Water Quality Criteria: An Introduction to the Biotic Ligand Model (BLM)

USEPA
November 2007
Arlington, VA

Water Quality Criteria (WQC)

- Clean Water Act
  - Section 304(a)
- 1985 Guidelines
- Criteria values
  - No negative effects

Problem with Metals Criteria

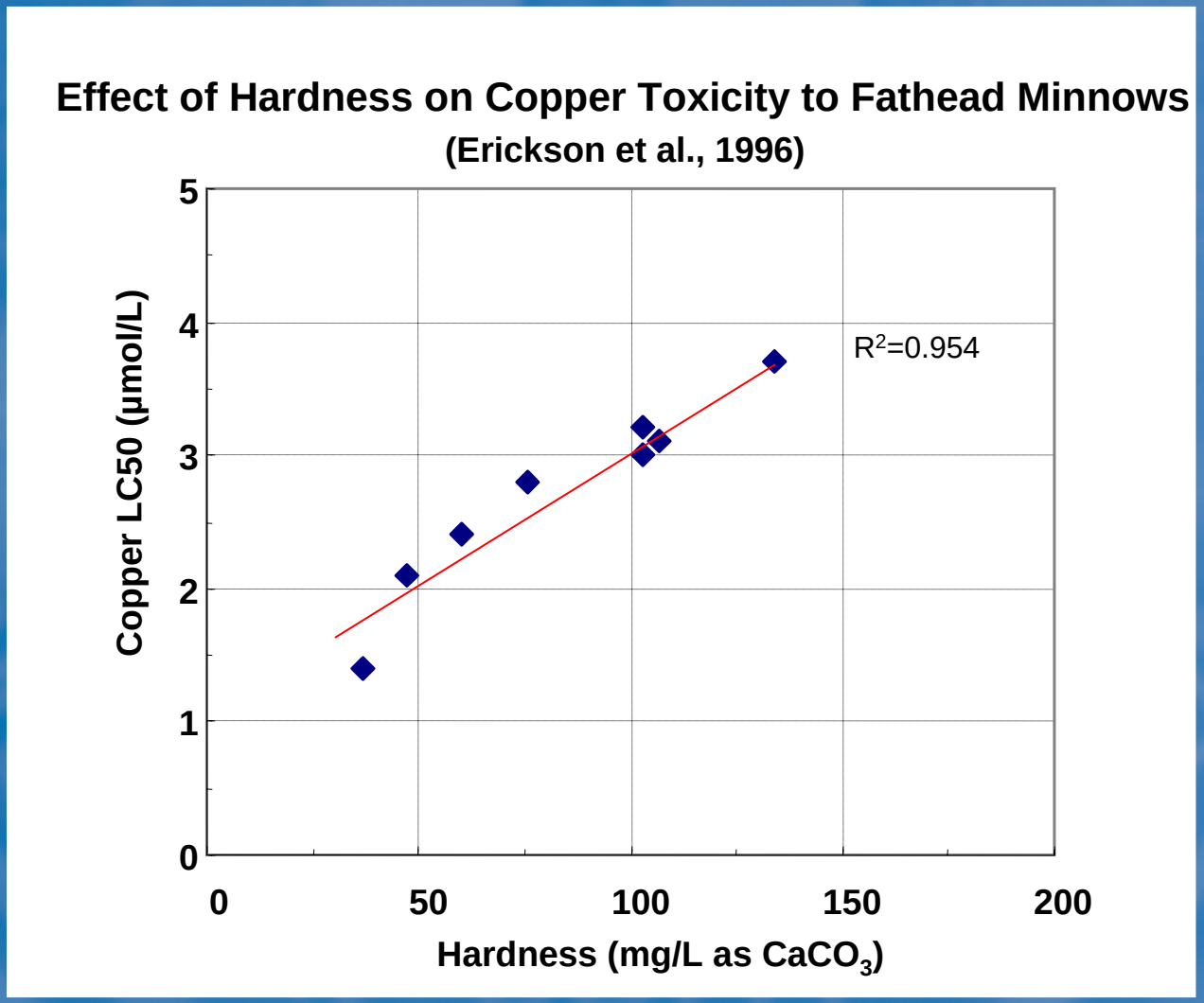
- Toxicity
  - Variable with time and place.
- Water chemistry
  - Controlled by constituents as pH, Ca, Na, CO_3 and Dissolved Organic Carbon (DOC).
- Consequence
  - WQC do not reflect the effects of water chemistry factors entirely.

Correction factors

- Water Hardness Equation
- Water Effect Ratio

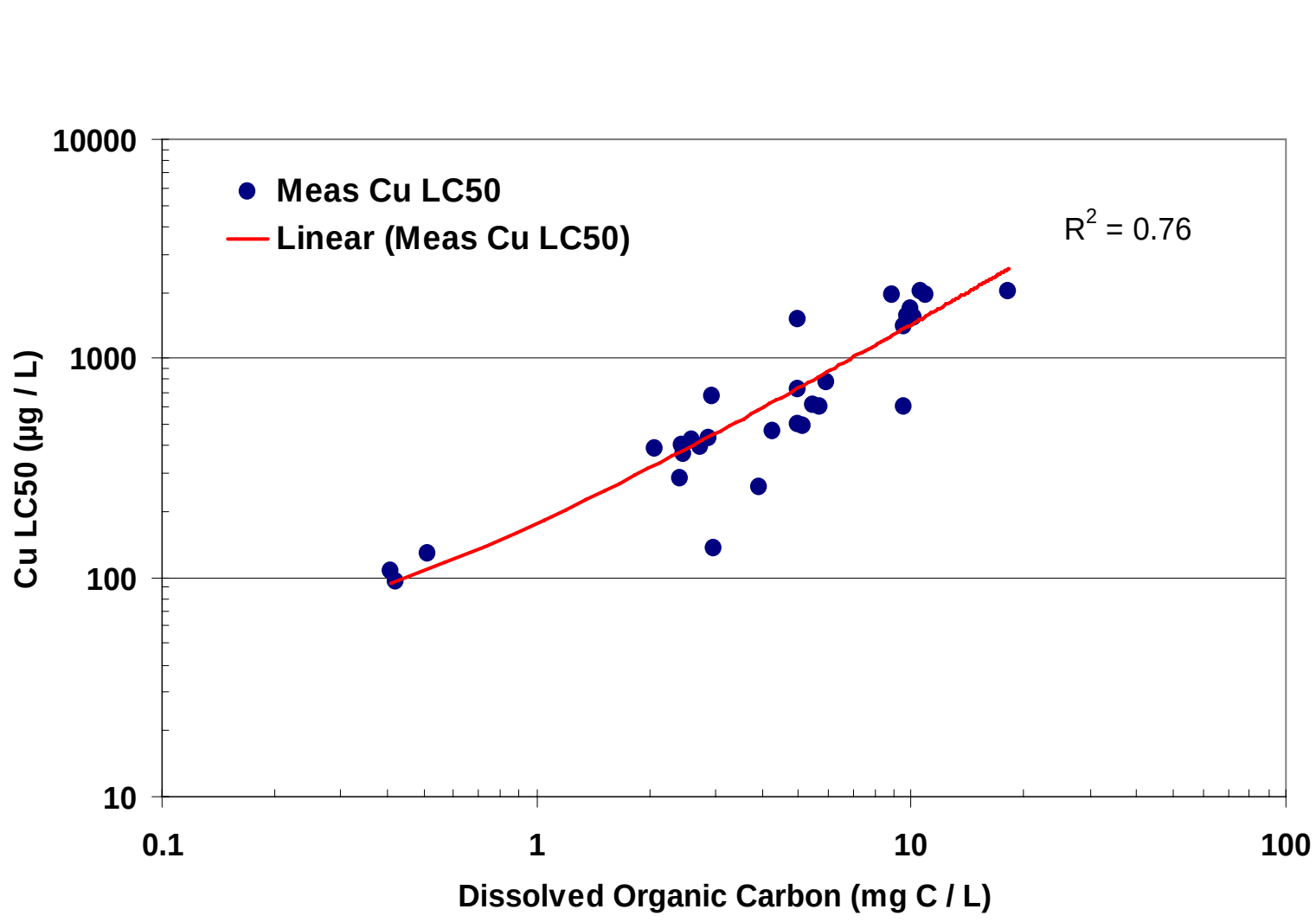
Effect of Hardness on Toxicity

Fathead Minnow Data



Effect of Dissolved Organic Carbon on Toxicity

Data from Clemson U. (WERF BLM Project)



Limits of Hardness Normalization

- Under-protective at low pH
- Over-protective at higher DOC
- Requires Water Effect Ratio (WER) for correction

WATER EFFECT RATIO

Quantifies the toxicity of a pollutant in site water as compared to lab water

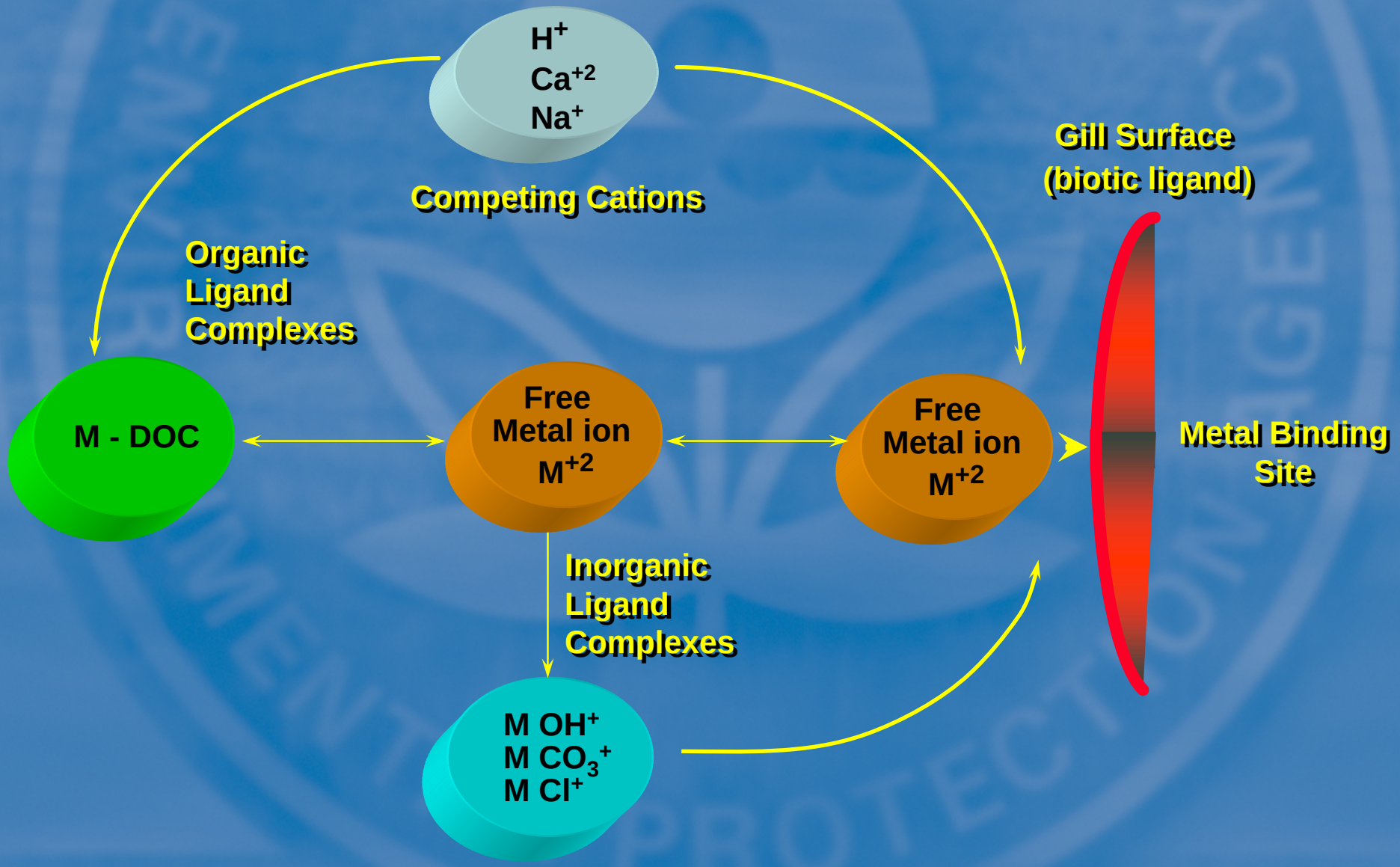
$$\text{WER} = \frac{\text{Site Water Toxicity Concentration}}{\text{Lab Water Toxicity Concentration}}$$

Site-Specific Criteria = WER x National Criteria

The Alternative: Biotic Ligand Model

- Evaluates the effects of other factors affecting toxicity.

Generalized BLM Framework



Biotic Ligand Model

Based on:

- Free Ion Model (1993): Chemical model
- Gill Model (1996):Toxicological model

Biotic Ligand Model: What does it do?

The BLM:

- Complements the existing EPA Guidelines procedure,
- Accounts for the effect of water chemistry, in addition to hardness, and
- Leads to an improved capability to assess potential adverse effects.

BLM Parameters (realities and assumptions)

- Inorganic
  - thermodynamic database
- Organic
  - chemical measurements with Organic Matter
- Biological
  - limited number of accumulation datasets
  - parameters assumed to be consistent for other organisms, since ion-transport mechanisms are similar, and
  - LA50 used to account for variation in species sensitivity.

Comparison of Approaches

BLM versus WER

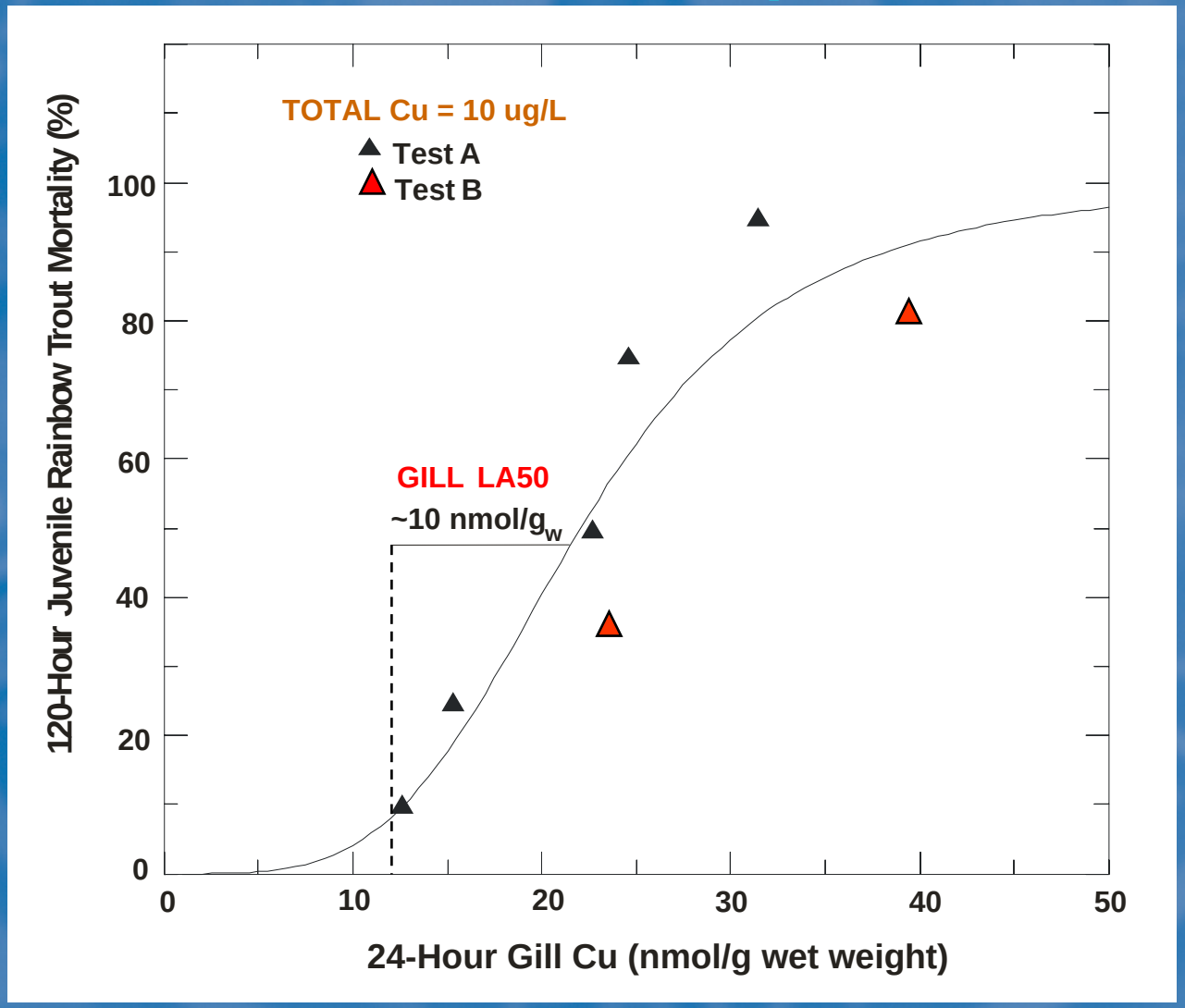
- WER:
  - Comprehensive, but
  - sampling error is high, and
  - precision is low.
- BLM:
  - Limited, but
  - sampling error low, and
  - precision is high.

Comparison of approaches (continuation)

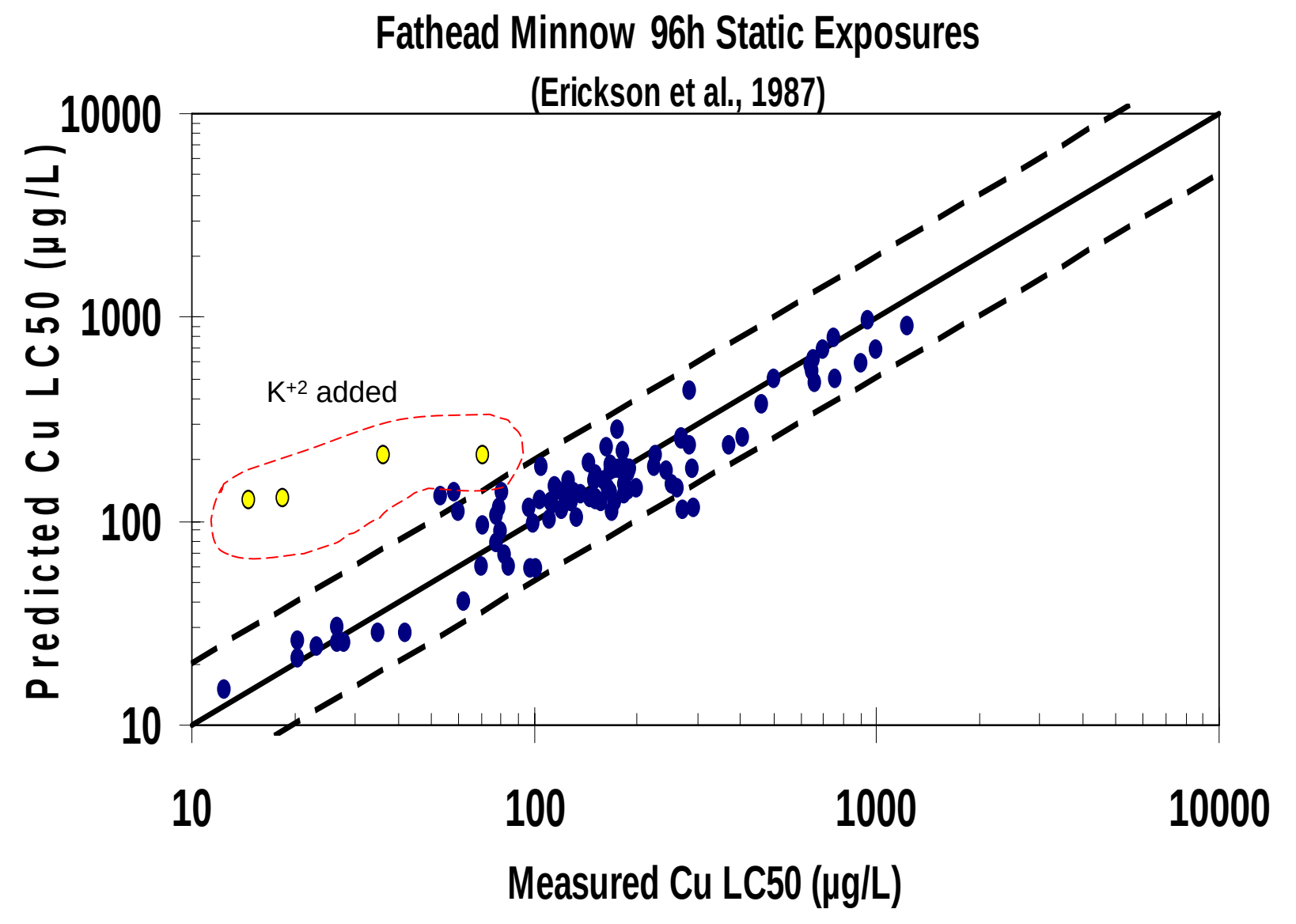
- BLM advantages:
  - Is implemented directly into the criterion as replacement for water hardness.
  - Water chemistry data are cheaper to obtain.
  - Improves our understanding of how water chemistry affects metal availability and toxicity.
  - A combination of bioassay-based methods and computational methods may be used.

Question: Can accumulation be uniquely related to a toxic effect? Yes.

(Data: MacRae, 1994 and 1999)



Predicted Versus Measured LC50s

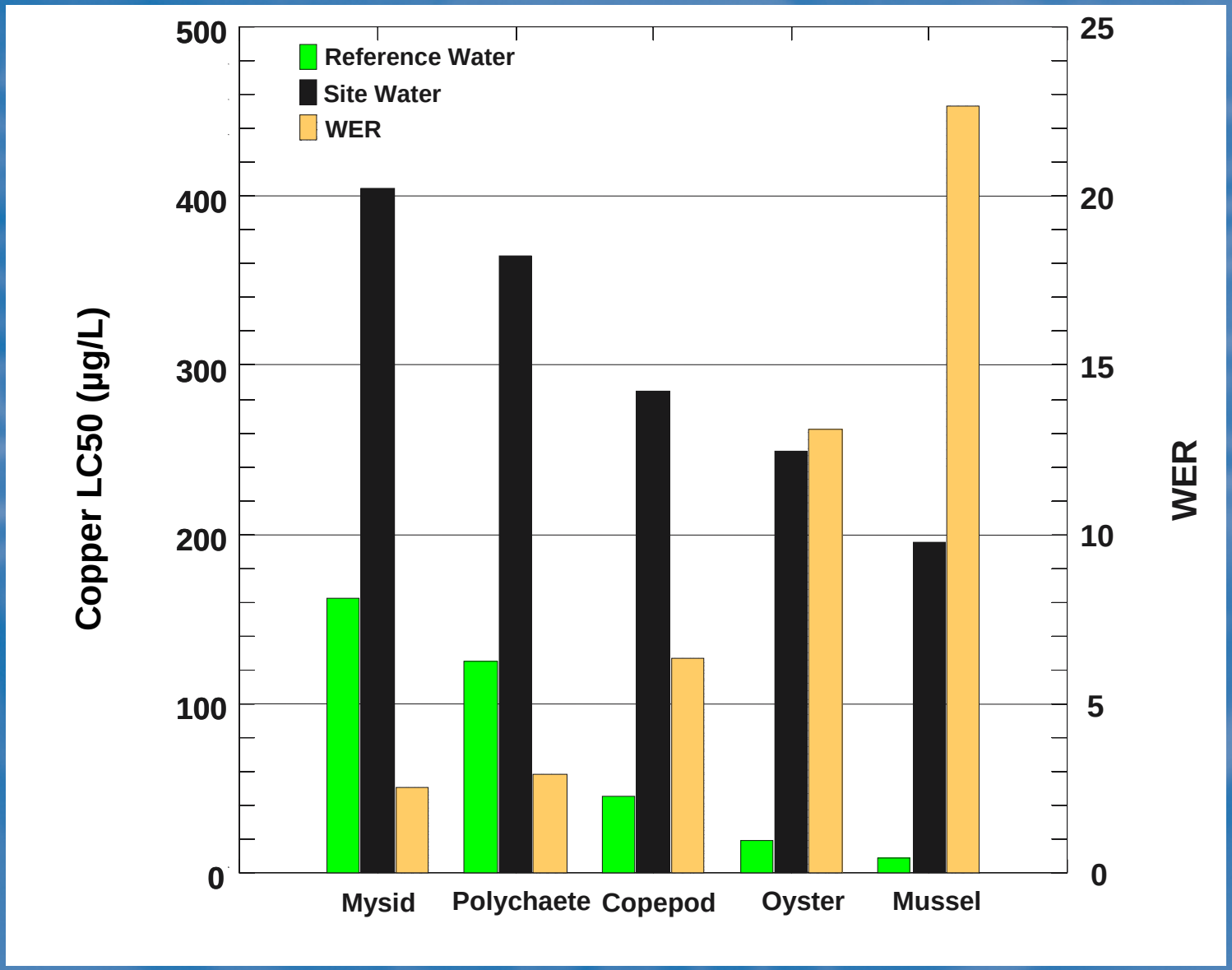


Recapitulation

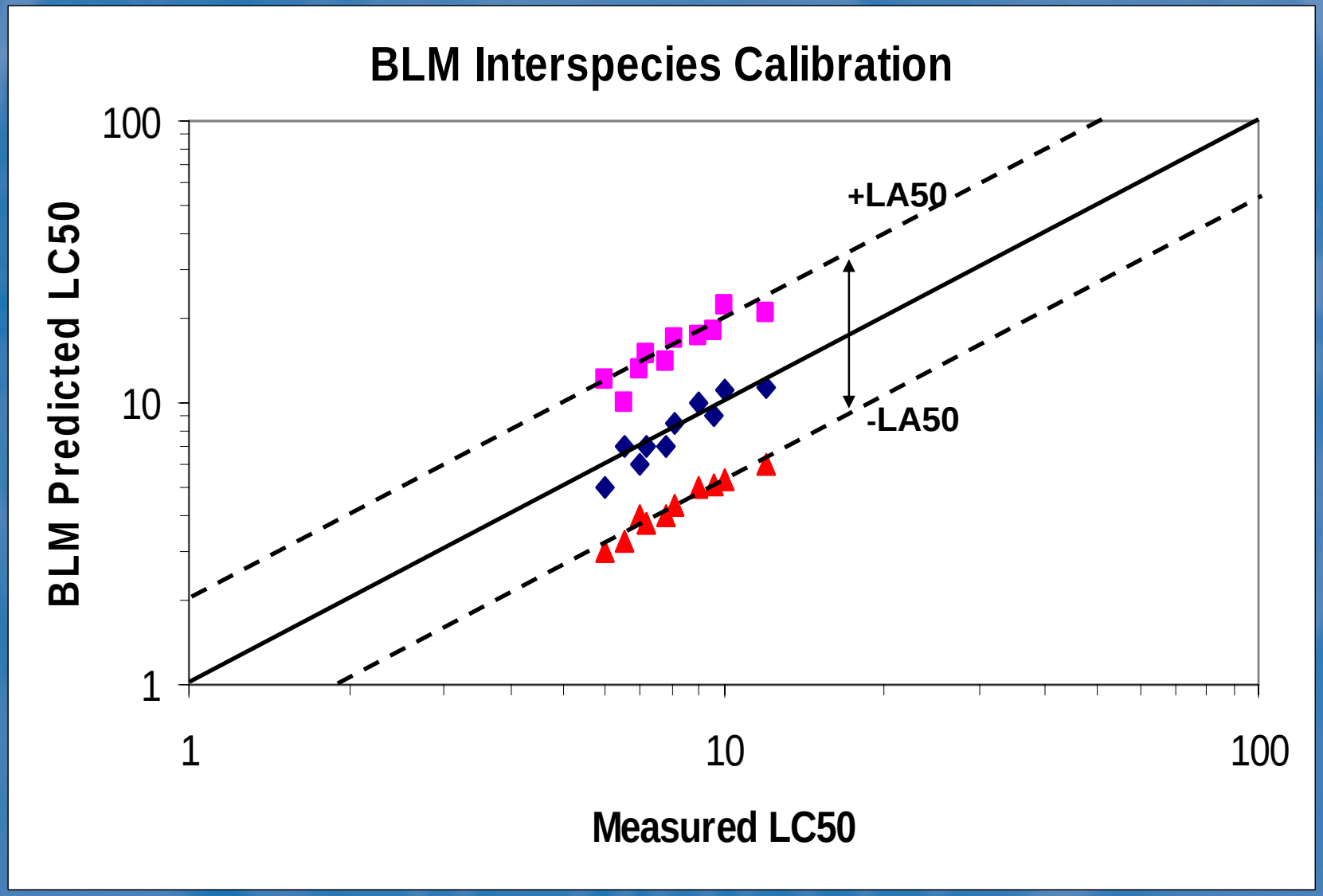
- Water chemistry affects metal toxicity.
- Water hardness and Water Effect Ratio used as correction factors.
- BLM is a replacement for water hardness.

Beginning with consideration of species sensitivity, we will explore how the BLM may be applied to other organisms and to other metals (e.g., Ag, Cd, Ni, Pb and Zn).

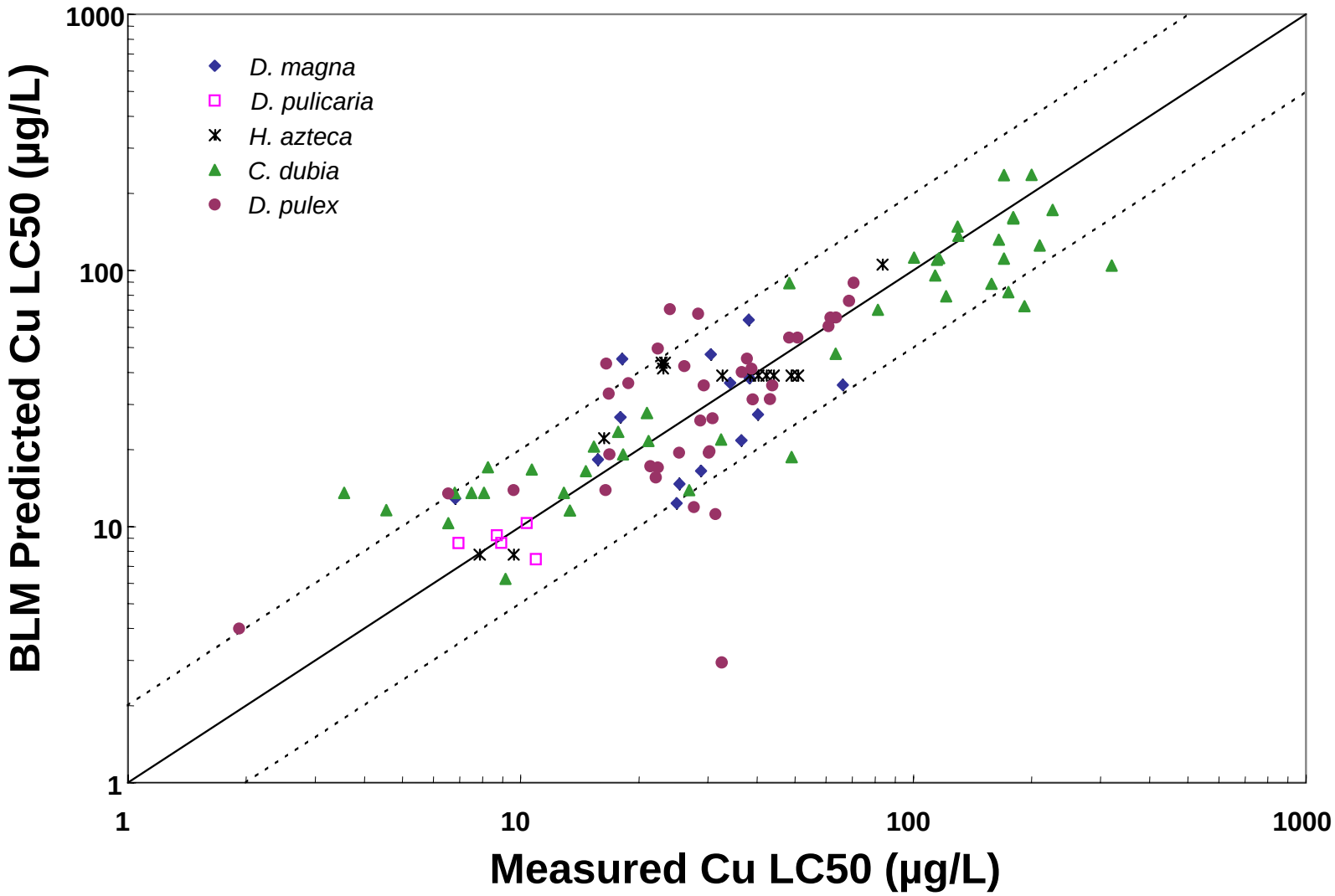
Importance of Species Sensitivity



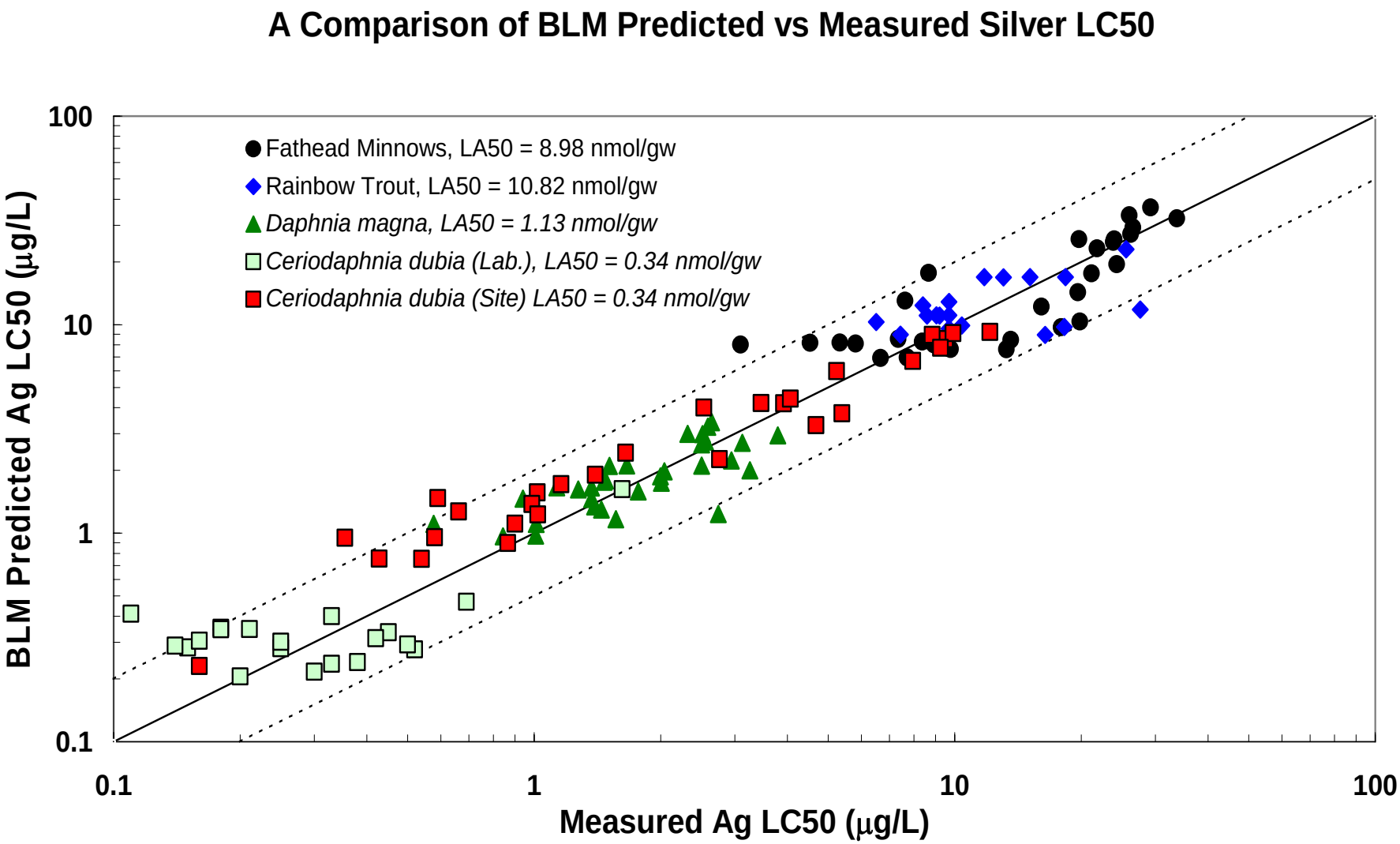
Application to Other Organisms



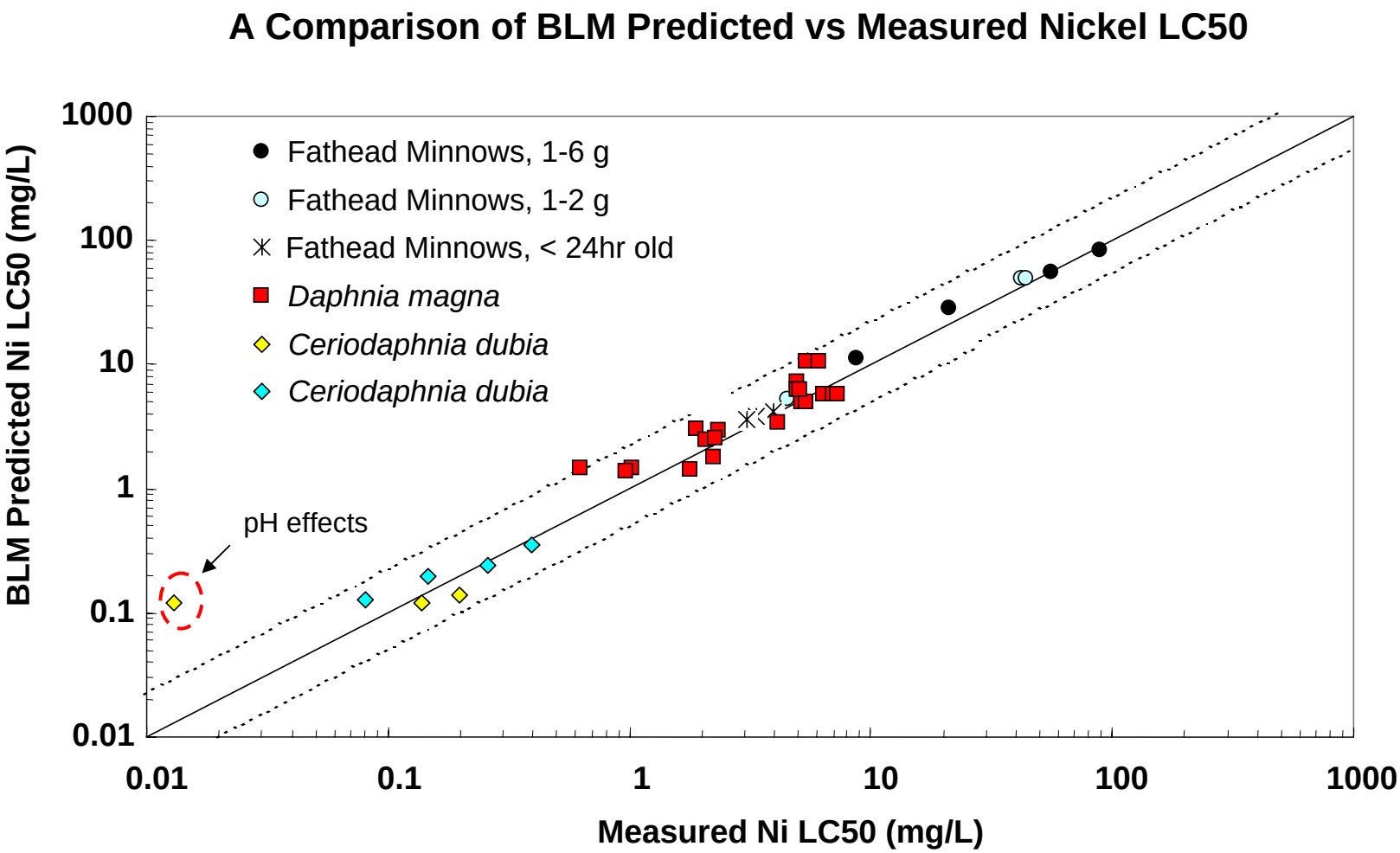
Cu BLM: Invertebrate Summary



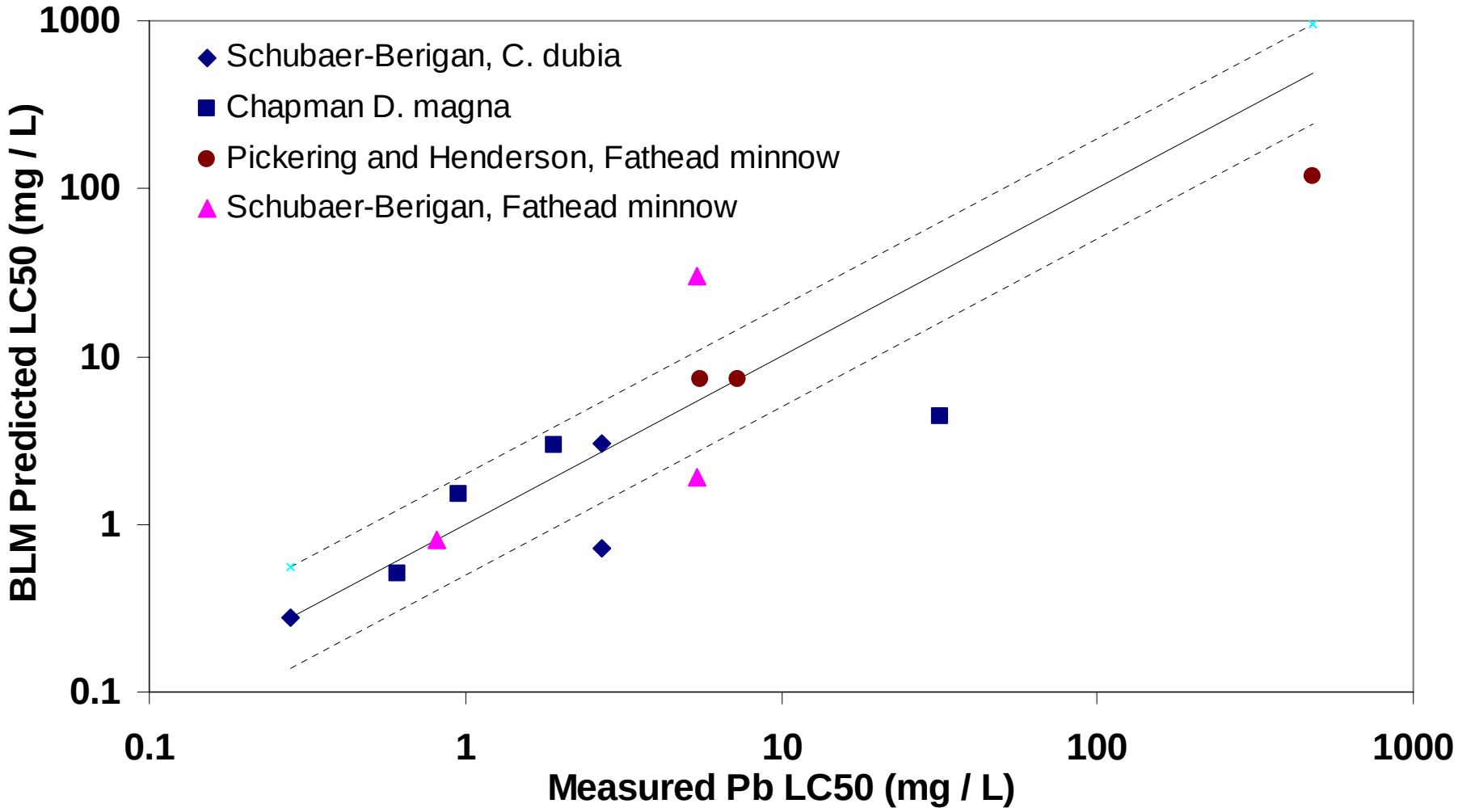
Ag BLM


A Comparison of BLM Predicted vs Measured Silver LC50
Fathead Minnows, LA50 = 8.98 nmol/gw
Rainbow Trout, LA50 = 10.82 nmol/gw
Daphnia magna, LA50 = 1.13 nmol/gw
Ceriodaphnia dubia (Lab.), LA50 = 0.34 nmol/gw
Ceriodaphnia dubia (Site) LA50 = 0.34 nmol/gw
BLM Predicted Ag LC50 (µg/L)
Measured Ag LC50 (µg/L)
100
10
1
0.1
0.1
1
10
100

Ni BLM: Fathead Minnow & Invertebrate Results



Pb BLM


Schubaer-Berigan, C. dubia
Chapman D. magna
Pickering and Henderson, Fathead minnow
Schubaer-Berigan, Fathead minnow
BLM Predicted LC50 (mg / L)
1000
100
10
1
0.1
0.1
1
10
100
1000
Measured Pb LC50 (mg / L)

Summary and Conclusions

The BLM:

- Can develop WQC in less time and at lower costs,
- Can develop estimates of spatial or temporal variation in metal bioavailability,
- Has been successfully applied to a number of organisms with varying sensitivity to metals, and
- Agrees remarkably well with bioassay-based WER studies.

Model equation

$$EC_A = EC_B \text{ X } \frac{f_{C,A} \text{ x } f_{L,A}}{f_{C,B} \text{ x } f_{L,B}}$$

Where:

- EC refers to the water effect concentrations.
- Subscripts A and B refer to different exposure conditions.
- Subscript C refers to the concentration of *competing cations* at the different exposure conditions.
- Subscript L refers to the concentration of the *complexing ligands* at the different exposure conditions.

For BLM application to criteria, the important concern is whether f_C and f_L are suitably formulated and parameterized, and not with issues that relate to lethal accumulations and accumulation capacities.

How is the BLM actually used?

- Since the BLM is designed to predict LC50s, it provides a way to predict the site water LC50s from water chemistry measurements alone without need to perform costly bioassays.

- Some advantages of using the BLM are as follows:
  - Water chemistry data are cheaper to obtain than are bioassays.
  - Historical data may be used providing for the capability to make hind-casts.
  - The results are obtained in the context of a rational framework that facilitates the attainment of an improved understanding of how water chemistry affects metal availability and toxicity.
  - A combination of bioassay-based methods and computational methods may be used.

EPA Draft Copper Criteria

Released December 2003

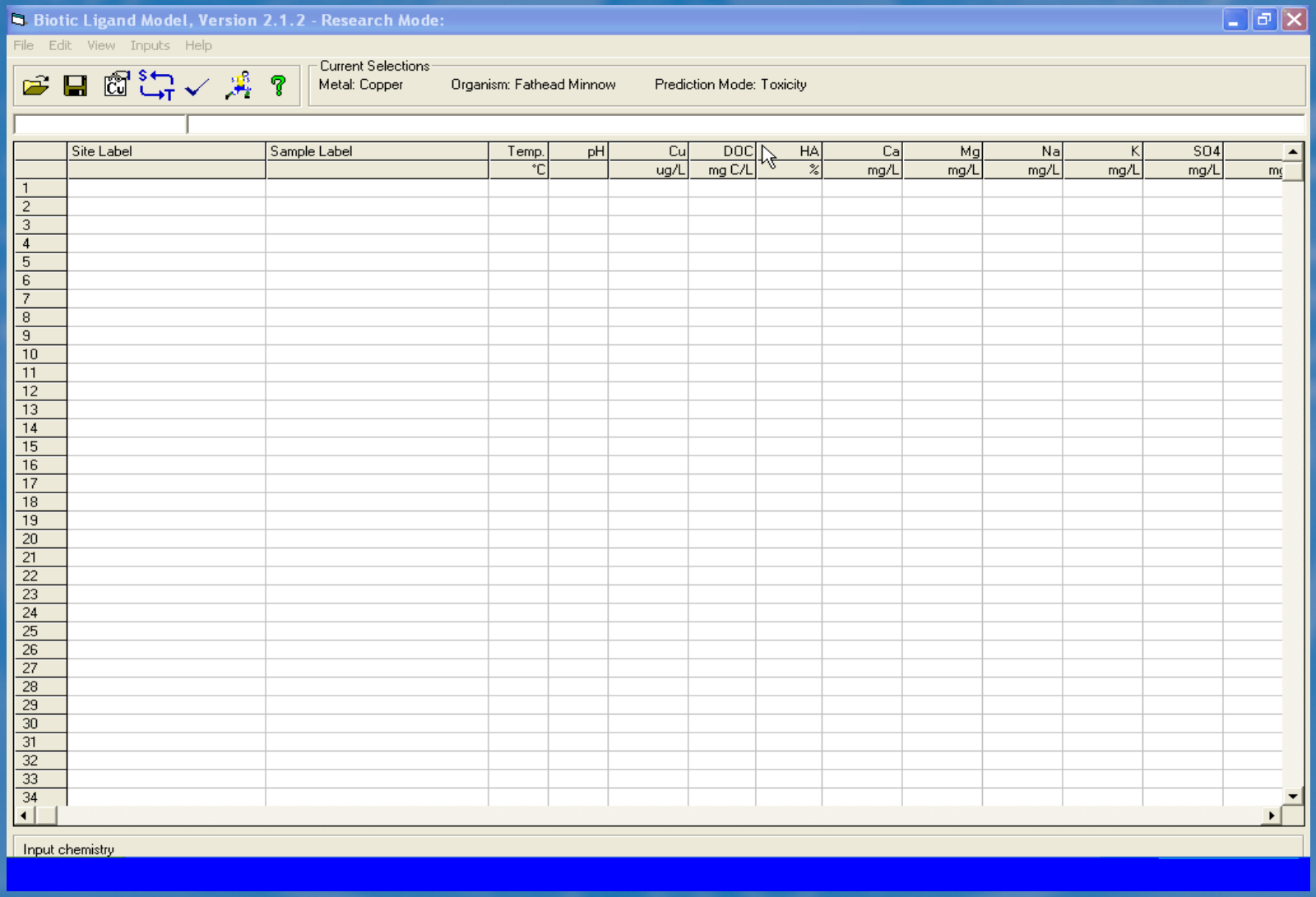
- Draft document: BLM based
  - freshwater criterion
  - replacement for the hardness equation

BLM software Version 2.1.2: An overview

Released February 2007

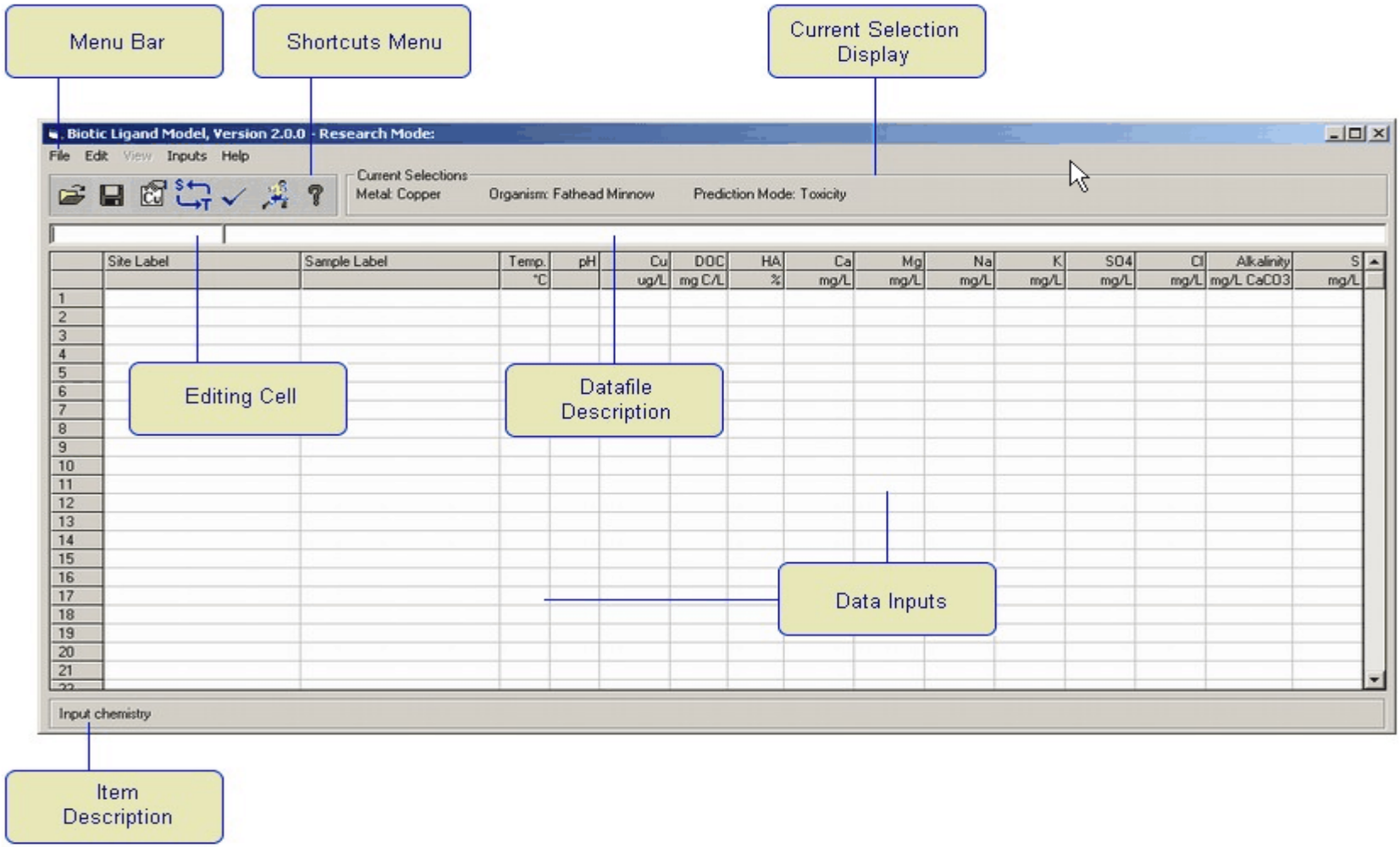
BLM software: an overview

Released February 2007



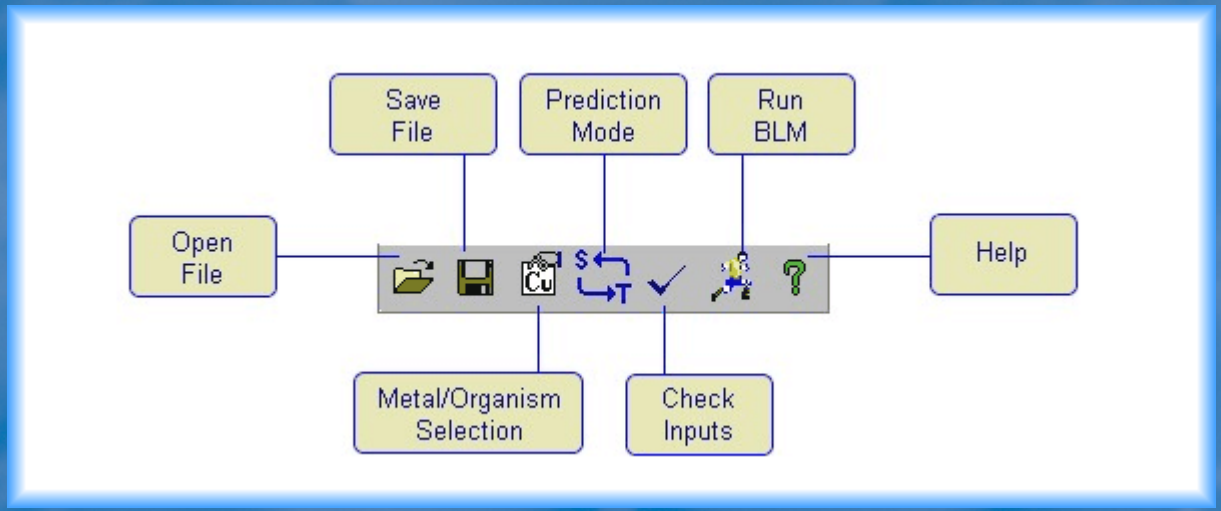
BLM window description

Released February 2007



BLM menu descriptions

Released February 2007



BLM interface populated with water chemistry data

Released February 2007

Biotic Ligand Model, Version 2.1.2 - Research Mode: Kansas River.blm

File Edit View Inputs Help

Current Selections
Metal: Copper Prediction Mode: Instantaneous WQC Calculation

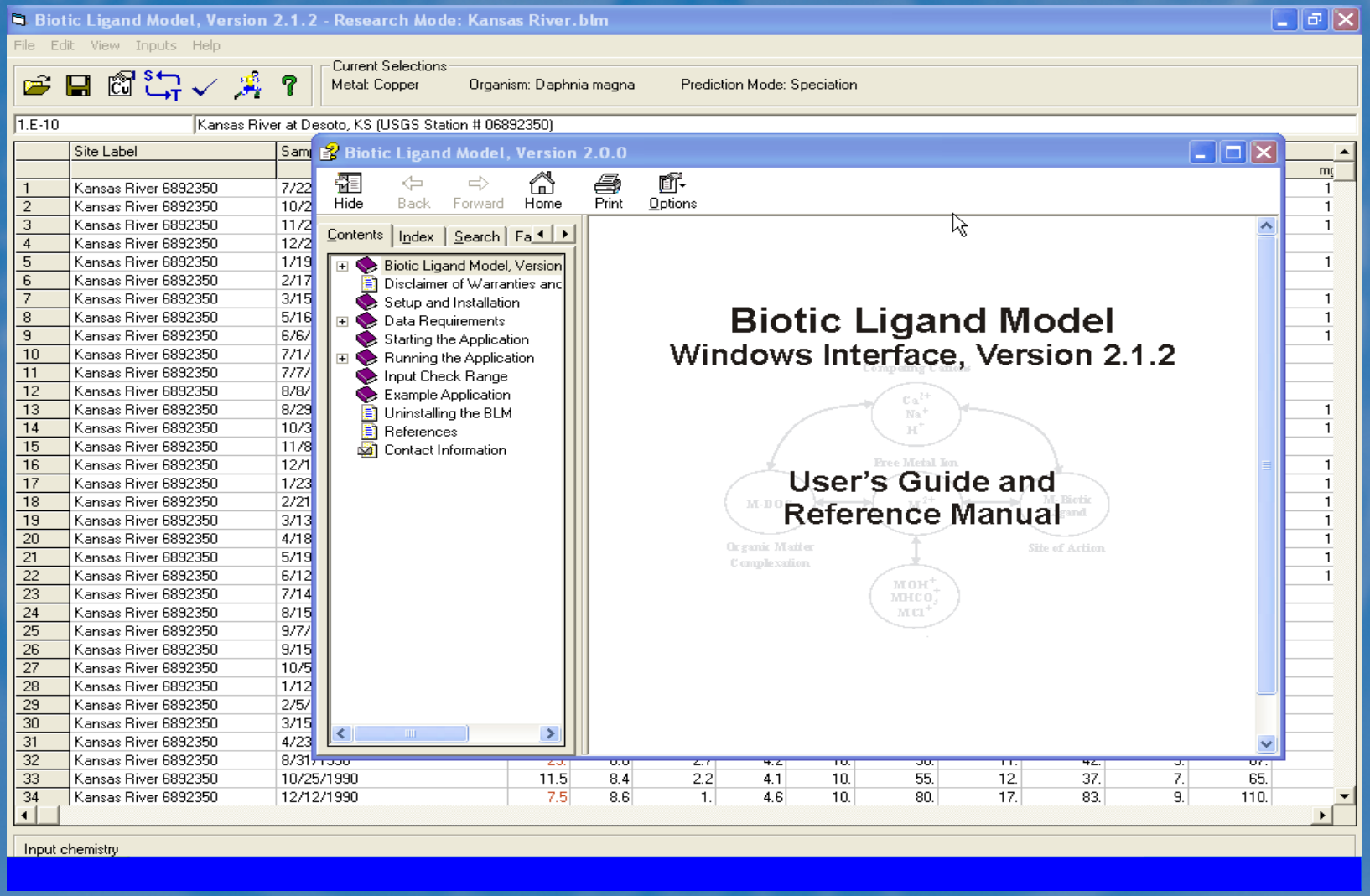
1.E-10 Kansas River at Desoto, KS (USGS Station # 06892350)

	Site Label	Sample Label	Temp.	pH	Cu	DOC	HA	Ca	Mg	Na	K	SO4	
			°C		ug/L	mg C/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg
1	Kansas River 6892350	7/22/1987	29.	8.45	6.	5.6	10.	81.	16.	76.	10.	140.	1
2	Kansas River 6892350	10/20/1987	10.	8.5	2.5	6.6	10.	92.	17.	90.	9.	130.	1
3	Kansas River 6892350	11/23/1987	7.	7.9	1.2	6.7	10.	110.	23.	130.	9.	180.	1
4	Kansas River 6892350	12/22/1987	3.	7.5	4.	9.6	10.	61.	13.	35.	6.	67.	
5	Kansas River 6892350	1/19/1988	2.	8.	2.5	3.9	10.	110.	23.	110.	8.	180.	1
6	Kansas River 6892350	2/17/1988	1.	7.3	2.	6.7	10.	91.	20.	73.	7.	120.	
7	Kansas River 6892350	3/15/1988	3.5	8.47	1.7	4.5	10.	91.	22.	110.	8.	160.	1
8	Kansas River 6892350	5/16/1988	22.	8.3	1.9	4.5	10.	73.	24.	130.	7.	180.	1
9	Kansas River 6892350	6/6/1988	24.	8.75	3.5	4.6	10.	55.	21.	110.	7.	140.	1
10	Kansas River 6892350	7/1/1988	20.	8.	2.6	6.	10.	39.	10.	46.	6.	61.	
11	Kansas River 6892350	7/7/1988	28.	8.4	1.7	5.7	10.	50.	14.	75.	6.	92.	
12	Kansas River 6892350	8/8/1988	32.	8.5	2.4	5.4	10.	43.	18.	84.	8.	100.	
13	Kansas River 6892350	8/29/1988	22.5	8.8	1.7	4.7	10.	75.	21.	130.	9.	160.	1
14	Kansas River 6892350	10/3/1988	18.	9.1	1.7	5.2	10.	68.	20.	120.	9.	150.	1
15	Kansas River 6892350	11/8/1988	10.	8.6	2.6	4.	10.	71.	19.	88.	8.	120.	
16	Kansas River 6892350	12/19/1988	5.	8.6	1.5	4.1	10.	82.	21.	120.	8.	150.	1
17	Kansas River 6892350	1/23/1989	5.	8.9	1.4	4.1	10.	86.	22.	120.	8.	160.	1
18	Kansas River 6892350	2/21/1989	1.	8.6	1.9	4.1	10.	80.	21.	110.	7.	160.	1
19	Kansas River 6892350	3/13/1989	10.	8.9	1.1	4.8	10.	83.	22.	110.	8.	160.	1
20	Kansas River 6892350	4/18/1989	19.	9.	1.4	4.8	10.	65.	21.	120.	8.	160.	1
21	Kansas River 6892350	5/19/1989	21.	8.8	1.3	5.	10.	54.	19.	120.	7.	140.	1
22	Kansas River 6892350	6/12/1989	23.5	8.8	1.5	5.1	10.	50.	18.	98.	8.	140.	1
23	Kansas River 6892350	7/14/1989	29.	8.1	3.1	6.	10.	48.	9.	27.	8.	56.	
24	Kansas River 6892350	8/15/1989	24.5	8.5	1.9	5.1	10.	60.	13.	68.	9.	100.	
25	Kansas River 6892350	9/7/1989	24.	7.9	1.6	7.	10.	29.	5.	9.	5.	20.	
26	Kansas River 6892350	9/15/1989	20.	8.1	2.1	5.5	10.	39.	9.	26.	9.	48.	
27	Kansas River 6892350	10/5/1989	17.	8.3	1.9	4.3	10.	55.	11.	48.	9.	84.	
28	Kansas River 6892350	1/12/1990	3.5	8.4	1.8	3.7	10.	80.	17.	67.	7.	120.	
29	Kansas River 6892350	2/5/1990	2.5	8.4	2.3	3.8	10.	74.	16.	70.	8.	100.	
30	Kansas River 6892350	3/15/1990	11.	7.9	1.9	7.2	10.	46.	8.	19.	5.	40.	
31	Kansas River 6892350	4/23/1990	20.5	8.8	0.5	4.	10.	76.	19.	62.	5.	100.	
32	Kansas River 6892350	8/31/1990	29.	8.6	2.7	4.2	10.	56.	11.	42.	9.	67.	
33	Kansas River 6892350	10/25/1990	11.5	8.4	2.2	4.1	10.	55.	12.	37.	7.	65.	
34	Kansas River 6892350	12/12/1990	7.5	8.6	1.	4.6	10.	80.	17.	83.	9.	110.	

Input chemistry

BLM ¡¡¡¡¡Help !!!!!

Released February 2007



BLM Input parameters check

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Biotic Ligand Model, Version 2.1.2 - Research Mode: Kansas River.blm

File Edit View Inputs Help

Current Selections
Metal: Copper Prediction Mode: Instantaneous WQC Calculation

1.E-10 Kansas River at Desoto, KS (USGS Station # 06892350)

	Site Label	Sample Label	Temp. °C	pH	Cu ug/L	DOC mg C/L	HA %	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	SO4 mg/L	mg
1	Kansas River 6892350	7/22/1987	29.	8.45	6.	5.6	10.	81.	16.	76.	10.	140.	1
2	Kansas River 6892350	10/20/1987	10.	8.5	2.5	6.6	10.	82.	17.	90.	9.	130.	1
3	Kansas River 6892350	11/23/1987	7.	7.9	1.2	6.7	10.	110.	23.	130.	9.	180.	1
4	Kansas River 6892350	12/22/1987							13.	35.	6.	67.	
5	Kansas River 6892350	1/19/1988							23.	110.	8.	180.	1
6	Kansas River 6892350	2/17/1988							20.	73.	7.	120.	
7	Kansas River 6892350	3/15/1988							22.	110.	8.	160.	1
8	Kansas River 6892350	5/16/1988							24.	130.	7.	180.	1
9	Kansas River 6892350	6/6/1988							21.	110.	7.	140.	1
10	Kansas River 6892350	7/1/1988							10.	46.	6.	61.	
11	Kansas River 6892350	7/7/1988							14.	75.	6.	92.	
12	Kansas River 6892350	8/8/1988							18.	84.	8.	100.	
13	Kansas River 6892350	8/29/1988							21.	130.	9.	160.	1
14	Kansas River 6892350	10/3/1988							20.	120.	9.	150.	1
15	Kansas River 6892350	11/8/1988							19.	88.	8.	120.	
16	Kansas River 6892350	12/19/1988							21.	120.	8.	150.	1
17	Kansas River 6892350	1/23/1989							22.	120.	8.	160.	1
18	Kansas River 6892350	2/21/1989							21.	110.	7.	160.	1
19	Kansas River 6892350	3/13/1989							22.	110.	8.	160.	1
20	Kansas River 6892350	4/18/1989							21.	120.	8.	160.	1
21	Kansas River 6892350	5/19/1989							19.	120.	7.	140.	1
22	Kansas River 6892350	6/12/1989							18.	98.	8.	140.	1
23	Kansas River 6892350	7/14/1989							9.	27.	8.	56.	
24	Kansas River 6892350	8/15/1989							13.	68.	9.	100.	
25	Kansas River 6892350	9/7/1989							5.	9.	5.	20.	
26	Kansas River 6892350	9/15/1989							9.	26.	9.	48.	
27	Kansas River 6892350	10/5/1989	17.	8.3	1.9	4.3	10.	55.	11.	48.	9.	84.	
28	Kansas River 6892350	1/12/1990	3.5	8.4	1.8	3.7	10.	80.	17.	67.	7.	120.	
29	Kansas River 6892350	2/5/1990	2.5	8.4	2.3	3.8	10.	74.	16.	70.	8.	100.	
30	Kansas River 6892350	3/15/1990	11.	7.9	1.9	7.2	10.	46.	8.	19.	5.	40.	
31	Kansas River 6892350	4/23/1990	20.5	8.8	0.5	4.	10.	76.	19.	62.	5.	100.	
32	Kansas River 6892350	8/31/1990	29.	8.6	2.7	4.2	10.	56.	11.	42.	9.	67.	
33	Kansas River 6892350	10/25/1990	11.5	8.4	2.2	4.1	10.	55.	12.	37.	7.	65.	
34	Kansas River 6892350	12/12/1990	7.5	8.6	1.	4.6	10.	80.	17.	83.	9.	110.	

Biotic Ligand Model, Version 2.1.2 - BLM Input Check Report

Input 1 has high Temperature (°C)
Input 1 has low Sulfide (mg/L)
Input 2 has low Sulfide (mg/L)
Input 3 has low Temperature (°C)
Input 3 has low Sulfide (mg/L)
Input 4 has low Temperature (°C)
Input 4 has low Sulfide (mg/L)
Input 5 has low Temperature (°C)
Input 5 has low Sulfide (mg/L)
Input 6 has low Temperature (°C)
Input 6 has low Sulfide (mg/L)
Input 7 has low Temperature (°C)
Input 7 has low Sulfide (mg/L)
Input 8 has low Sulfide (mg/L)
Input 9 has low Sulfide (mg/L)
Input 10 has low Sulfide (mg/L)
Input 11 has high Temperature (°C)
Input 11 has low Sulfide (mg/L)
Input 12 has high Temperature (°C)
Input 12 has low Sulfide (mg/L)
Input 13 has low Sulfide (mg/L)

Input chemistry

BLM Input parameters unit selection

Released February 2007

Biotic Ligand Model, Version 2.1.2 - Research Mode: Kansas River.blm

File Edit View Inputs Help

Current Selections
Metal: Copper Prediction Mode: Instantaneous WQC Calculation

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			°C		ug/L	mg C/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg
1	Kansas River 6892350	7/22/1987	29.	8.45	6.	5.6	10.	81.	16.	76.	10.	140.	1
2	Kansas River 6892350	10/20/1987	10.	8.5	2.5	6.6	10.	82.	17.	90.	9.	130.	1
3	Kansas River 6892350	11/23/1987	7.	7.9	1.2	6.7	10.	110.	23.	130.	9.	180.	1
4	Kansas River 6892350	12/22/1987	3.	7.5	4.	9.6	10.	61.	13.	35.	6.	67.	
5	Kansas River 6892350	1/19/1988						110.	23.	110.	8.	180.	1
6	Kansas River 6892350	2/17/1988						91.	20.	73.	7.	120.	
7	Kansas River 6892350	3/15/1988						91.	22.	110.	8.	160.	1
8	Kansas River 6892350	5/16/1988						73.	24.	130.	7.	180.	1
9	Kansas River 6892350	6/6/1988						55.	21.	110.	7.	140.	1
10	Kansas River 6892350	7/1/1988						39.	10.	46.	6.	61.	
11	Kansas River 6892350	7/7/1988						50.	14.	75.	6.	92.	
12	Kansas River 6892350	8/8/1988						43.	18.	84.	8.	100.	
13	Kansas River 6892350	8/29/1988						75.	21.	130.	9.	160.	1
14	Kansas River 6892350	10/3/1988						68.	20.	120.	9.	150.	1
15	Kansas River 6892350	11/8/1988						71.	19.	88.	8.	120.	
16	Kansas River 6892350	12/19/1988						82.	21.	120.	8.	150.	1
17	Kansas River 6892350	1/23/1989						86.	22.	120.	8.	160.	1
18	Kansas River 6892350	2/21/1989						80.	21.	110.	7.	160.	1
19	Kansas River 6892350	3/13/1989						83.	22.	110.	8.	160.	1
20	Kansas River 6892350	4/18/1989						65.	21.	120.	8.	160.	1
21	Kansas River 6892350	5/19/1989						54.	19.	120.	7.	140.	1
22	Kansas River 6892350	6/12/1989						50.	18.	98.	8.	140.	1
23	Kansas River 6892350	7/14/1989						48.	9.	27.	8.	56.	
24	Kansas River 6892350	8/15/1989						60.	13.	68.	9.	100.	
25	Kansas River 6892350	9/7/1989	24.	7.9	1.6	7.	10.	29.	5.	9.	5.	20.	
26	Kansas River 6892350	9/15/1989	20.	8.1	2.1	5.5	10.	39.	9.	26.	9.	48.	
27	Kansas River 6892350	10/5/1989	17.	8.3	1.9	4.3	10.	55.	11.	48.	9.	84.	
28	Kansas River 6892350	1/12/1990	3.5	8.4	1.8	3.7	10.	80.	17.	67.	7.	120.	
29	Kansas River 6892350	2/5/1990	2.5	8.4	2.3	3.8	10.	74.	16.	70.	8.	100.	
30	Kansas River 6892350	3/15/1990	11.	7.9	1.9	7.2	10.	46.	8.	19.	5.	40.	
31	Kansas River 6892350	4/23/1990	20.5	8.8	0.5	4.	10.	76.	19.	62.	5.	100.	
32	Kansas River 6892350	8/31/1990	29.	8.6	2.7	4.2	10.	56.	11.	42.	9.	67.	
33	Kansas River 6892350	10/25/1990	11.5	8.4	2.2	4.1	10.	55.	12.	37.	7.	65.	
34	Kansas River 6892350	12/12/1990	7.5	8.6	1.	4.6	10.	80.	17.	83.	9.	110.	

Biotic Ligand Model, Version 2...

Select Units

Select Component:
Temperature
pH
Cu
DOC
HA
Ca
Mg
Na
K
SO4
Cl
Alkalinity
S

Select Units:
ug/L
mg/L
g/L
umol/L
mmol/L
mol/L

Ok Cancel Help

Input chemistry

BLM simulation options

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Biotic Ligand Model, Version 2.1.2 - Research Mode: Kansas River.blm

File Edit View Inputs Help

Current Selections
Metal: Copper Prediction Mode: Instantaneous WQC Calculation

1.E-10 Kansas River at Desoto, KS (USGS Station # 06892350)

	Site Label	Sample Label	Temp. °C	pH	Cu ug/L	DOC mg C/L	HA %	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	SO4 mg/L	mg
1	Kansas River 6892350	7/22/1987	29.	8.45	6.	5.6	10.	81.	16.	76.	10.	140.	1
2	Kansas River 6892350	10/20/1987	10.	8.5	2.5	6.6	10.	82.	17.	90.	9.	130.	1
3	Kansas River 6892350	11/23/1987	7.	7.9	1.2	6.7	10.	110.	23.	130.	9.	180.	1
4	Kansas River 6892350	12/22/1987	3.	7.5	4.	9.6	10.	61.	13.	35.	6.	67.	
5	Kansas River 6892350	1/19/1988	2.	8.	2.5	3.9	10.	110.	23.	110.	8.	180.	1
6	Kansas River 6892350	2/17/1988						91.	20.	73.	7.	120.	
7	Kansas River 6892350	3/15/1988						91.	22.	110.	8.	160.	1
8	Kansas River 6892350	5/16/1988						73.	24.	130.	7.	180.	1
9	Kansas River 6892350	6/6/1988						55.	21.	110.	7.	140.	1
10	Kansas River 6892350	7/1/1988						39.	10.	46.	6.	61.	
11	Kansas River 6892350	7/7/1988						50.	14.	75.	6.	92.	
12	Kansas River 6892350	8/8/1988						43.	18.	84.	8.	100.	
13	Kansas River 6892350	8/29/1988						75.	21.	130.	9.	160.	1
14	Kansas River 6892350	10/3/1988						68.	20.	120.	9.	150.	1
15	Kansas River 6892350	11/8/1988						71.	19.	88.	8.	120.	
16	Kansas River 6892350	12/19/1988						82.	21.	120.	8.	150.	1
17	Kansas River 6892350	1/23/1989						86.	22.	120.	8.	160.	1
18	Kansas River 6892350	2/21/1989						80.	21.	110.	7.	160.	1
19	Kansas River 6892350	3/13/1989						83.	22.	110.	8.	160.	1
20	Kansas River 6892350	4/18/1989						65.	21.	120.	8.	160.	1
21	Kansas River 6892350	5/19/1989						54.	19.	120.	7.	140.	1
22	Kansas River 6892350	6/12/1989						50.	18.	98.	8.	140.	1
23	Kansas River 6892350	7/14/1989						48.	9.	27.	8.	56.	
24	Kansas River 6892350	8/15/1989						60.	13.	68.	9.	100.	
25	Kansas River 6892350	9/7/1989	24.	7.9	1.6	7.	10.	29.	5.	9.	5.	20.	
26	Kansas River 6892350	9/15/1989	20.	8.1	2.1	5.5	10.	39.	9.	26.	9.	48.	
27	Kansas River 6892350	10/5/1989	17.	8.3	1.9	4.3	10.	55.	11.	48.	9.	84.	
28	Kansas River 6892350	1/12/1990	3.5	8.4	1.8	3.7	10.	80.	17.	67.	7.	120.	
29	Kansas River 6892350	2/5/1990	2.5	8.4	2.3	3.8	10.	74.	16.	70.	8.	100.	
30	Kansas River 6892350	3/15/1990	11.	7.9	1.9	7.2	10.	46.	8.	19.	5.	40.	
31	Kansas River 6892350	4/23/1990	20.5	8.8	0.5	4.	10.	76.	19.	62.	5.	100.	
32	Kansas River 6892350	8/31/1990	29.	8.6	2.7	4.2	10.	56.	11.	42.	9.	67.	
33	Kansas River 6892350	10/25/1990	11.5	8.4	2.2	4.1	10.	55.	12.	37.	7.	65.	
34	Kansas River 6892350	12/12/1990	7.5	8.6	1.	4.6	10.	80.	17.	83.	9.	110.	

Input chemistry

Biotic Ligand Model, Version 2.1.2

Select Options for BLM Simulation

Organism	Copper	Silver	Cadmium	Zinc
Fathead Minnow	●	○	○	○
Rainbow trout	○	○	○	○
Daphnia magna	○	○	○	○
Daphnia pulex	○	○	○	○
Ceriodaphnia dubia	○	○	○	○
User Defined	○	○	○	○

User Selected Metal/Organism ○

Cu WQC Calculation ○

Ok Cancel Help

BLM run completion message

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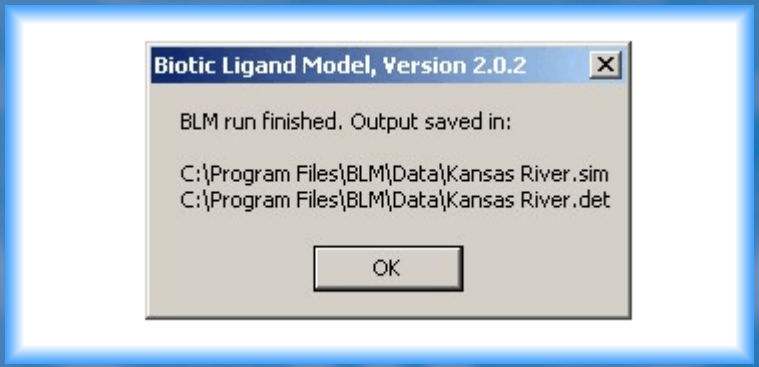

BLM WQC report

Released February 2007

Biotic Ligand Model, Version 2.1.2 - Instantaneous Cu WQC Report: Kansas River.blm

	Site Label	Sample Label	Final Acute Value	Instantaneous WQC	Cu	Toxic Units
			ug/L	ug/L	ug/L	
1	Kansas River 6892350	7/22/1987	216.1199	108.06	6.	0.0555
2	Kansas River 6892350	10/20/1987	177.3569	88.6784	2.5	0.0282
3	Kansas River 6892350	11/23/1987	119.53	59.7[illegible]	1.2	0.0201
4	Kansas River 6892350	12/22/1987	87.6935	43.8467	4.	0.0912
5	Kansas River 6892350	1/19/1988	70.9173	35.4587	2.5	0.0705
6	Kansas River 6892350	2/17/1988	56.4987	28.2494	2.	0.0708
7	Kansas River 6892350	3/15/1988	110.4429	55.2215	1.7	0.0308
8	Kansas River 6892350	5/16/1988	139.6106	69.8053	1.9	0.0272
9	Kansas River 6892350	6/6/1988	203.9191	101.9596	3.5	0.0343
10	Kansas River 6892350	7/1/1988	106.4396	53.2198	2.6	0.0489
11	Kansas River 6892350	7/7/1988	196.103	98.0515	1.7	0.0173
12	Kansas River 6892350	8/8/1988	222.0933	111.0466	2.4	0.0216
13	Kansas River 6892350	8/29/1988	220.7588	110.3794	1.7	0.0154
14	Kansas River 6892350	10/3/1988	252.0234	126.0117	1.7	0.0135
15	Kansas River 6892350	11/8/1988	114.7641	57.382	2.6	0.0453
16	Kansas River 6892350	12/19/1988	114.2557	57.1279	1.5	0.0263
17	Kansas River 6892350	1/23/1989	133.8279	66.9139	1.4	0.0209
18	Kansas River 6892350	2/21/1989	103.6435	51.8218	1.9	0.0367
19	Kansas River 6892350	3/13/1989	172.6545	86.3272	1.1	0.0127
20	Kansas River 6892350	4/18/1989	229.6552	114.8276	1.4	0.0122
21	Kansas River 6892350	5/19/1989	219.2972	109.6486	1.3	0.0119
22	Kansas River 6892350	6/12/1989	225.6518	112.8259	1.5	0.0133
23	Kansas River 6892350	7/14/1989	134.2727	67.1363	3.1	0.0462
24	Kansas River 6892350	8/15/1989	177.5475	88.7738	1.9	0.0214
25	Kansas River 6892350	9/7/1989	98.6869	49.3435	1.6	0.0324
26	Kansas River 6892350	9/15/1989	99.8943	49.9472	2.1	0.042
27	Kansas River 6892350	10/5/1989	100.212	50.106	1.9	0.0379
28	Kansas River 6892350	1/12/1990	79.9409	39.9704	1.8	0.045
29	Kansas River 6892350	2/5/1990	81.2753	40.6377	2.3	0.0566
30	Kansas River 6892350	3/15/1990	95.3825	47.6913	1.9	0.0398
31	Kansas River 6892350	4/23/1990	161.5975	80.7987	0.5	0.0062
32	Kansas River 6892350	8/31/1990	166.4905	83.2453	2.7	0.0324
33	Kansas River 6892350	10/25/1990	89.7905	44.8952	2.2	0.049
34	Kansas River 6892350	12/12/1990	124.5502	62.2751	1.	0.0161
35	Kansas River 6892350	2/19/1991	124.1689	62.0844	1.8	0.029
36	Kansas River 6892350	6/10/1991	114.8276	57.4138	4.2	0.0732
37	Kansas River 6892350	8/14/1991	275.9167	137.9584	2.	0.0145

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