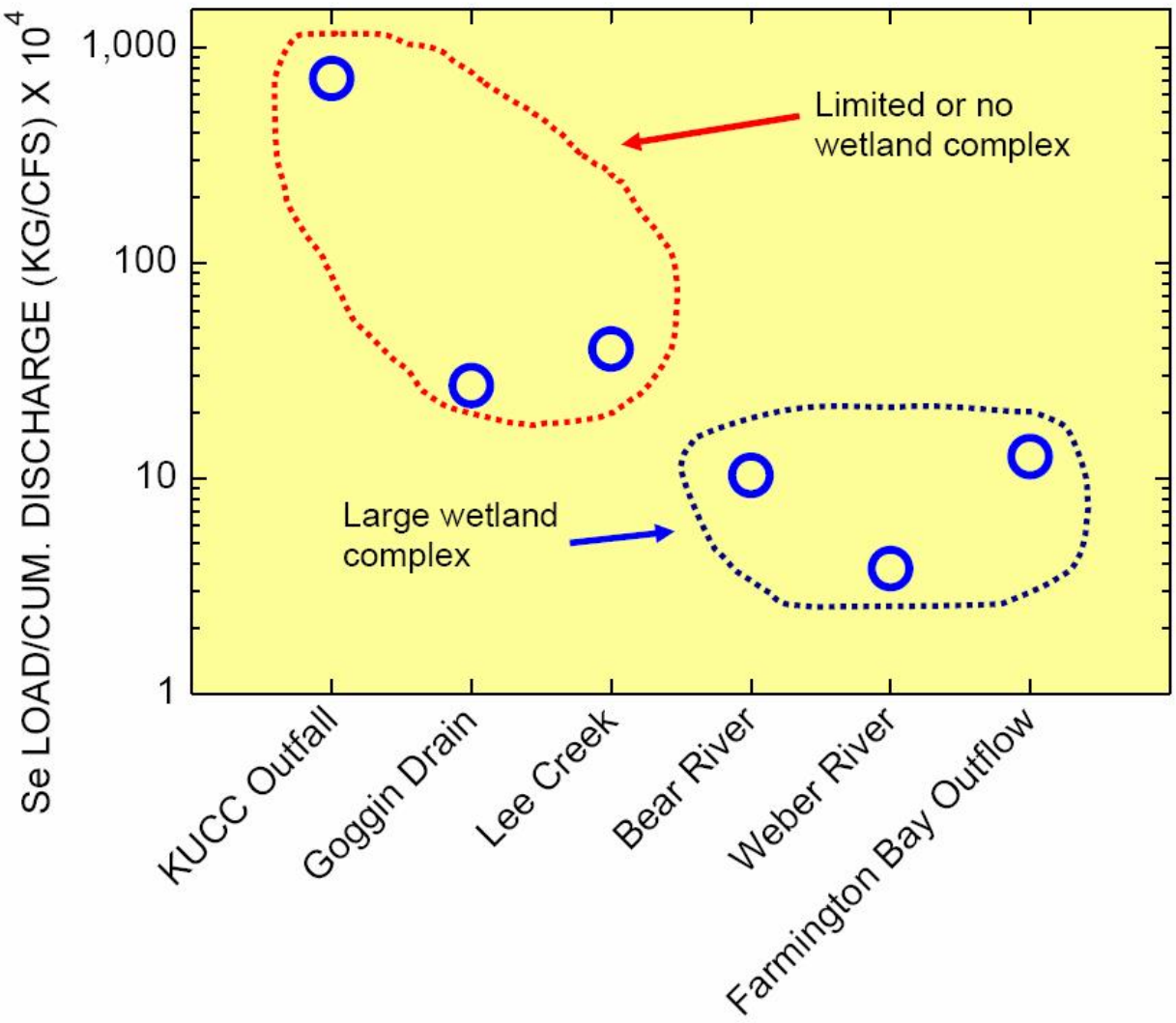
Dissolved vs. particulate



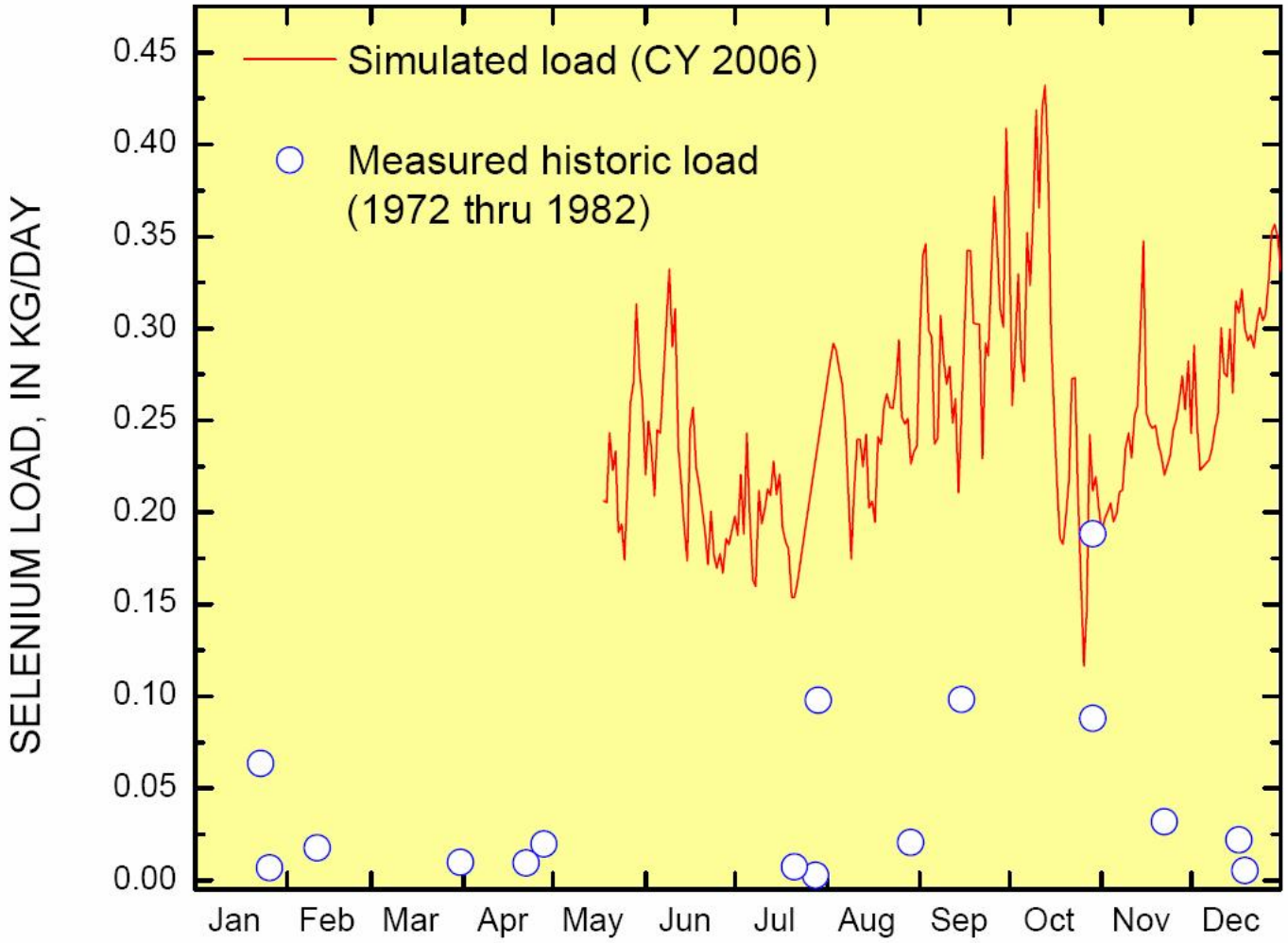
Selenate vs. selenite



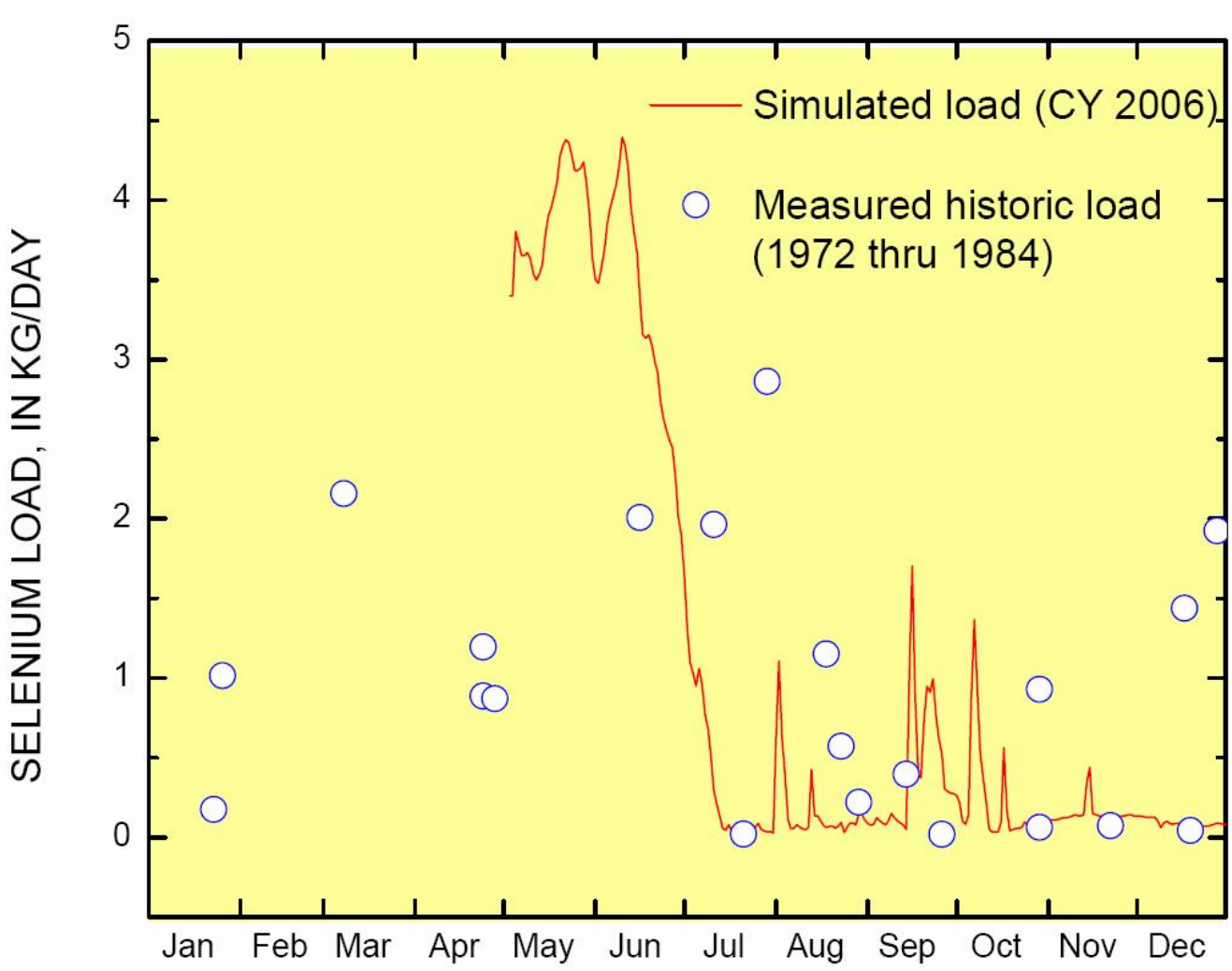
Wetland vs. non-wetland



Lee Creek historic loads



Goggin Drain historic loads



Monthly Se loads/GSL [Se]

Site 3510

Table 5. Changes in Great Salt Lake south arm volume and selenium concentration as a function of lake level and monthly selenium load compared to measured total selenium concentration in water samples from site 3510 from May through December 2006. Lake volume based on data presented in Baskin (2005).

[ug/L, micrograms per liter; kg, kilograms]

Date (2006)	Water-surface altitude, in feet#	South arm lake volume, in liters	Total mass of selenium added from inflow sites, in kg	Resulting increase in lake selenium concentration, in ug/L (assuming conservative behavior)	Observed change from previous month in total selenium concentration at site 3510 (0.2 m depth), in ug/L
May 15	4198.1	1.03×10^{13}	0	0	--
June 15	4198.0	1.02×10^{13}	269	0.026	-0.135
July 15	4197.4	9.86×10^{12}	144	0.015	-0.042
August 15	4196.8	9.51×10^{12}	58	0.006	+0.342
September 15	4196.4	9.29×10^{12}	48	0.005	-0.245
October 15	4196.4	9.29×10^{12}	56	0.006	+0.131
November 15	4196.5	9.34×10^{12}	72	0.008	+0.058
December 15	4196.7	9.46×10^{12}	75	0.008	-0.100
			Total net change	**0.074**	**+0.009**

#Altitude referenced to National Geodetic Vertical Datum of 1929 (NGVD 29)

Monthly Se loads/GSL [Se]

Site 2767

Table 6. Changes in Great Salt Lake south arm volume and selenium concentration as a function of lake level and monthly selenium load compared to measured total selenium concentration in water samples from site 2767 from May through December 2006. Lake volume based on data presented in Baskin (2005).

[ug/L, micrograms per liter; kg, kilograms]

Date (2006)	Water-surface altitude, in feet#	South arm lake volume, in liters	Total mass of selenium added from inflow sites, in kg	Resulting increase in lake selenium concentration, in ug/L (assuming conservative behavior)	Observed change from previous month in total selenium concentration at site 2767 (0.2 m depth), in ug/L
May 15	4198.1	1.03×10^{13}	0	0	--
June 15	4198.0	1.02×10^{13}	269	0.026	+0.169
July 15	4197.4	9.86×10^{12}	144	0.015	-0.143
August 15	4196.8	9.51×10^{12}	58	0.006	+0.486
September 15	4196.4	9.29×10^{12}	48	0.005	-0.412
October 15	4196.4	9.29×10^{12}	56	0.006	+0.144
November 15	4196.5	9.34×10^{12}	72	0.008	-0.197
December 15	4196.7	9.46×10^{12}	75	0.008	+0.004
			Total net change	**0.074**	**+0.051**

#Altitude referenced to National Geodetic Vertical Datum of 1929 (NGVD 29)

Monthly Se loads/GSL [Se]

Site 2267

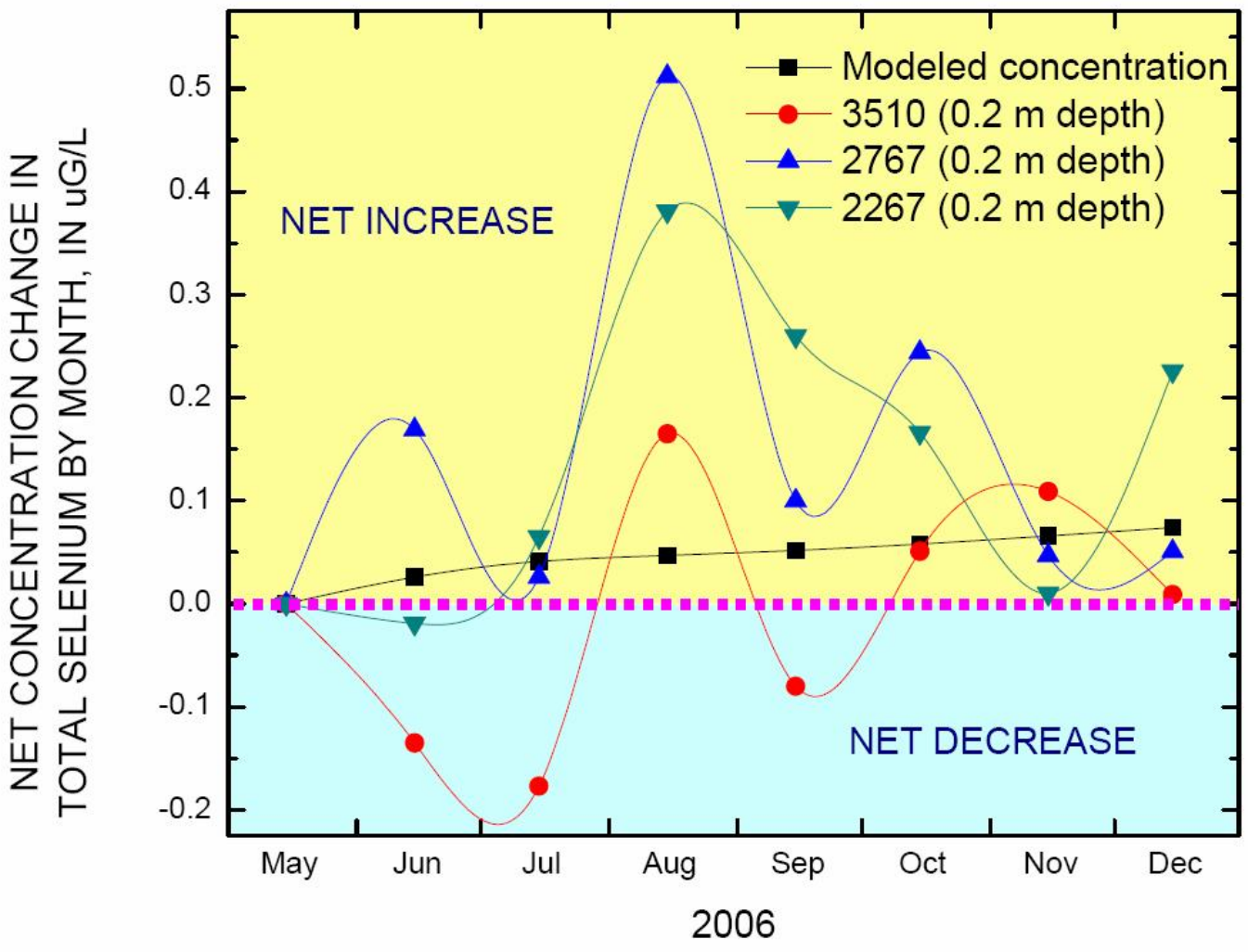
Table 7. Changes in Great Salt Lake south arm volume and selenium concentration as a function of lake level and monthly selenium load compared to measured total selenium concentration in water samples from site 2267 from May through December 2006. Lake volume based on data presented in Baskin (2005).

[ug/L, micrograms per liter; kg, kilograms]

Date (2006)	Water-surface altitude, in feet[#]	South arm lake volume, in liters	Total mass of selenium added from inflow sites, in kg	Resulting increase in lake selenium concentration, in ug/L (assuming conservative behavior)	Observed change from previous month in total selenium concentration at site 2767 (0.2 m depth), in ug/L
May 15	4198.1	1.03×10^{13}	0	0	--
June 15	4198.0	1.02×10^{13}	269	0.026	-0.019
July 15	4197.4	9.86×10^{12}	144	0.015	+0.084
August 15	4196.8	9.51×10^{12}	58	0.006	+0.316
September 15	4196.4	9.29×10^{12}	48	0.005	-0.121
October 15	4196.4	9.29×10^{12}	56	0.006	-0.094
November 15	4196.5	9.34×10^{12}	72	0.008	-0.156
December 15	4196.7	9.46×10^{12}	75	0.008	+0.216
			Total net change	**0.074**	**+0.226**

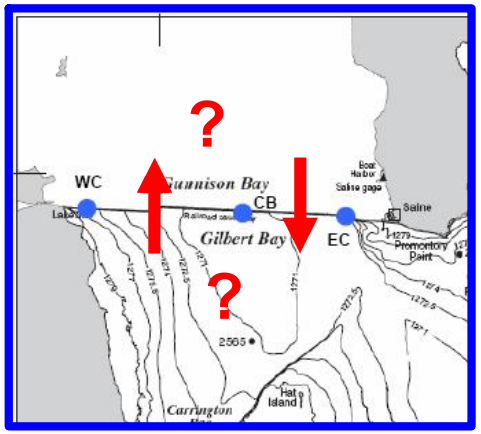
[#]Altitude referenced to National Geodetic Vertical Datum of 1929 (NGVD 29)

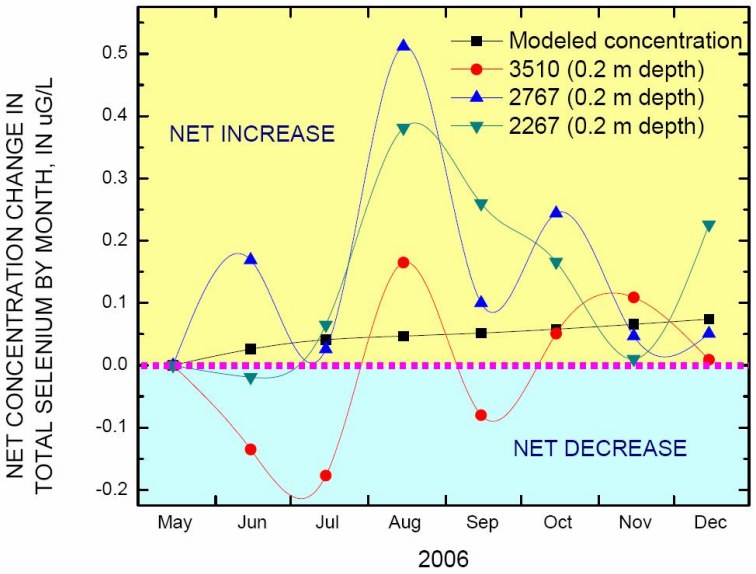
Cumulative analysis/future trends



?

Continued monitoring/modeling





- Quantify N. Arm exchange
- Continued lake/load monitoring and modeling
- Real-time, daily Se loads on web site
- Non-parametric trend analysis at lake/inflow sites
- Other constituents