Evaluation of the Integrated Watershed and Receiving Water Model for Sinclair and Dyes Inlets

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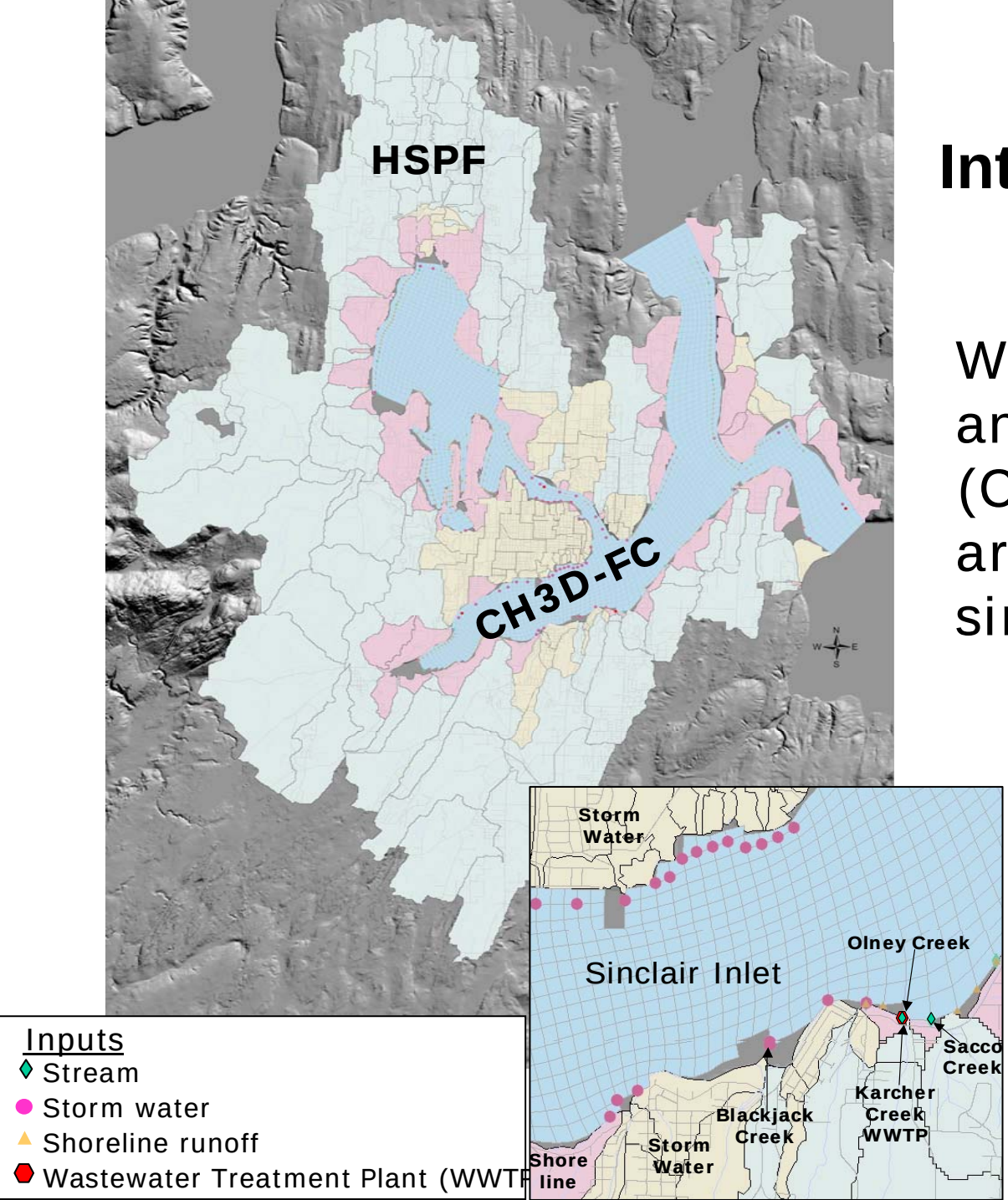
- Inputs
  - Hydrological Model (HSPF)
  - FC Loading Model
  - Estuarine Model (CH3D-FC)
- Loading from Watershed
  - Streams, Stormwater, WWTPs
  - Loading Analysis
- CH3D-FC Predictions
  - Resolution
  - Comparison to Observed Data
- TMDL Simulations
- Sensitivity and Uncertainty

Integrated Modeling



Watershed (HSPF) and receiving water (CH3D-FC) models are combined to simulate all inputs.

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Current Configuration:
 39 Streams
 50 Stormwater Outfalls
 44 Shoreline Drainages
  4 Treatment Plants
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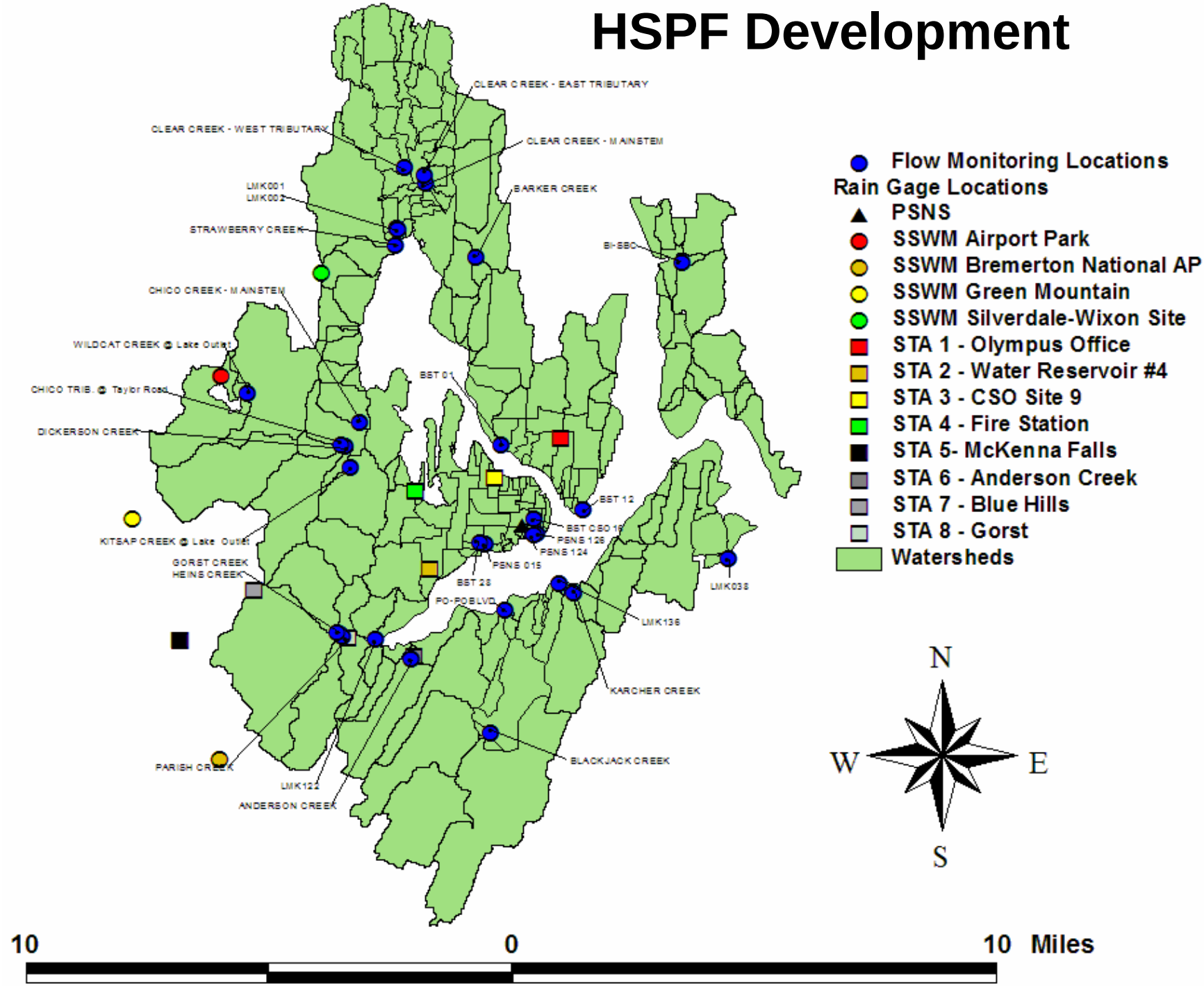
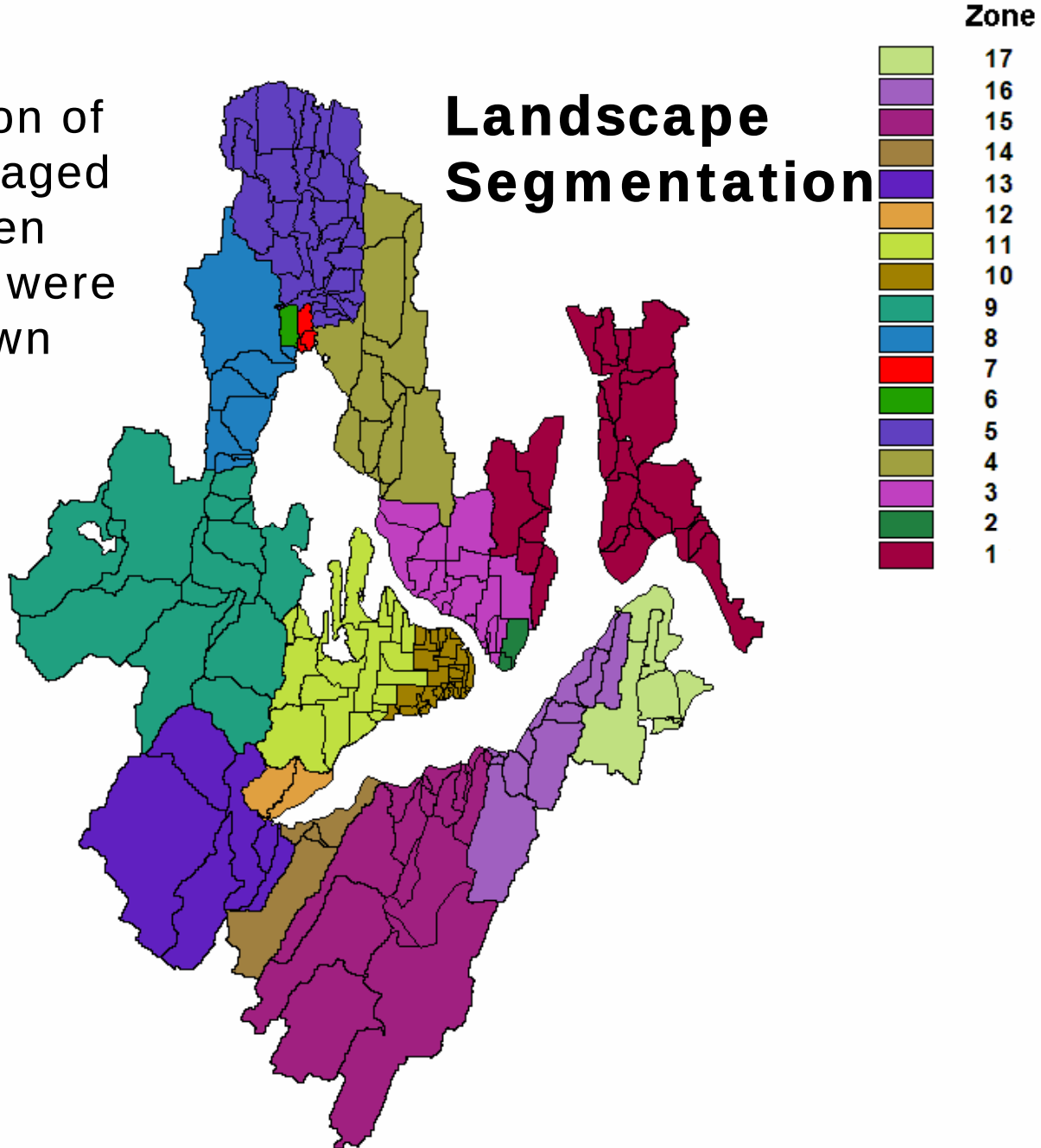
137 Separate Inputs
```

HSPF Development

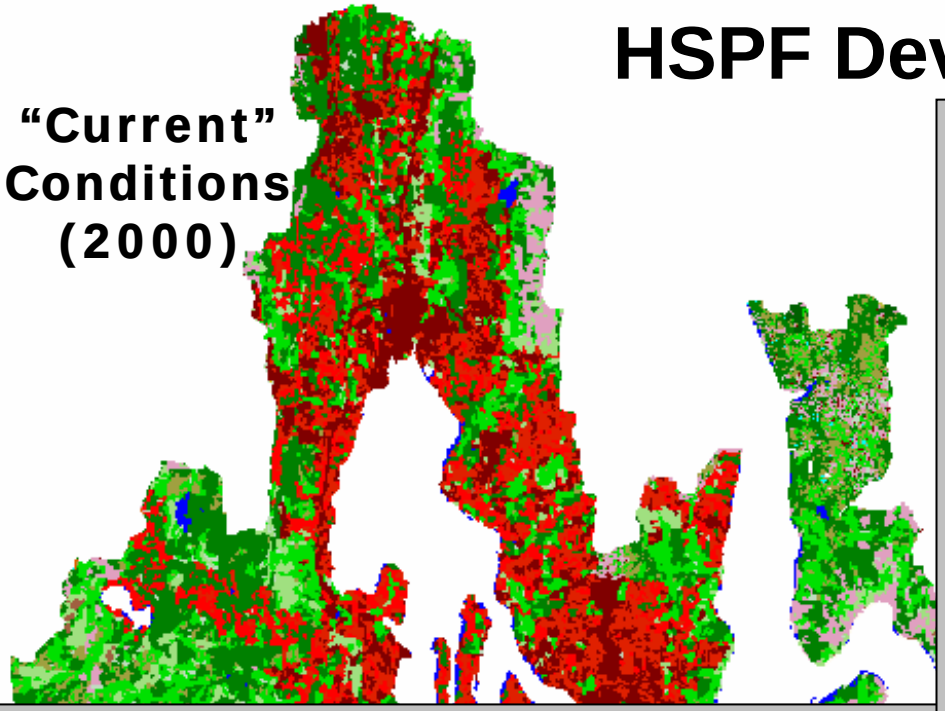


HSPF Development (Cont.)

To support parameterization of models for ungaged areas, seventeen land segments were defined as shown



HSPF Development (Cont.)



Conceptual Model: Fit the hard data and predetermined expectations for the partition of average annual precipitation across:

surface runoff (**SUFO**),
interflow runoff (**IFWO**),
baseflow runoff (**AGWO**), and
evapotranspiration (**TAET**) for each LULC represented in models

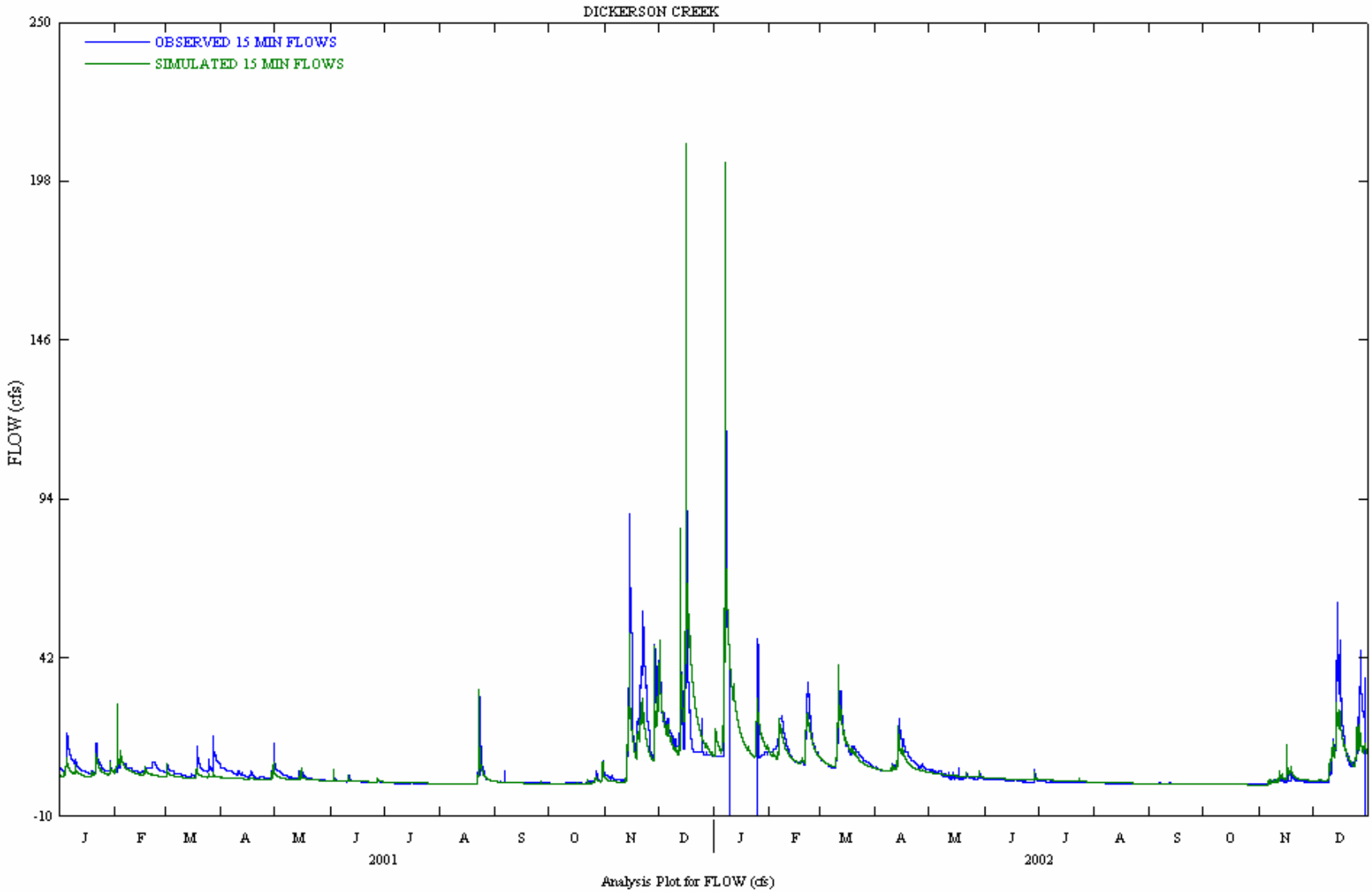
Regularization Scheme

Used to Balance "Data Fit" with Model Stability. Enhancements (Skahill and Doherty, 2006) and adaptations (Doherty and Skahill, 2006) to the Levenberg Marquardt method of computer-based parameter estimation were employed to calibrate the HSPF models developed for the ENVVEST project.

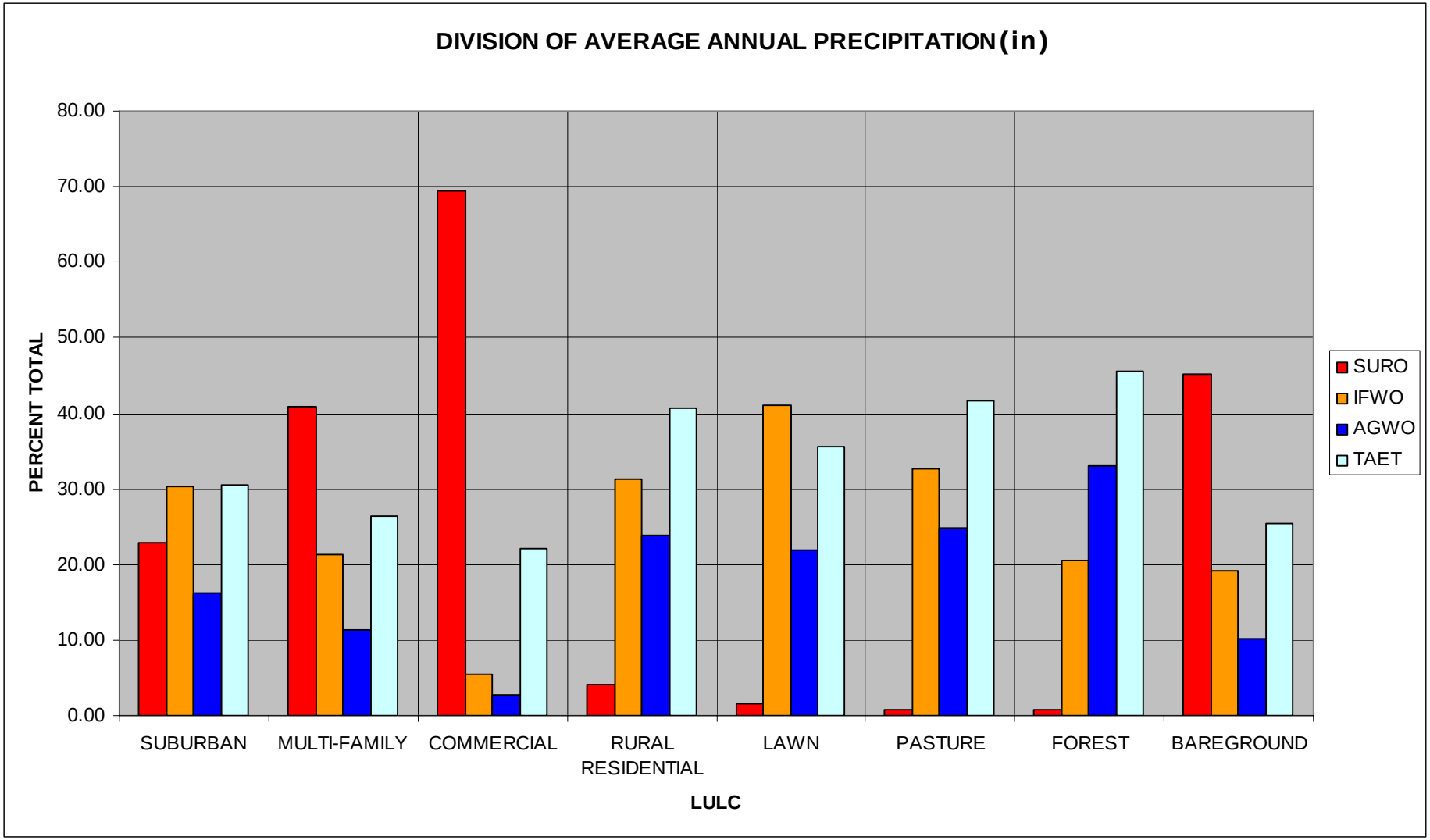
Doherty, J., and Skahill, B. 2006. An Advanced Regularization Methodology for Use in Watershed Model Calibration. **Journal of Hydrology**, 327, 564– 577.

Skahill, B., and Doherty, J. 2006. Efficient accommodation of local minima in watershed model calibration. **Journal of Hydrology**, 329, 122-139.

Representative Results from HSPF

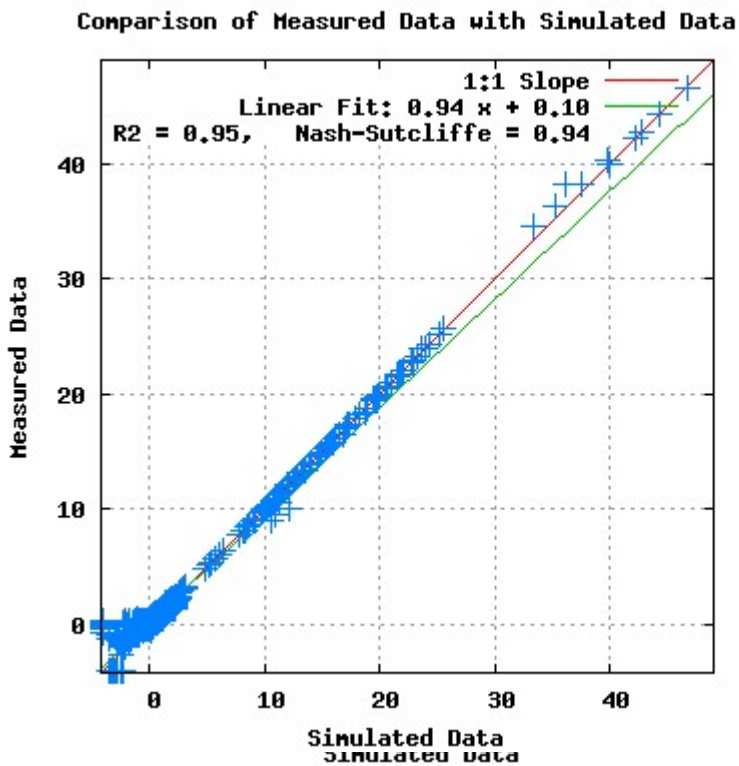


Simulated Partition of Average Annual Precipitation for Chico Creek Basin



SURO = direct surface runoff;
IFWO = interflow runoff;
AGWO = baseflow runoff;
TAET = total simulated evapotranspiration

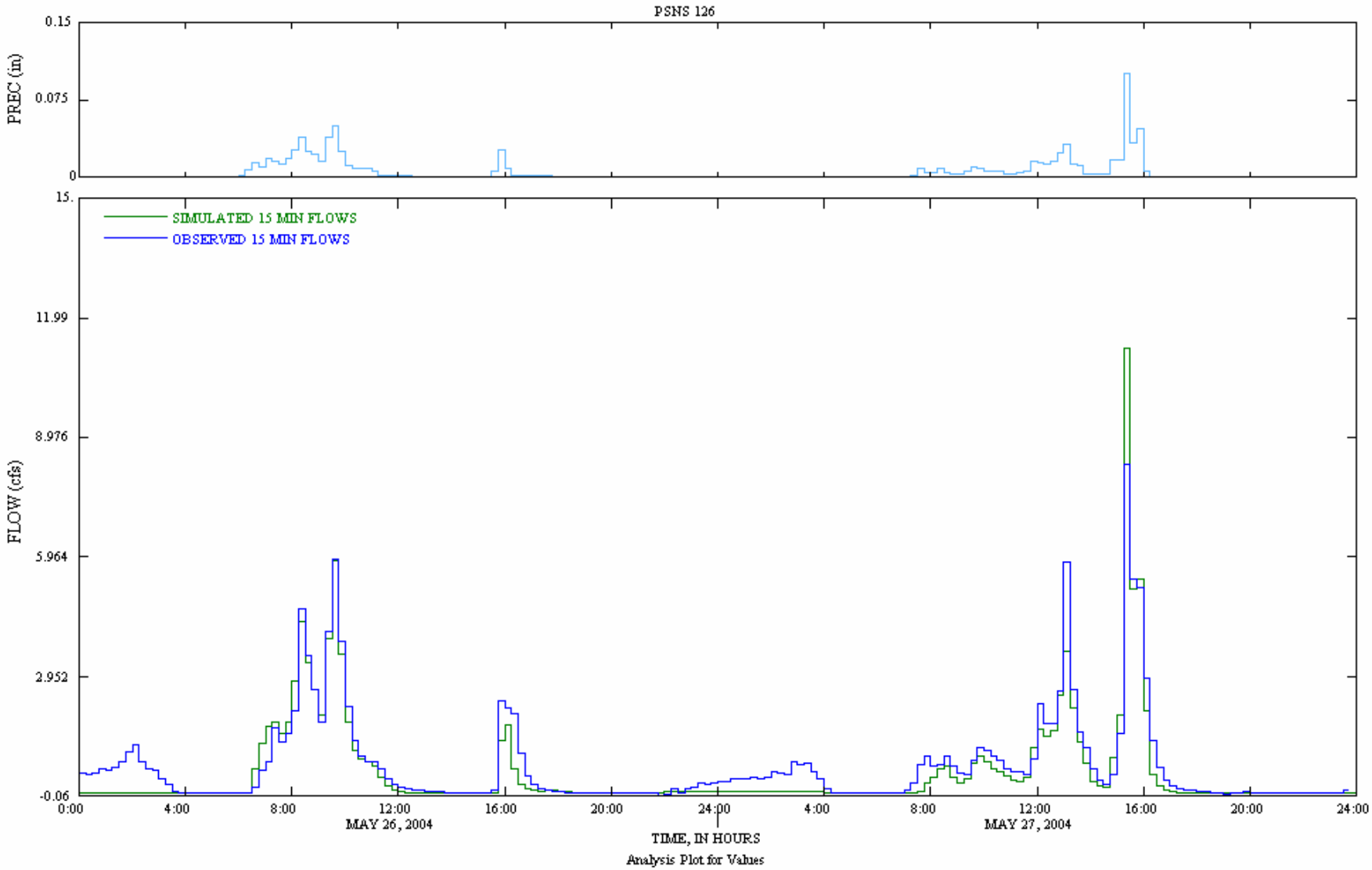
Representative Results from HSPF



Calibration model results for Chico Creek Maquoketa

Comparison of all the data (15 minute flow data, mean daily flow data, and the targets for the partition of average annual precipitation across SURO, IFWO, AGWO, and TAET) that was used in the calibration of the Chico Creek HSPF hydrologic model.

Simulated and Observed Flow for Stormwater Outfall PSNS126



Status of HSPF Modeling

- Hydrological Model Development Complete

  OUT5_PRE.WDM - Simulated flow from Oct 1992 to Nov 2004 for each watershed (DSN) in the model at 15 min time steps

  ENVVEST_2006_07_20.WDM – Observed flow and meteorological data from ENVVEST study area used to calibrate and validate the model
- Hydrology and Suspended Sediment Model Complete
  - Calibarted/Validated Submodels for watersheds and shipyard for simulating flow and discharge of suspended sediment

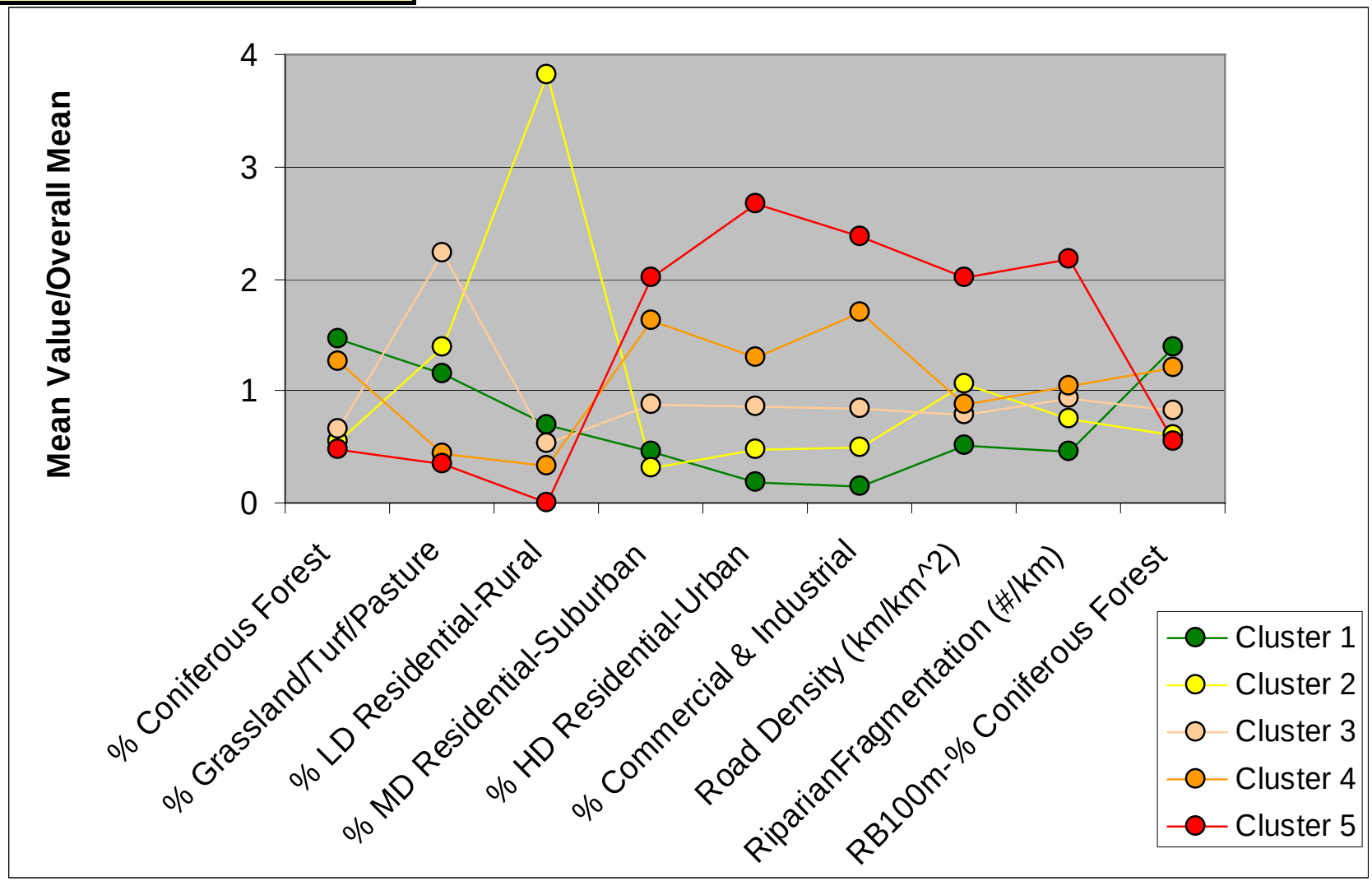
Simulating FC Loading

- Flow Data
  - Volume of water discharged (cubic feet per second – cfs)
  - Only limited number of streams and storm water outfalls are gauged
  - Watershed model predicts flows for all “pour points”
- Concentration Data
  - FC cfu/100 ml being discharged
  - No data for many streams and outfalls
  - **Estimate concentration from existing data**
- Load = Flow x Concentration

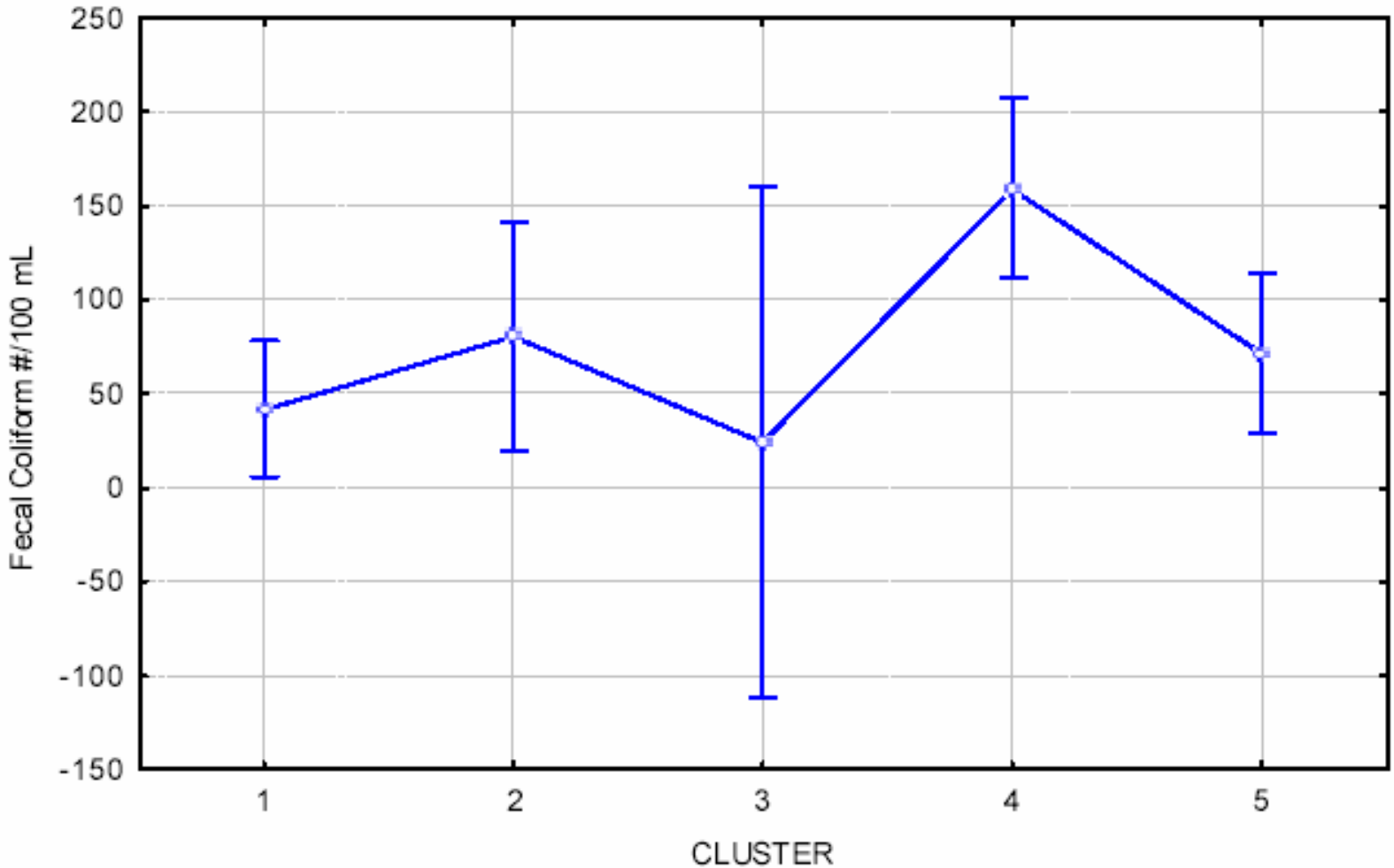
  FC cfu/day (millions of counts)

Land Use/Land Cover Clusters

Cluster	Description
1	Least Developed
2	Rural/LD Residential
3	Grass/Turf/Pasture
4	MD-HD Residential
5	Greatest Development



Estimating FC Loading Conc.

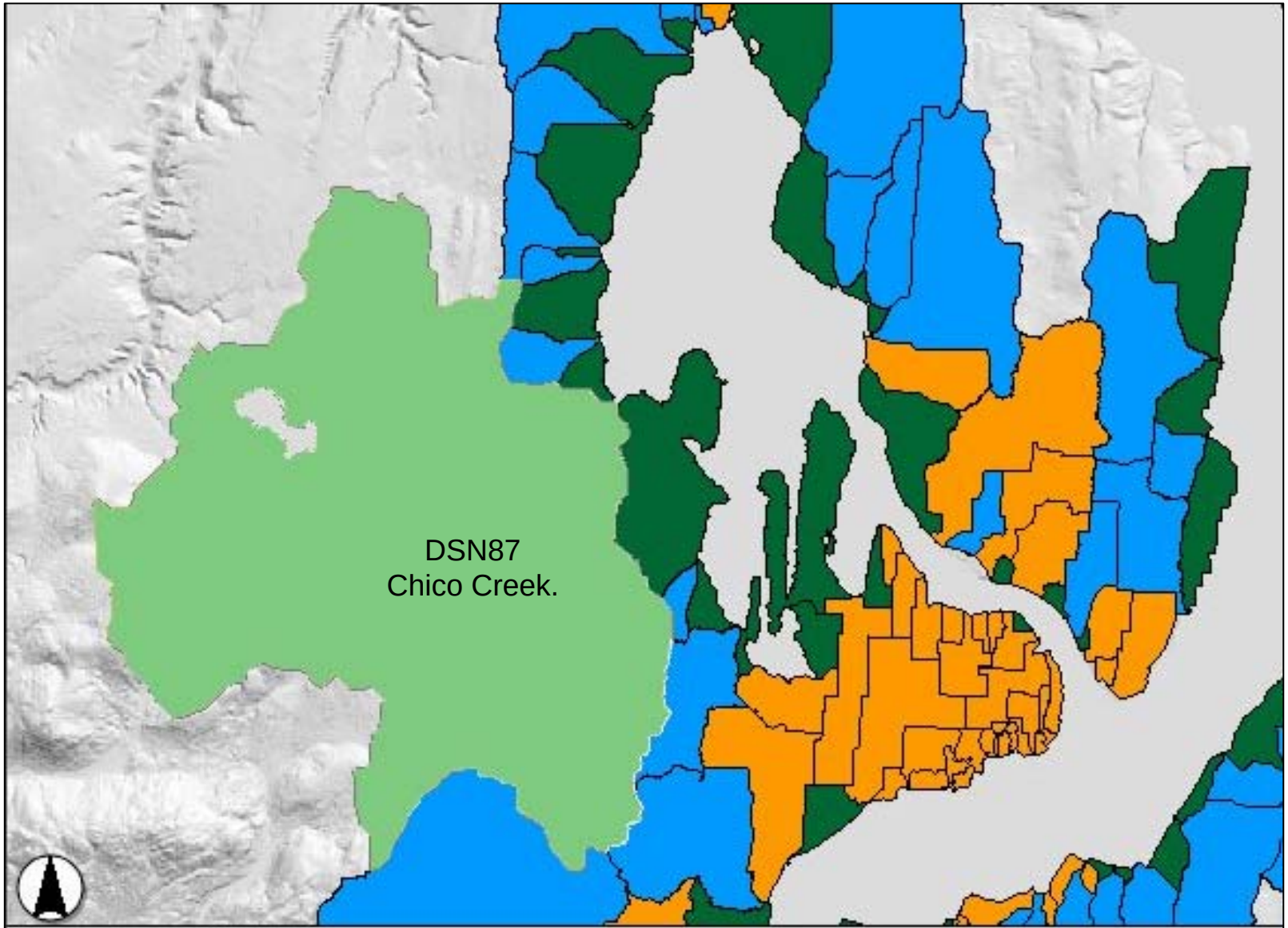


Cluster	Description
1	Least Developed
2	Rural/LD Residential
3	Grass/Turf/Pasture
4	MD-HD Residential
5	Greatest Development

Example of FC Concentration Assignments for Selected Watershed

		Cluster	Cluster Percentile		
TYPE	Basin Description/Location	Assignment	25th	GeoMean	75th
Shore	East Bremerton-Parkside Dr	4	12.3	179.8	705.0
Stormwater	East Bremerton-Manette Bridge	1	210.0	947.0	1255.0
Stormwater	East Bremerton-Upper Trenton	1	210.0	947.0	1255.0
Shore	Illahee (MESO-NW)	3	9.5	23.7 *	50.0
Shore	Ross Point Shore	5	11.1	65.5	294.0
Stormwater	Port Orchard Downtown - Wilkens	3	62.0	140.0	263.0
Stormwater	Port Orchard Downtown - Bay St	1	210.0	947.0	1255.0
Shore	Port Orchard Annapolis Point	4	12.3	131.2	705.0
Shore	BI-Crystal Springs	1	11.0	26.0	138.0
Stream	Schel Chelb Creek (BI)	2	23.0	48.6	263.0
Stormwater	BI-Fort Ward	2	158.0	321.0	459.0
Shore	Manchester Point Shore	2	23.0	31.2	263.0
Stream	Gorst Creek @ Sam Christopherson	1	11.0	29.9	138.0
Stream	Barker Creek	2	23.0	84.3	263.0
Stream	Earlands Creek	3	9.5	23.7 *	50.0
Stormwater	Silverdale Bayview Dr	1	210.0	947.0	1255.0
Stormwater	PSNS015 McDonalds NavSta	1	210.0	947.0	1255.0
Stormwater	PSNS124 Dry Dock 3	1	210.0	947.0	1255.0
Stream	Blackjack Lower Mainstem	1	11.0	48.2	138.0

* Predicted geomean was greater than the Cluster 75th percentile, the 75th percentile was used.



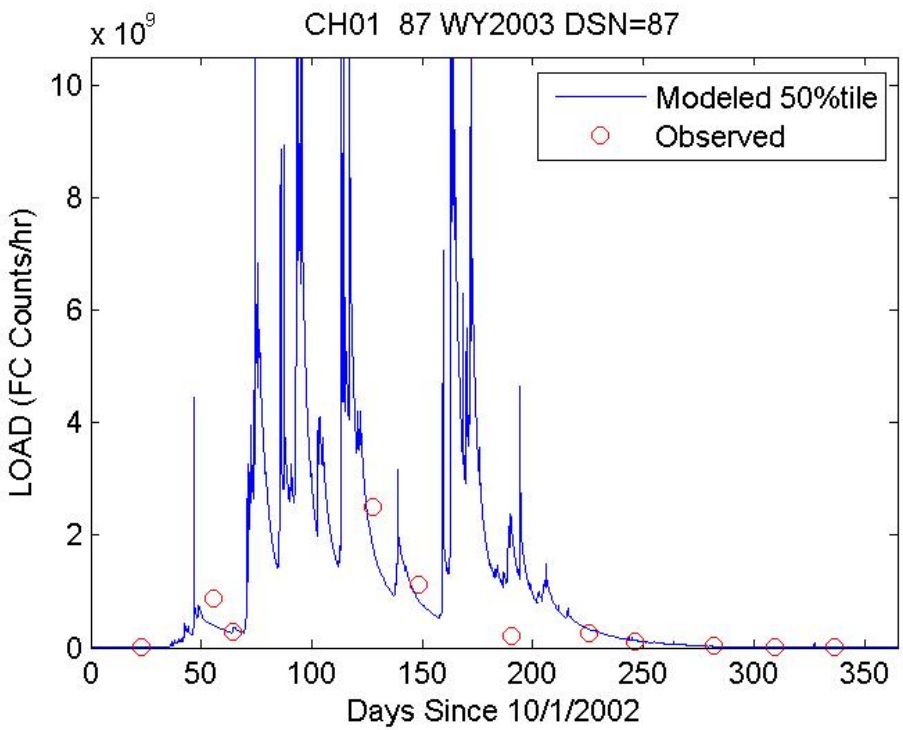
Map created for Project ENVVEST - 2006

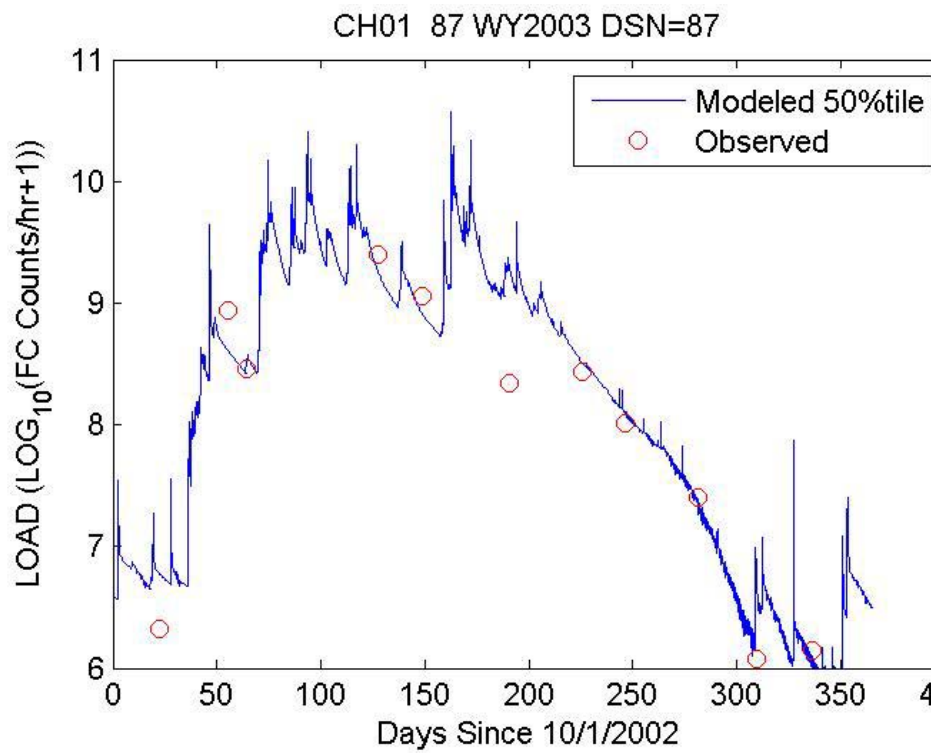
0 11584ft

Drainage Basins

Rec	DSN	Type	Fecal Coliform 50%	Hydrograph
1	87	stream	36.63	Click for plot

Chico Creek (Stream Example)



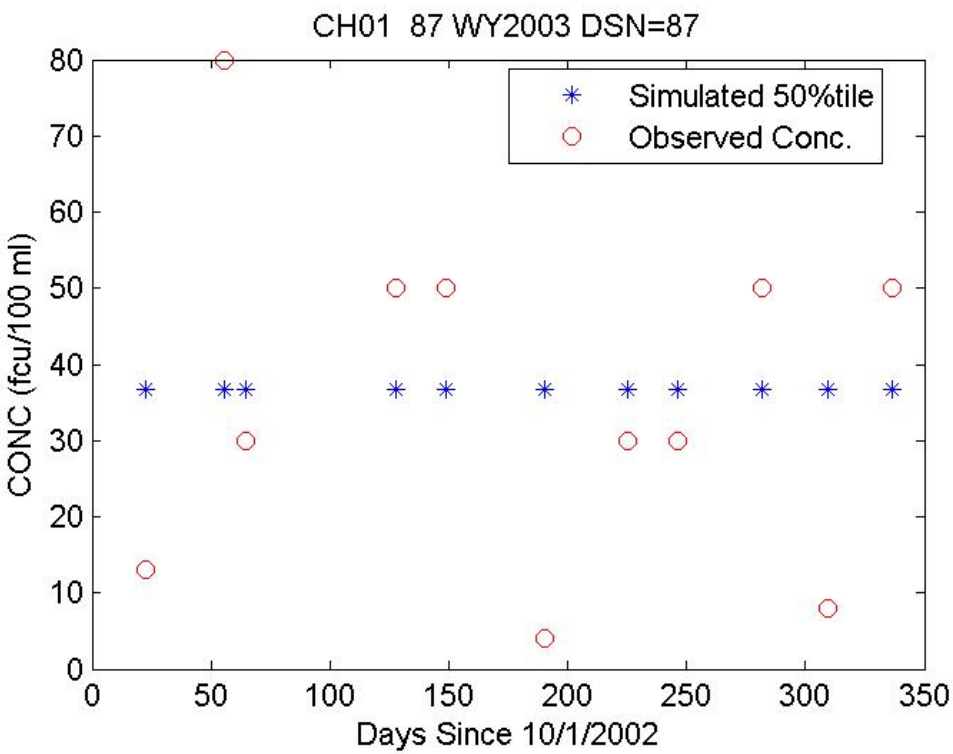


Comparison of observed load (circles) and simulated load (line)

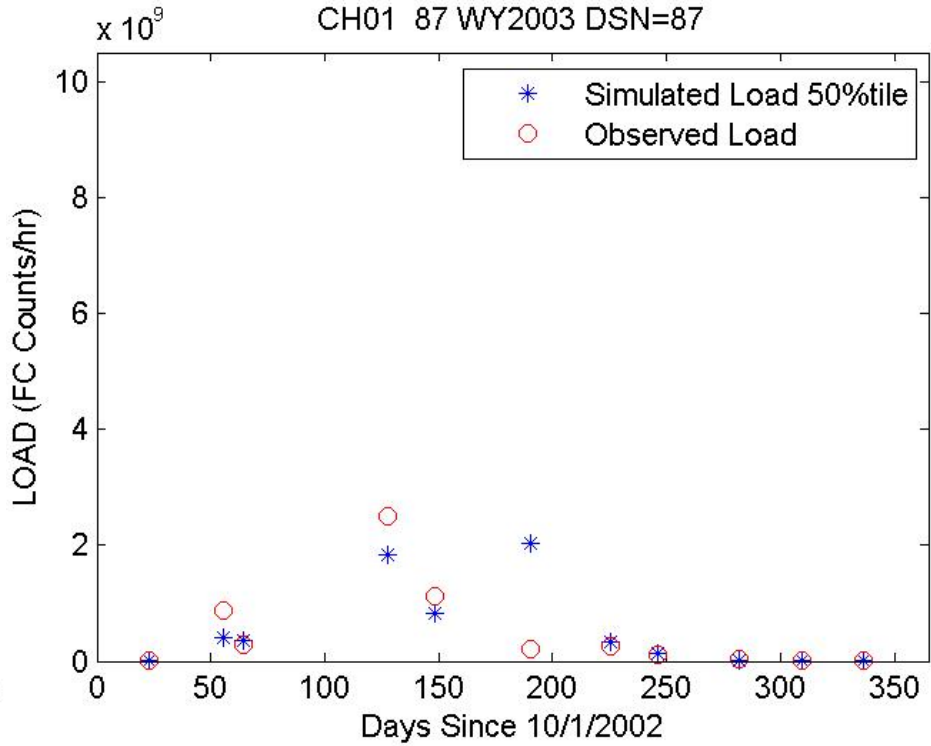
Observed Load = Model Flow x Obs FC

Simulated Load = Model Flow x Pred FC (Geomean)

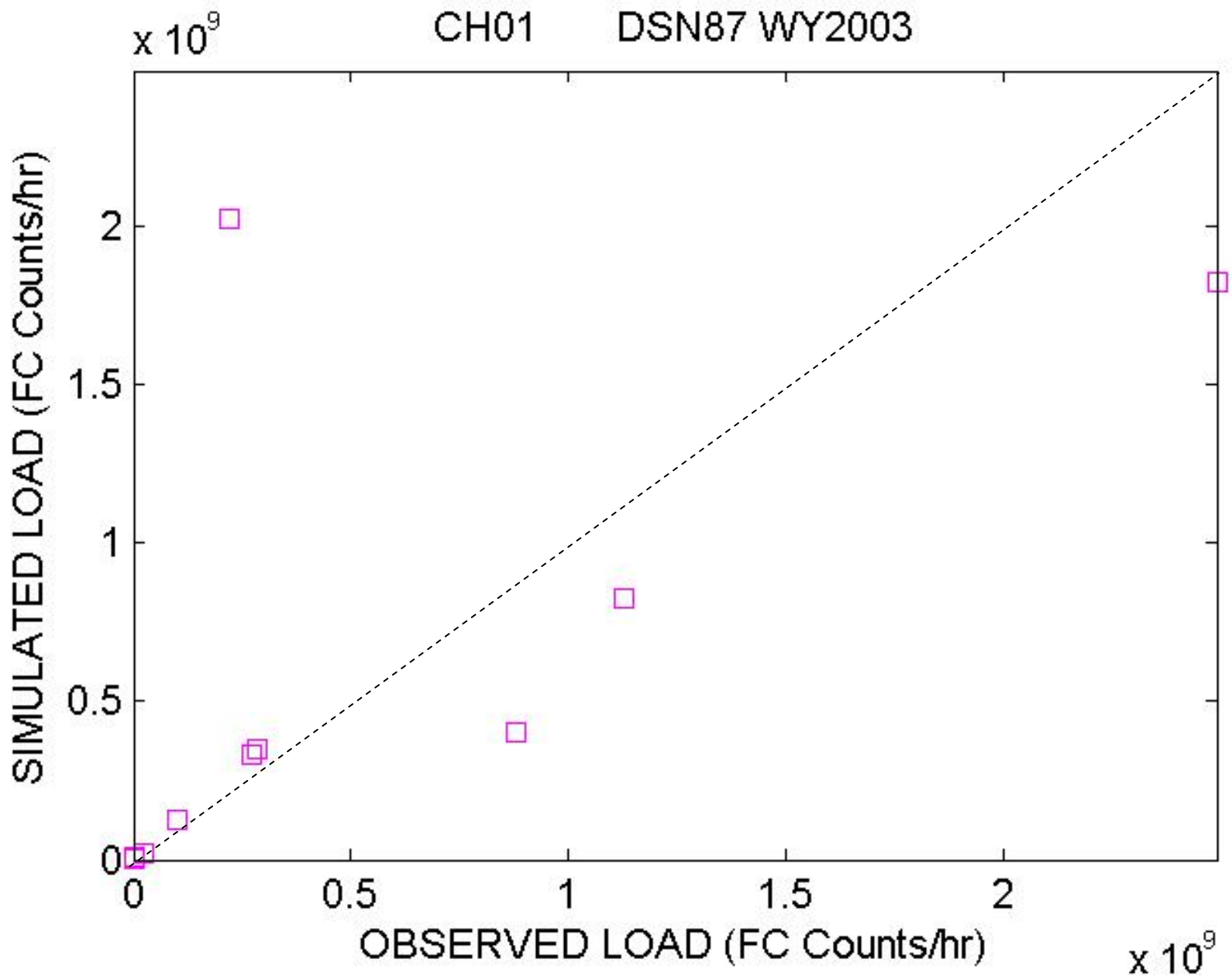
Chico Creek



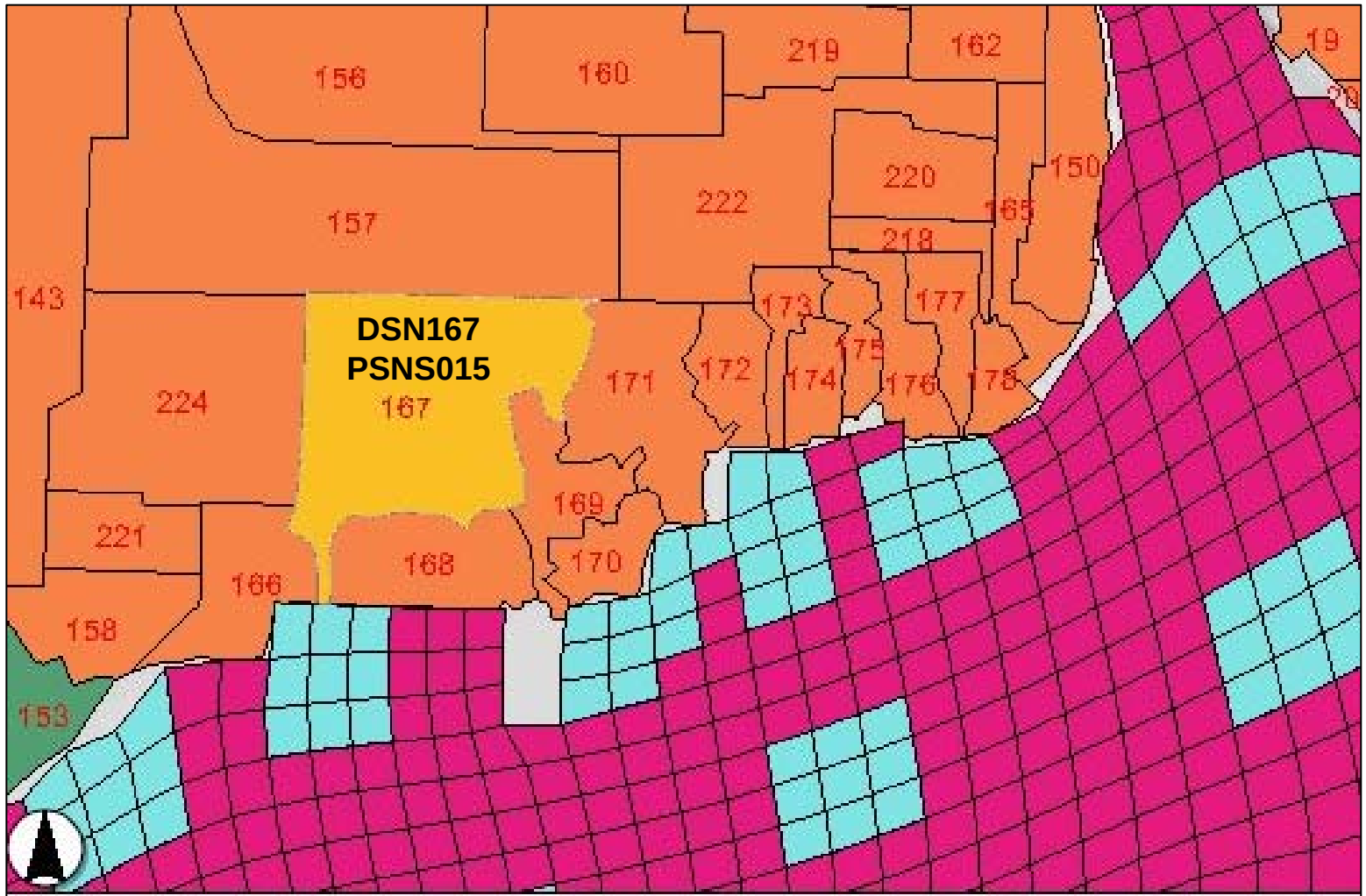
Observed Concn. (circles)
Predicted Concn. (stars)



Observed Load (circles)
Simulated Load (stars)


CH01 DSN87 WY2003
x 10^9
SIMULATED LOAD (FC Counts/hr)
OBSERVED LOAD (FC Counts/hr)
x 10^9
0
0.5
1
1.5
2

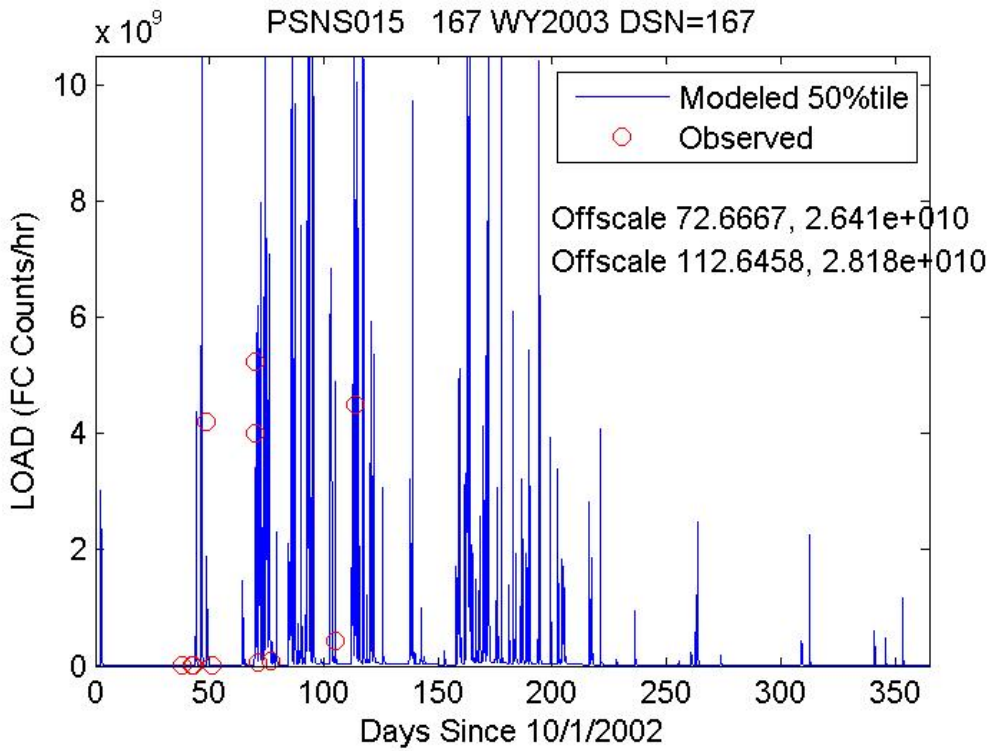
PSNS015 (Stormwater Example)

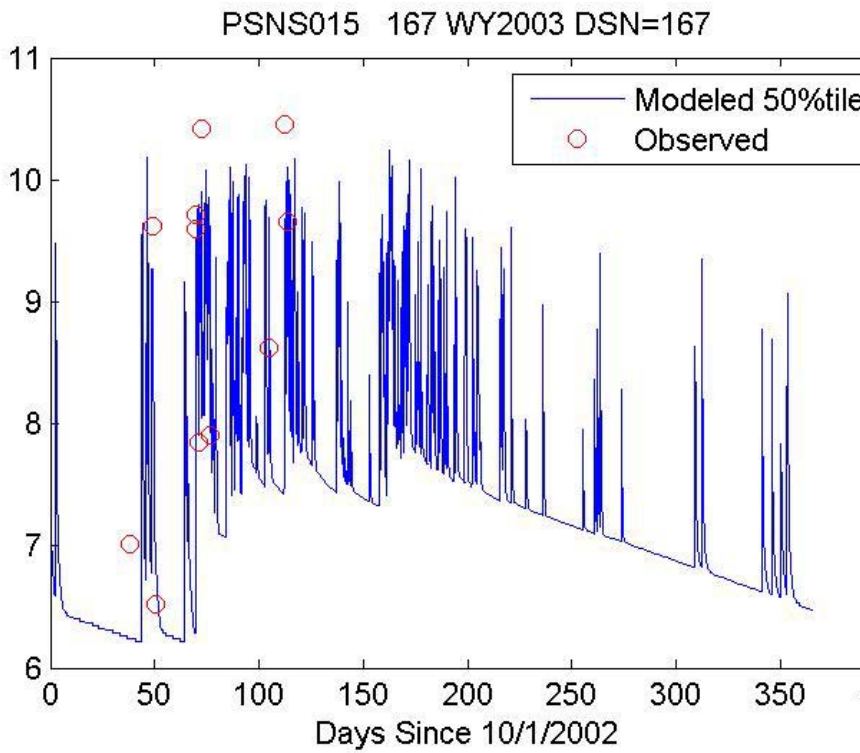


Drainage Basins

DSN	Type	Fecal Coliform WY2003 50%	Hydrograph
167	stormwater	947	Click for plot

PSNS015 Simulated and Observed



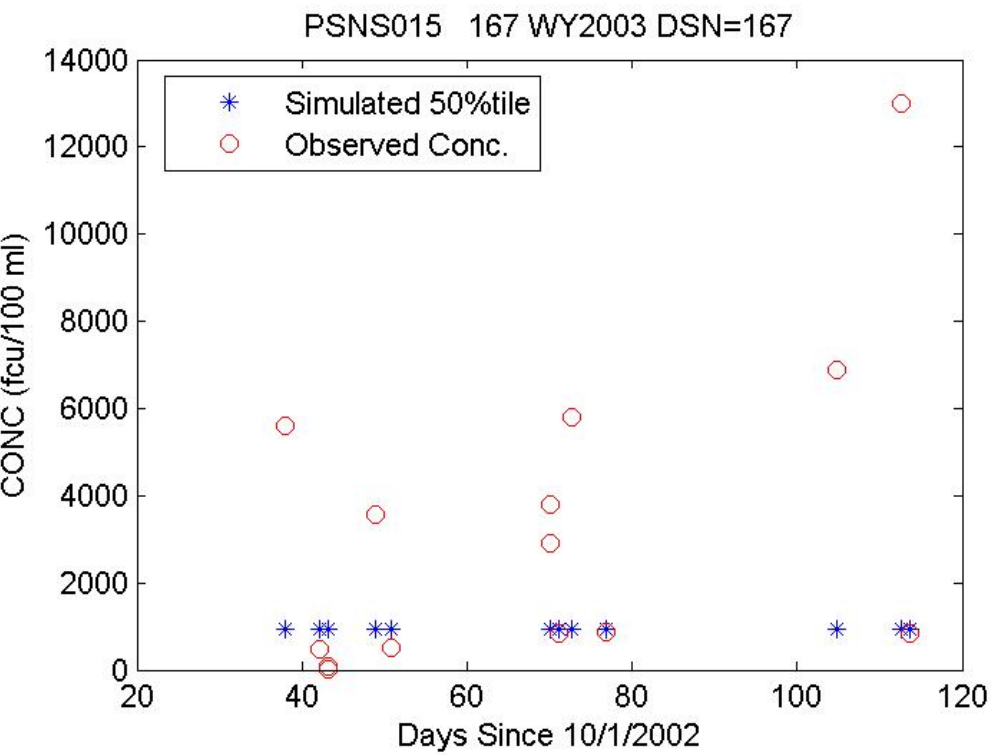


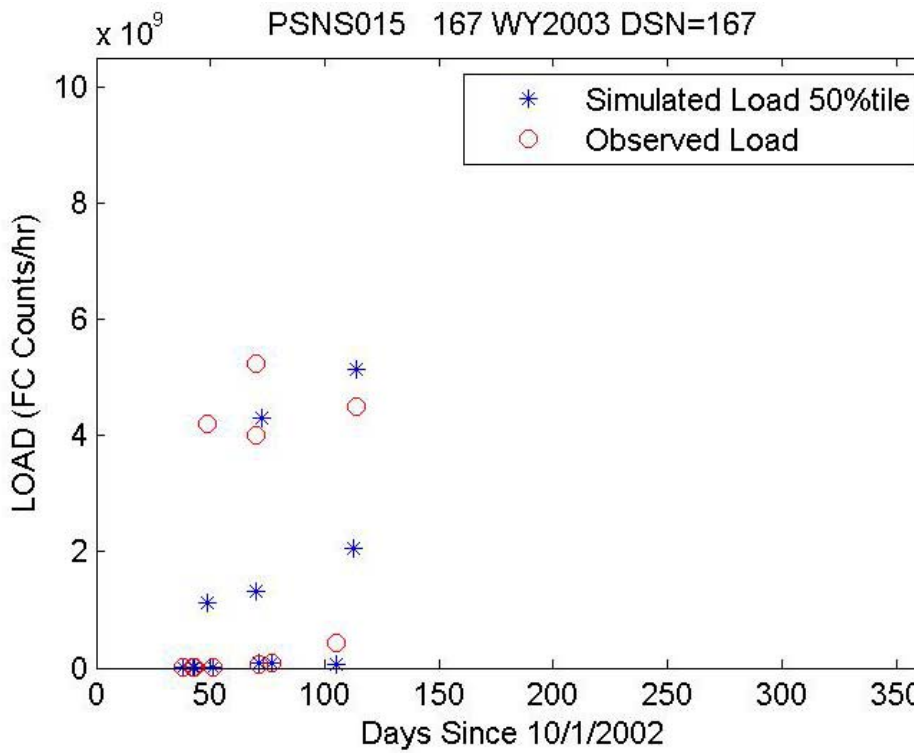
Comparison of observed load (circles) and simulated load (line)

Observed Load = Model Flow x Obs FC

Simulated Load = Model Flow x Pred FC (Geomean)

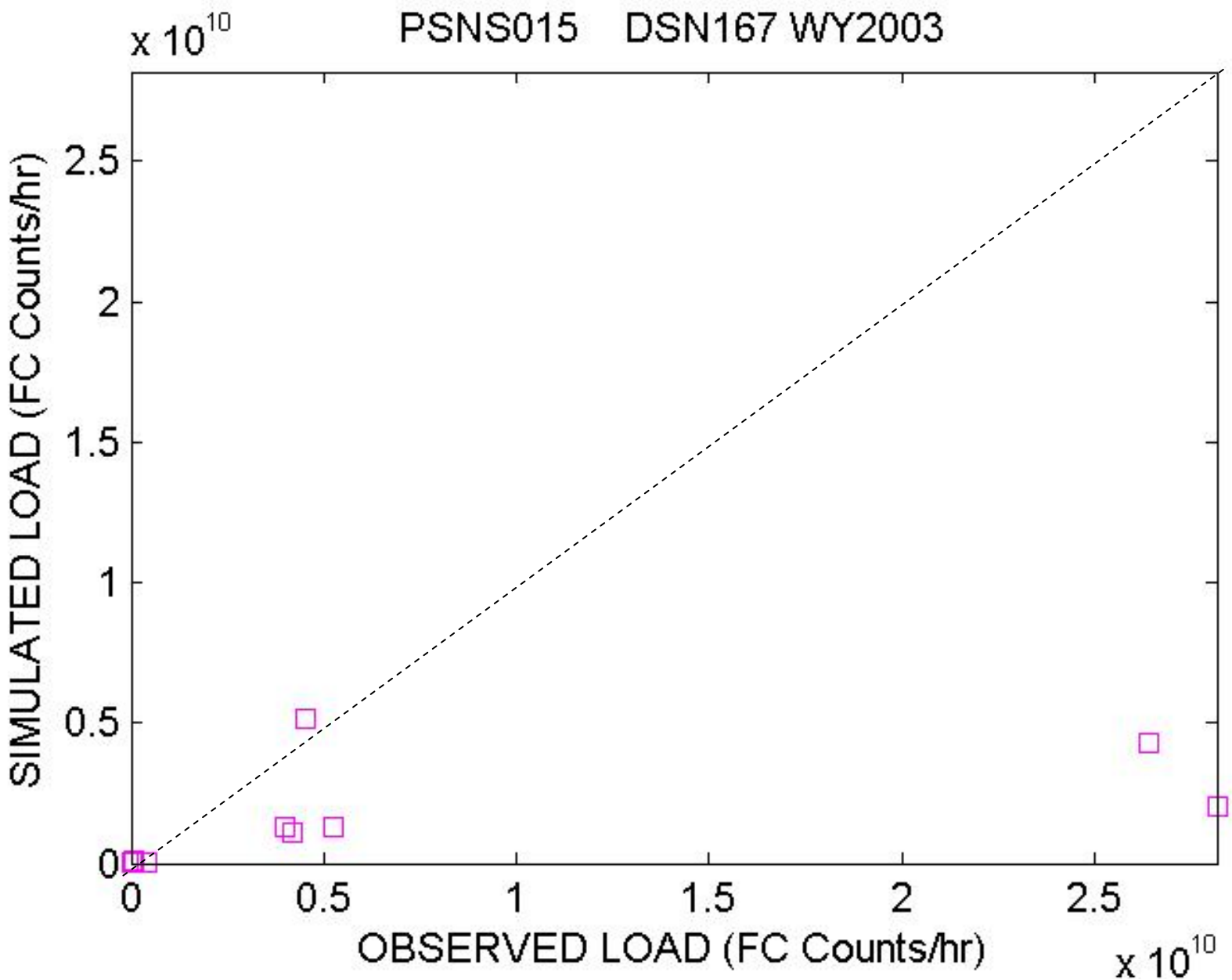
PSNS015





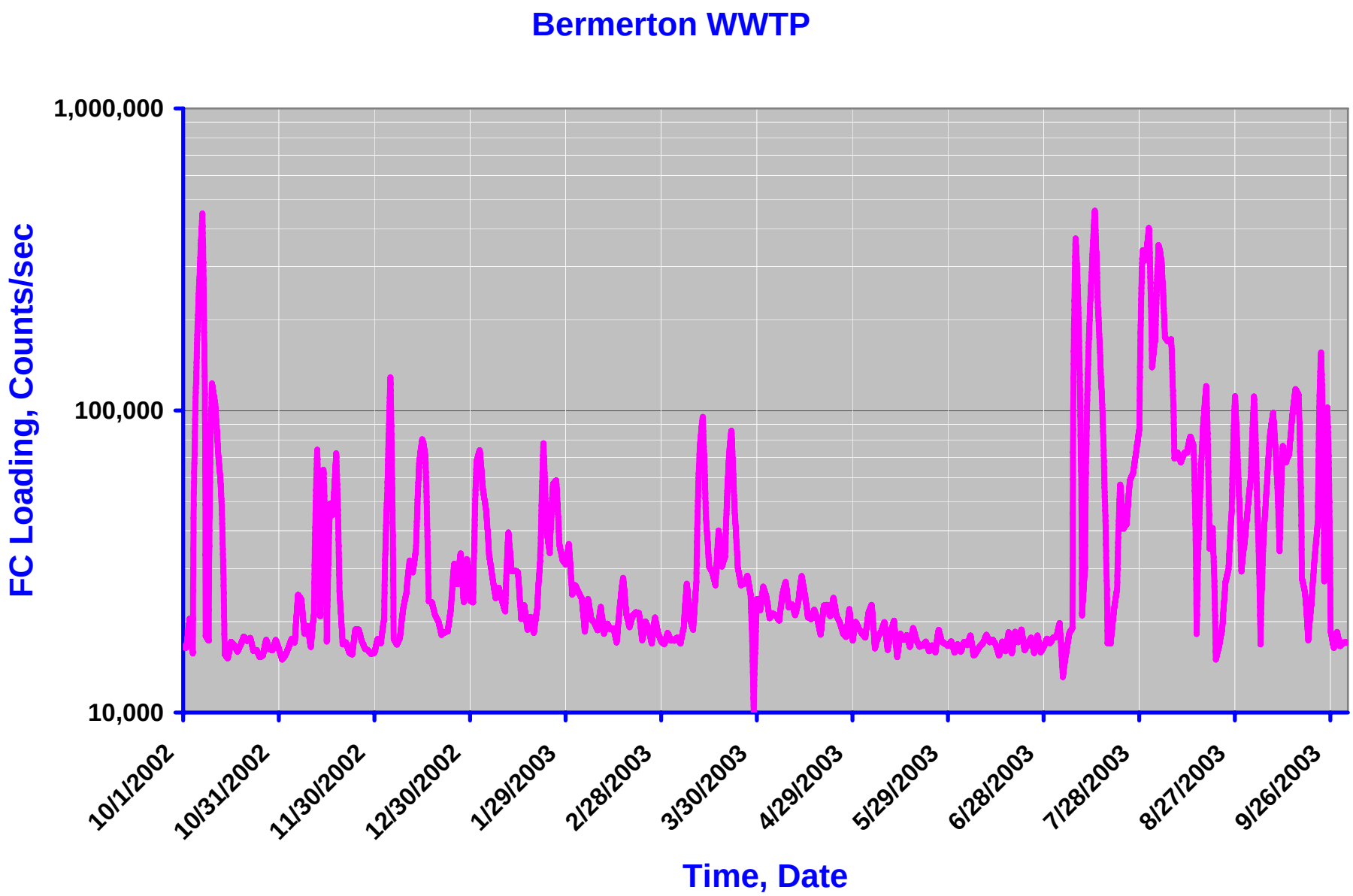
Observed Concn. (circles)
Predicted Concn. (stars)

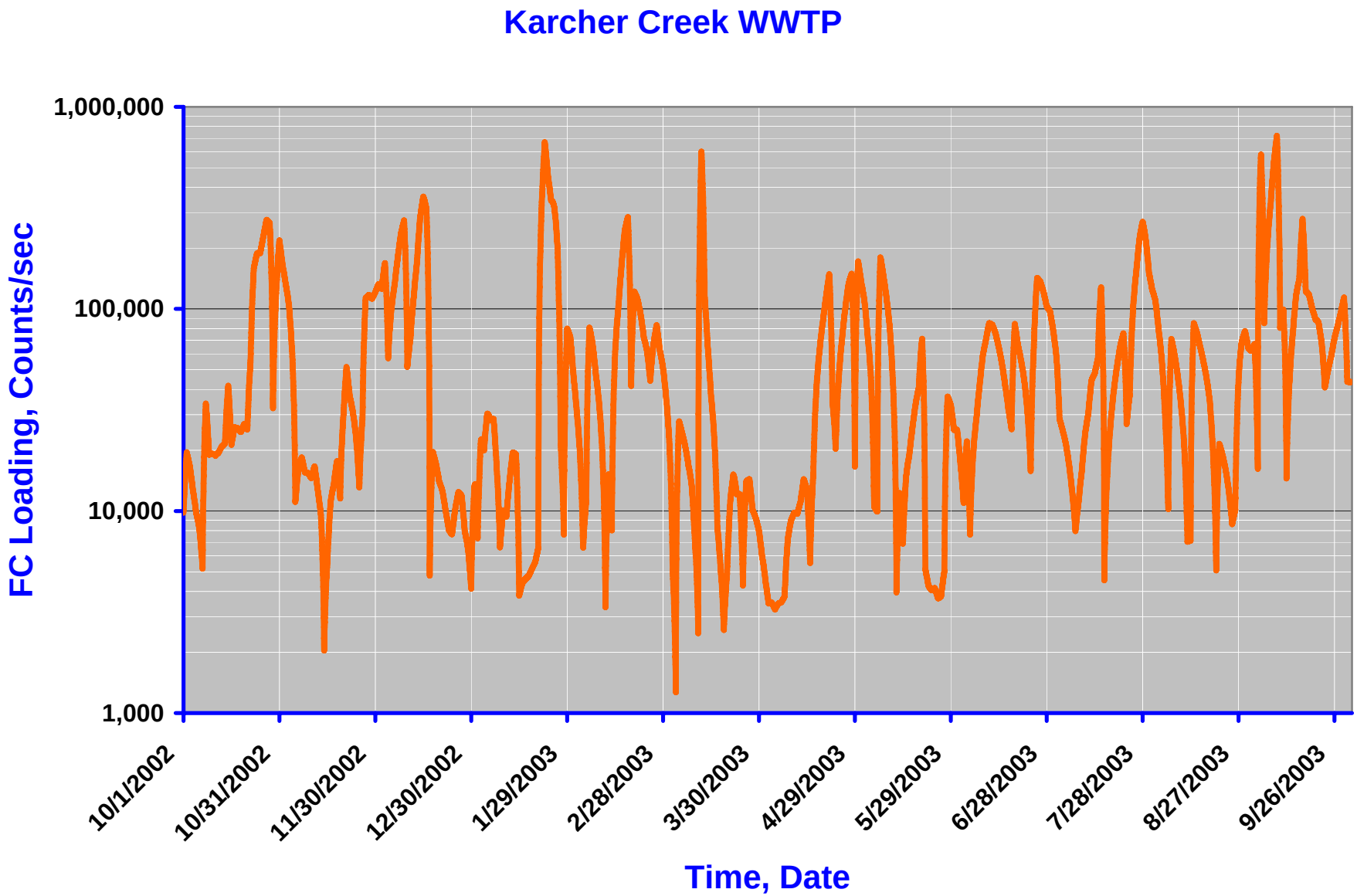
Observed Load (circles)
Simulated Load (stars)

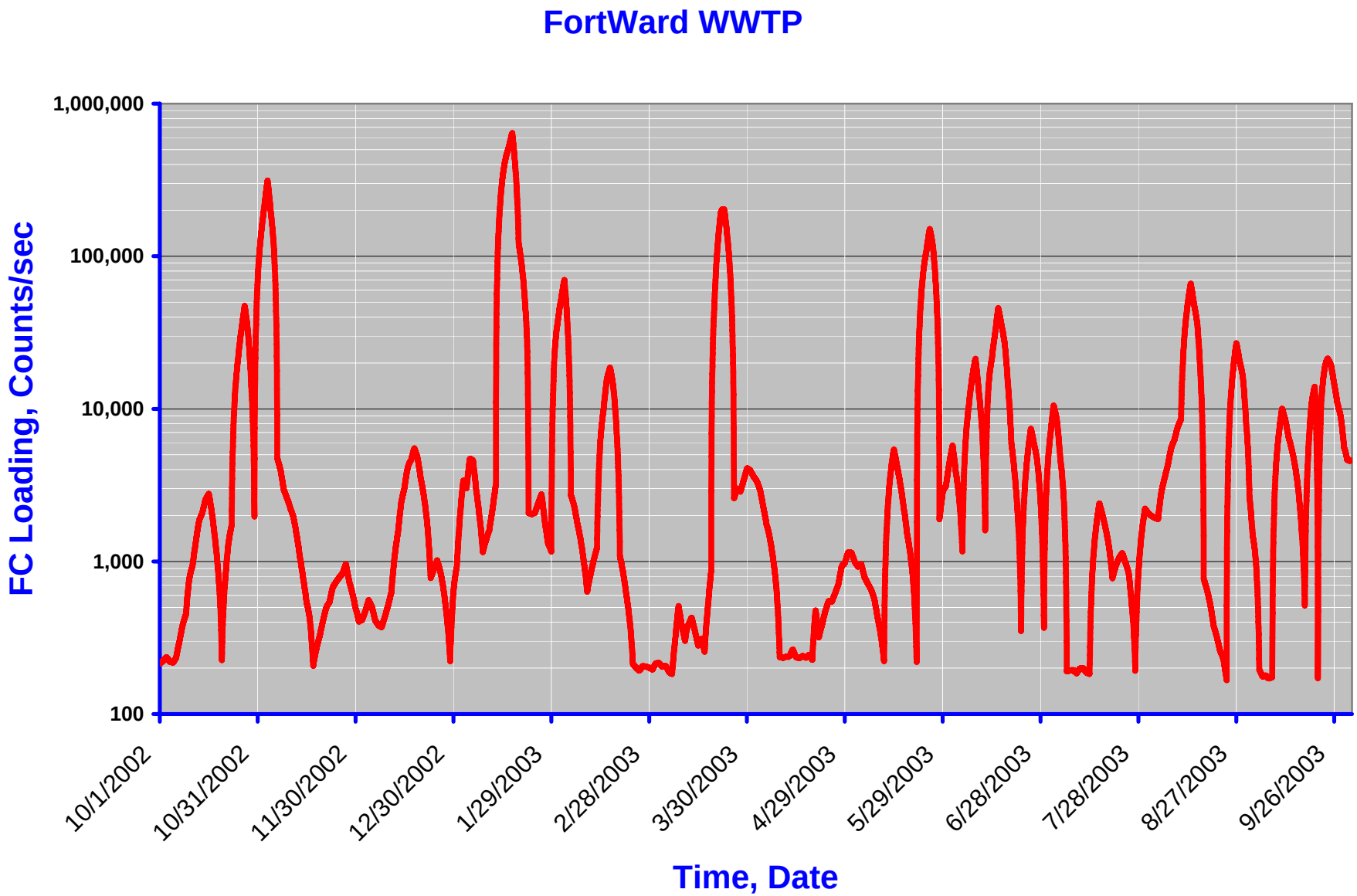

PSNS015 DSN167 WY2003
x 10^10
SIMULATED LOAD (FC Counts/hr)
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
OBSERVED LOAD (FC Counts/hr)
x 10^10

Loading from WWTPs

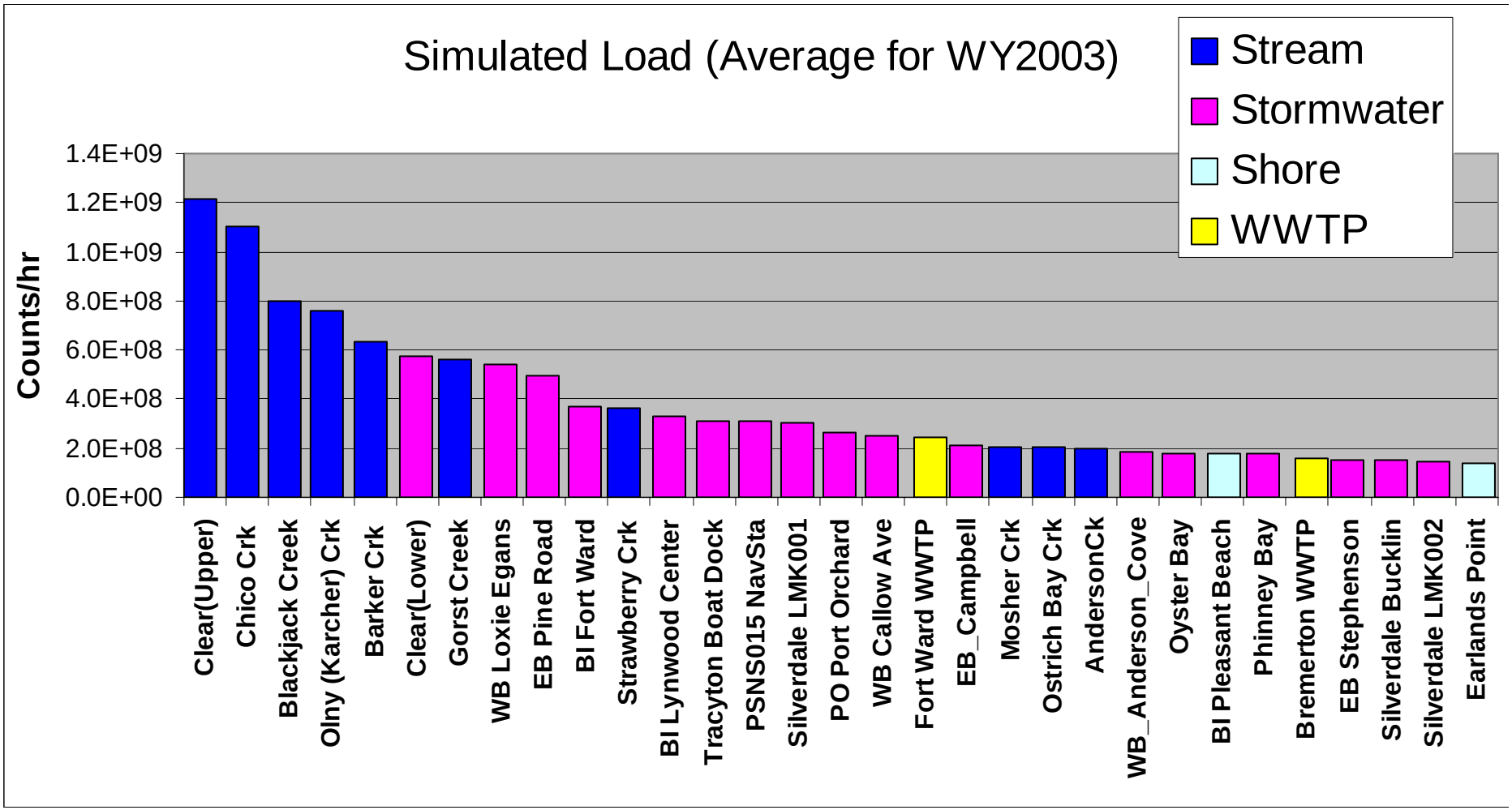
- DMR data used to develop empirical loading for WY2003
  - BREM WWTP
  - BREM ETF (no discharge in WY2003)
  - Karcher Cr. WWTP
  - Fort Ward WWTP
- Observed flow and measured FC levels used to simulate 2004 storm events
  - BREM WWTP
  - BREM ETF (no discharge during events simulated)
  - Karcher Cr. WWTP
  - Fort Ward WWTP (not included)

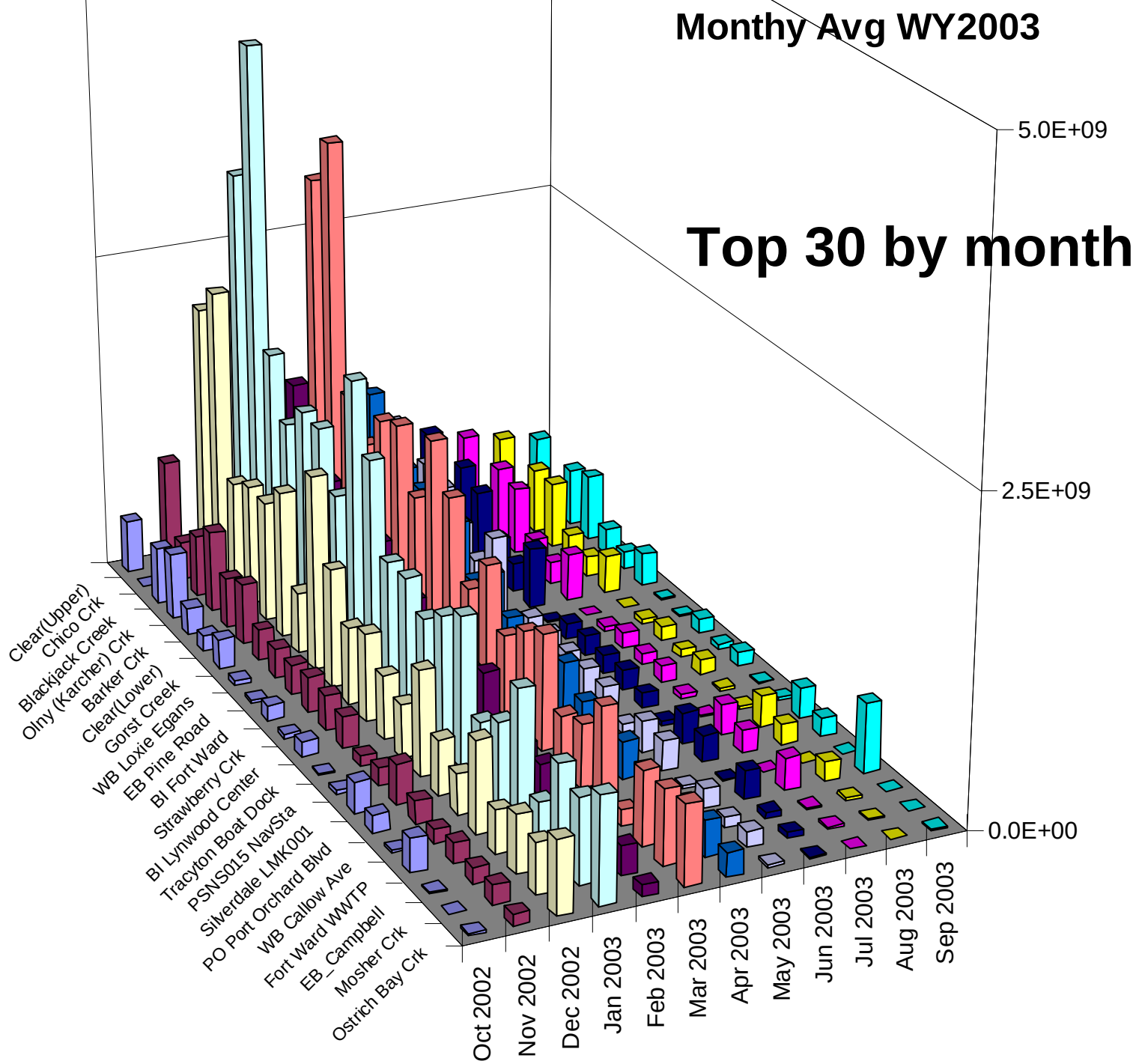

Bermerton WWTP
1,000,000
100,000
10,000
FC Loading, Counts/sec
10/1/2002
10/31/2002
11/30/2002
12/30/2002
1/29/2003
2/28/2003
3/30/2003
4/29/2003
5/29/2003
6/28/2003
7/28/2003
8/27/2003
9/26/2003
Time, Date

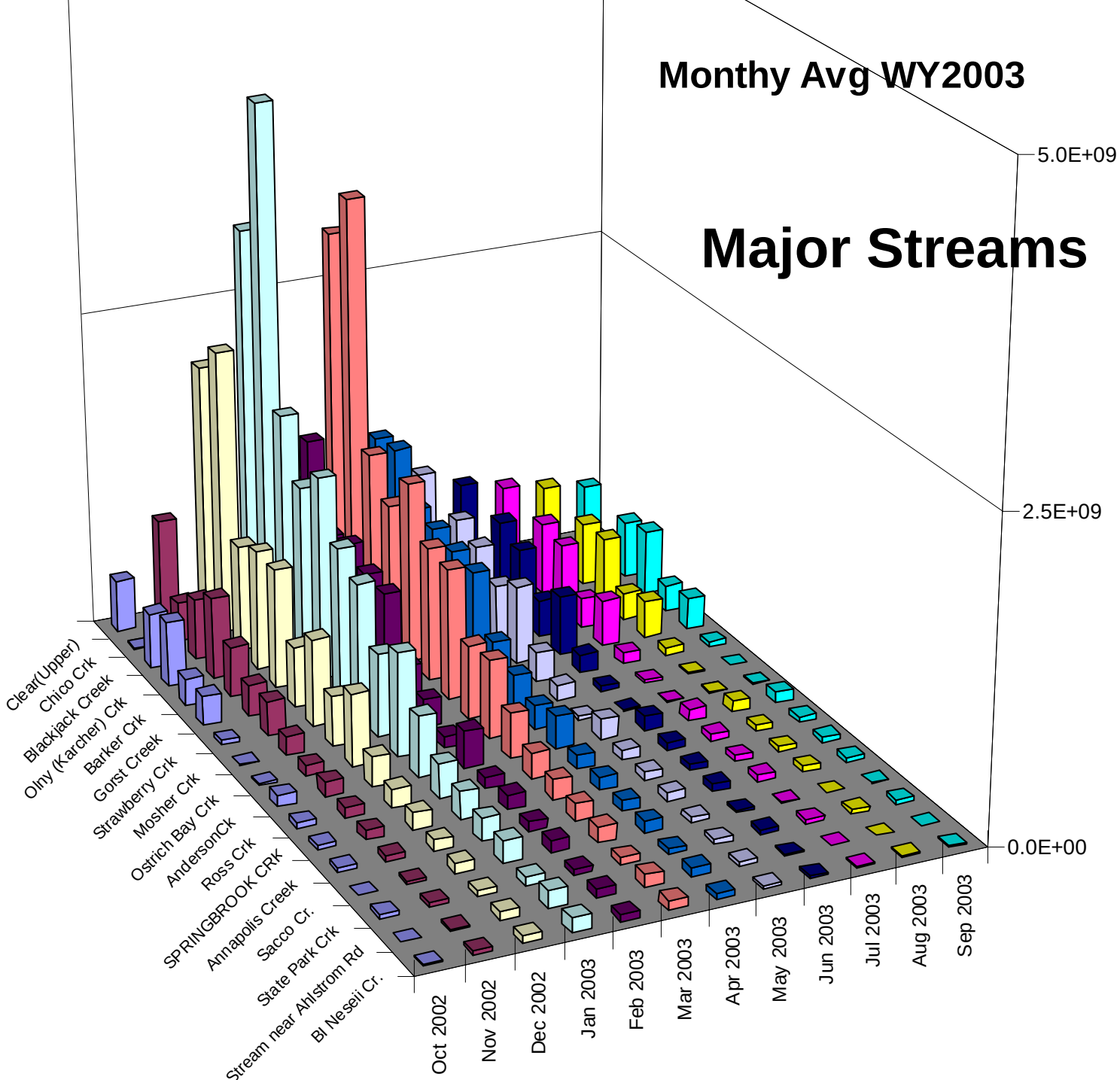

Karcher Creek WWTP
1,000,000
100,000
10,000
1,000
FC Loading, Counts/sec
10/1/2002
10/31/2002
11/30/2002
12/30/2002
1/29/2003
2/28/2003
3/30/2003
4/29/2003
5/29/2003
6/28/2003
7/28/2003
8/27/2003
9/26/2003
Time, Date

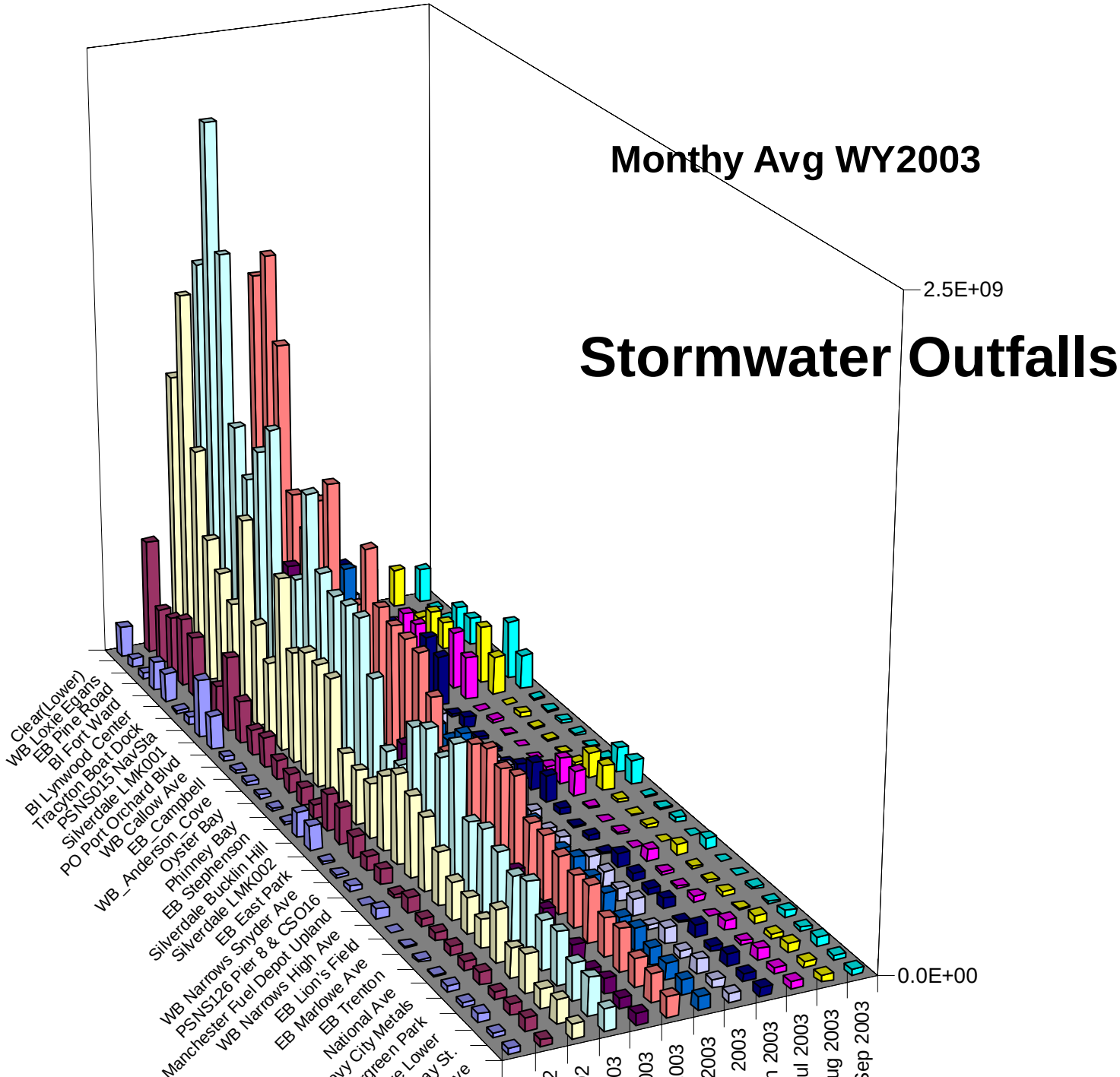

FortWard WWTP
FC Loading, Counts/sec
1,000,000
100,000
10,000
1,000
100
10/1/2002
10/31/2002
11/30/2002
12/30/2002
1/29/2003
2/28/2003
3/30/2003
4/29/2003
5/29/2003
6/28/2003
7/28/2003
8/27/2003
9/26/2003
Time, Date

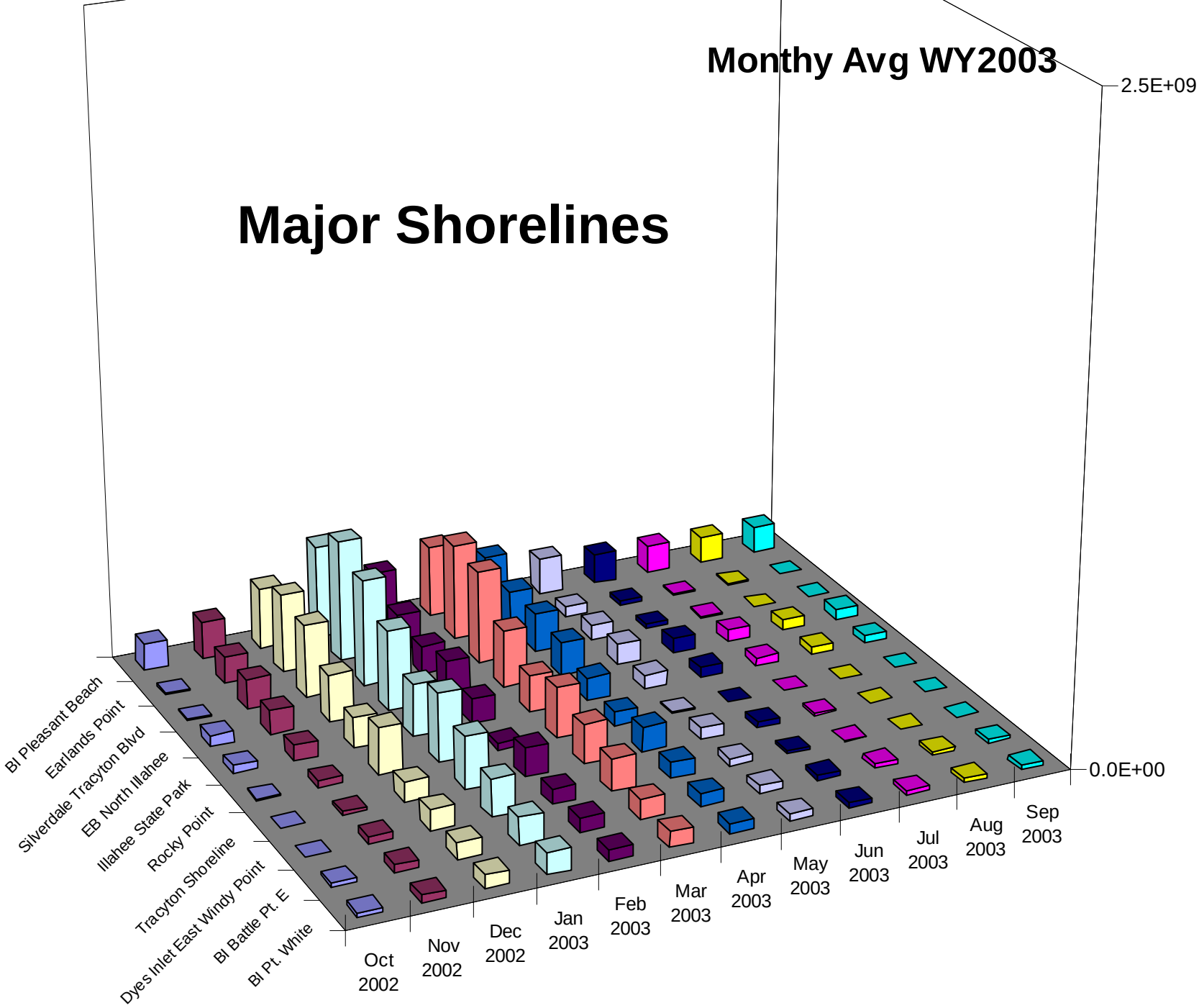
Top Thirty Loads from Watershed

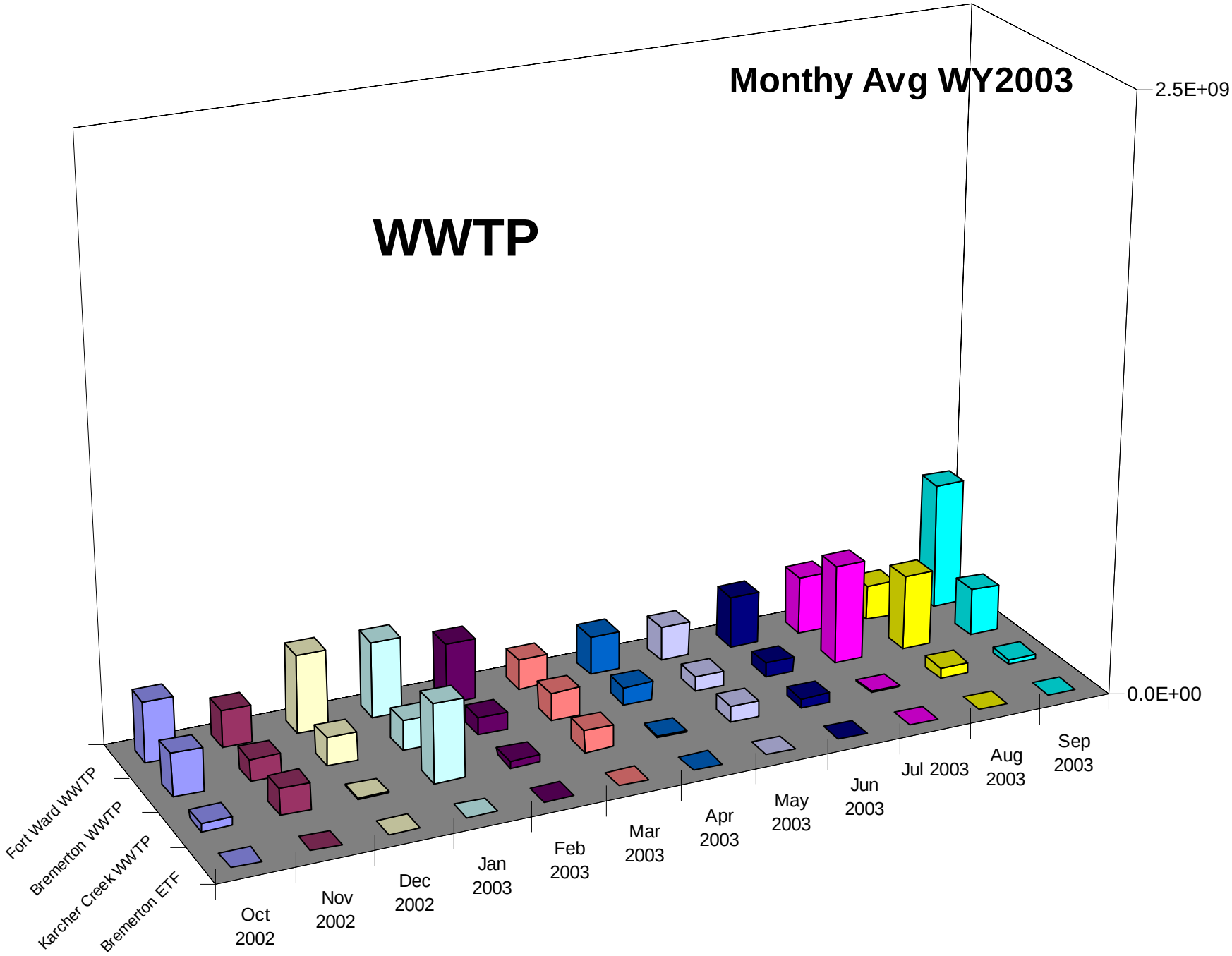



Monthy Avg WY2003
Top 30 by month
5.0E+09
2.5E+09
0.0E+00
Clear(Upper)
Chico Crk
Blackjack Creek
Olny (Karcher) Crk
Barker Crk
Clear(Lower)
Gorst Creek
WB Loxie Egans
EB Pine Road
BI Fort Ward
Strawberry Crk
BI Lynwood Center
Tracyton Boat Dock
PSNS015 NavSta
Silverdale LMK001
PO Port Orchard Blvd
WB Callow Ave
Fort Ward WWTP
EB_Campbell
Mosher Crk
Ostrich Bay Crk
Oct 2002
Nov 2002
Dec 2002
Jan 2003
Feb 2003
Mar 2003
Apr 2003
May 2003
Jun 2003
Jul 2003
Aug 2003
Sep 2003

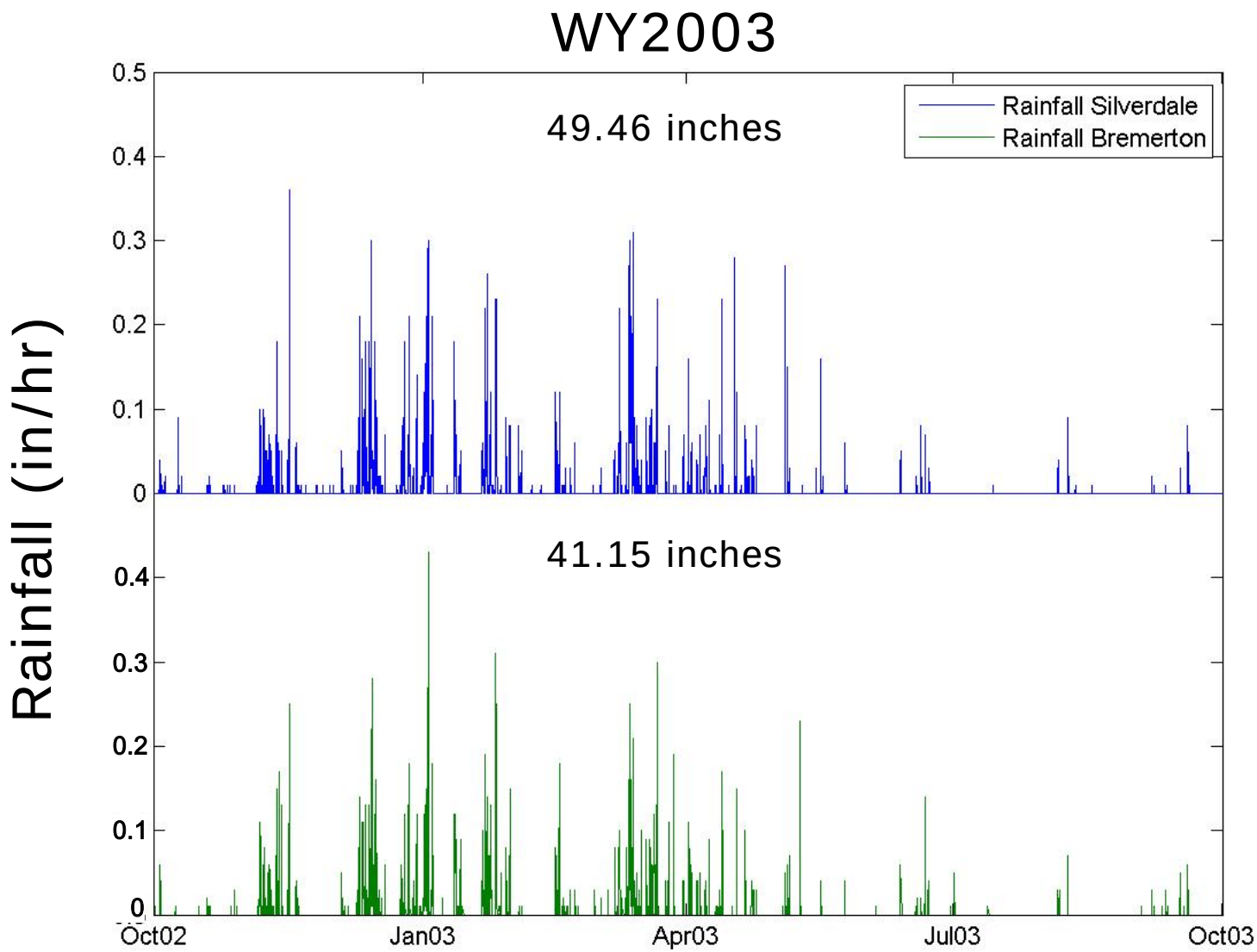

Monthy Avg WY2003
Major Streams
5.0E+09
2.5E+09
0.0E+00
Clear(Upper)
Chico Crk
Blackjack Creek
Olny (Karcher) Crk
Barker Crk
Gorst Creek
Strawberry Crk
Mosher Crk
Ostrich Bay Crk
AndersonCk
Ross Crk
SPRINGBROOK CRk
Annapolis Creek
Sacco Cr.
State Park Crk
Stream near Ahlstrom Rd
Bl Neseii Cr.
Oct 2002
Nov 2002
Dec 2002
Jan 2003
Feb 2003
Mar 2003
Apr 2003
May 2003
Jun 2003
Jul 2003
Aug 2003
Sep 2003


Monthy Avg WY2003
Stormwater Outfalls
2.5E+09
0.0E+00
Clear(Lower)
WB Loxie Egans
EB Pine Road
BI Fort Ward
BI Lynwood Center
Tracyton Boat Dock
PSNS015 NavSta
Silverdale LMK001
PO Port Orchard Blvd
WB Callow Ave
EB_Campbell
WB_Anderson_Cove
Oyster Bay
Phinney Bay
EB Stephenson
Silverdale Bucklin Hill
Silverdale LMK002
EB East Park
WB Narrows Snyder Ave
PSNS126 Pier 8 & CSO16
Manchester Fuel Depot Upland
WB Narrows High Ave
EB Lion's Field
EB Marlowe Ave
EB Trenton
National Ave
Navy City Metals
Green Park
Lower
St.
Sep 2003


Monthy Avg WY2003
Major Shorelines
2.5E+09
0.0E+00
Bl Pleasant Beach
Earlands Point
Silverdale Tracyton Blvd
EB North Illahee
Illahee State Park
Rocky Point
Tracyton Shoreline
Dyes Inlet East Windy Point
Bl Battle Pt. E
Bl Pt. White
Oct 2002
Nov 2002
Dec 2002
Jan 2003
Feb 2003
Mar 2003
Apr 2003
May 2003
Jun 2003
Jul 2003
Aug 2003
Sep 2003


Monthy Avg WY2003
WWTP
2.5E+09
0.0E+00
Fort Ward WWTP
Bremerton WWTP
Karcher Creek WWTP
Bremerton ETF
Oct 2002
Nov 2002
Dec 2002
Jan 2003
Feb 2003
Mar 2003
Apr 2003
May 2003
Jun 2003
Jul 2003
Aug 2003
Sep 2003

Watershed Model Driven by Weather



Evaluation Criteria for Loading from Watershed

Observed Load = Model Flow x Obs FC

Simulated Load = Model Flow x Pred FC (Geomean)

Calculate

- Observed Mean, Median, Mode
- Simulated Mean, Median, Mode
- Simulated/Observed
  - Mean
  - Median
  - Mode

Evaluation Criteria			
	2	0.50	**Excellent**
	5	0.20	**Good**
	10	0.10	**Fair**
	50	0.02	**Poor**
>	50	0.02	**Very Poor**
n<7 Not Evaluated			

Outcome was the lowest of score between Mean and Median.
Did simulated average over or under predicted observed data?

Streams

				Loading in fecal coliform counts/hr														
				Observed				Simulated			Simulated/Observed							
Type	**StationID**	**DSN**	**n**	mean	median	mode		mean	median	mode	**mean**			**median**			**mode**		
Stream	CC (upper)	127	32	9.132E+09	4.868E+09	2.804E+10		1.215E+09	7.140E+08	3.809E+08	0.13	Fair	Under	0.15	Fair	Under	0.01	Poor	Under
Stream	CH01	87	11	4.916E+08	2.213E+08	1.189E+06		1.102E+09	2.840E+08	9.373E+05	2.24	**Good**	Over	1.28	**Excellent**	Over	0.79	Excellent	Under
Stream	BJ01	193	29	4.441E+09	8.337E+08	7.155E+07		7.994E+08	6.473E+08	4.039E+08	0.18	**Fair**	Under	0.78	**Excellent**	Under	5.65	Fair	Over
Stream	KA01	64	38	8.645E+09	1.712E+09	2.370E+07		7.605E+08	5.805E+08	5.157E+08	0.09	Poor	Under	0.34	**Good**	Under	21.76	Poor	Over
Stream	BA	58	48	3.826E+09	8.961E+08	7.519E+07		6.364E+08	3.558E+08	2.086E+08	0.17	**Fair**	Under	0.40	**Good**	Under	2.77	Good	Over
Stream	GC	55	41	2.993E+09	1.344E+09	9.349E+07		5.642E+08	4.590E+08	2.368E+08	0.19	**Fair**	Under	0.34	**Good**	Under	2.53	Good	Over
Stream	SC	94	46	4.075E+09	4.580E+08	1.414E+08		3.663E+08	1.790E+08	3.408E+07	0.09	Poor	Under	0.39	**Good**	Under	0.24	Good	Under
Stream	MS01	92	12	1.490E+07	8.270E+06	3.184E+05		2.076E+08	7.289E+07	3.155E+06	13.93	Poor	Over	8.81	**Fair**	Over	9.91	Fair	Over
Stream	OB01	149	11	4.170E+08	2.153E+06	3.028E+05		2.048E+08	1.448E+06	1.609E+05	0.49	**Good**	Under	0.67	**Excellent**	Under	0.53	Excellent	Under
Stream	AN01	57	12	2.357E+08	1.097E+08	1.157E+07		1.970E+08	1.267E+08	8.754E+07	0.84	**Excellent**	Same	1.16	**Excellent**	Same	7.57	Fair	Over
Stream	RS02	93	12	1.440E+08	3.138E+07	1.396E+06		1.025E+08	6.179E+07	4.010E+07	0.71	**Excellent**	Under	1.97	**Excellent**	Over	28.73	Poor	Over
Stream	BI-SBC	210	5	2.870E+08	9.095E+07	6.854E+07		8.911E+07	6.162E+07	4.026E+07	0.31	**Good**	Under	0.68	**Excellent**	Under	0.59	Excellent	Under
Stream	ANNAP	187	31	4.477E+08	5.443E+07	6.468E+06		7.553E+07	5.794E+07	3.779E+07	0.17	**Fair**	Under	1.06	**Excellent**	Same	5.84	Fair	Over
Stream	SACCO	76	32	2.736E+08	4.088E+07	3.962E+05		5.352E+07	2.479E+07	1.856E+06	0.20	**Fair**	Under	0.61	**Excellent**	Under	4.68	Good	Over
Stream	PH01	73	7	5.368E+07	1.232E+07	1.747E+06		3.059E+07	8.391E+06	4.379E+05	0.57	**Excellent**	Under	0.68	**Excellent**	Under	0.25	Good	Under
Stream	BE-LOW	81	32	3.464E+08	1.021E+07	1.376E+04		3.030E+07	1.661E+06	7.211E+04	0.09	Poor	Under	0.16	**Fair**	Under	5.24	Fair	Over
Stream	WC01	152	7	2.46E+06	1.66E+05	2.04E+04		2.92E+07	3.24E+05	6.04E+04	11.88	Poor	Over	1.95	**Excellent**	Over	2.96	Good	Over
Stream	IC01	74	8	3.951E+07	9.272E+06	1.703E+06		2.751E+07	1.689E+07	8.156E+06	0.70	**Excellent**	Under	1.82	**Excellent**	Over	4.79	Good	Over
Stream	DE01	6	34	2.655E+08	2.037E+07	8.125E+06		2.751E+07	1.075E+07	5.664E+05	0.10	**Fair**	Under	0.53	**Excellent**	Under	0.07	Poor	Under

Stormwater

				Loading in fecal coliform counts/hr														
				Observed				Simulated			Simulated/Observed							
Type	**StationID**	**DSN**	**n**	mean	median	mode		mean	median	mode	**mean**			**median**			**mode**		
SW	CC01 (Combined)	136	12	2.350E+09	5.264E+08	6.748E+07		1.127E+09	9.547E+08	4.982E+08	0.48	**Good**	Under	1.81	**Excellent**	Over			
SW	LMK164	154	16	4.347E+09	8.597E+07	3.119E+06		5.427E+08	5.213E+06	6.758E+05	0.12	**Fair**	Under	0.06	Poor	Under	0.22	Good	Under
SW	B-ST01	7	15	3.541E+09	3.653E+08	1.537E+06		4.928E+08	1.361E+08	4.151E+06	0.14	**Fair**	Under	0.37	**Good**	Under	2.70	Good	Over
SW	BI-FWSW	45	4	6.615E+09	3.400E+09	3.725E+08		3.714E+08	2.249E+08	1.099E+08	0.06		Under	0.07		Under	0.30	Good	Under
SW	B-ST28	158	10	4.984E+09	1.613E+08	4.893E+05		3.611E+08	2.413E+06	2.896E+05	0.07	Poor	Under	0.01	Poor	Under	0.59	Excellent	Under
SW	BI-LCSW	84	4	5.563E+08	2.357E+08	3.363E+07		3.273E+08	2.111E+08	1.155E+08	0.59		Under	0.90		Same	3.43	Good	Over
SW	LMK055	195	21	2.391E+08	5.562E+07	2.324E+06		3.126E+08	1.327E+08	8.495E+06	1.31	**Excellent**	Over	2.39	**Good**	Over	3.66	Good	Over
SW	PSNS015	167	14	5.223E+09	2.520E+08	5.372E+04		3.098E+08	1.733E+07	1.738E+06	0.06	Poor	Under	0.07	Poor	Under	32.35	Poor	Over
SW	LMK001	217	20	2.083E+08	1.238E+08	5.709E+08		3.015E+08	2.357E+08	2.351E+08	1.45	**Excellent**	Over	1.90	**Excellent**	Over	0.41	Good	Under
SW	PO-POBLVD	183	22	1.709E+09	1.532E+08	2.781E+07		2.674E+08	2.026E+08	1.251E+08	0.16	**Fair**	Under	1.32	**Excellent**	Over	4.50	Good	Over
SW	B-ST04	11	11	3.219E+09	2.016E+08	3.681E+07		2.125E+08	4.170E+07	1.738E+06	0.07	Poor	Under	0.21	**Good**	Under	0.05	Poor	Under
SW	B-ST26	151	16	9.319E+08	1.698E+07	2.447E+04		1.800E+08	1.158E+06	1.931E+05	0.19	**Fair**	Under	0.07	Poor	Under	7.89	Fair	Over
SW	LMK020	143	20	2.095E+09	5.209E+07	7.849E+04		1.754E+08	1.545E+06	1.931E+05	0.08	Poor	Under	0.03	Poor	Under	2.46	Good	Over
SW	B-ST03	9	19	2.339E+08	6.541E+07	1.869E+06		1.548E+08	5.952E+07	3.379E+06	0.66	**Excellent**	Under	0.91	**Excellent**	Same	1.81	Excellent	Over
SW	LMK026	104	19	1.399E+08	5.833E+07	2.282E+08		1.497E+08	1.100E+08	9.815E+07	1.07	**Excellent**	Same	1.89	**Excellent**	Over	0.43	Good	Under
SW	LMK002	216	21	1.268E+08	3.254E+07	2.410E+06		1.461E+08	1.061E+08	9.692E+07	1.15	**Excellent**	Same	3.26	**Good**	Over	40.22	Poor	Over
SW	PSNS126	177	13	1.782E+10	5.026E+08	6.422E+03		1.284E+08	9.750E+06	5.792E+06	0.01	Very Poor	Under	0.02	Poor	Under	901.90	Very Poor	Over
SW	B-ST12	16	19	1.410E+08	9.379E+05	2.549E+04		8.296E+07	4.759E+07	8.592E+06	0.59	**Excellent**	Under	50.75	Poor	Over	337.13	Very Poor	Over
SW	LMK122	215	20	2.614E+08	1.345E+07	2.356E+06		7.652E+07	5.218E+07	2.559E+07	0.29	**Good**	Under	3.88	**Good**	Over	10.86	Poor	Over
SW	B-ST27	162	10	5.585E+08	1.579E+08	2.658E+08		6.563E+07	1.583E+07	9.750E+06	0.12	**Fair**	Under	0.10	**Fair**	Under	0.04	Poor	Under
SW	LMK060	199	21	4.457E+08	7.123E+07	2.608E+09		6.178E+07	2.593E+07	1.664E+06	0.14	**Fair**	Under	0.36	**Good**	Under	0.00	Very Poor	Under
SW	PO-BAYST	32	19	7.267E+08	7.785E+07	3.083E+05		5.401E+07	2.761E+07	1.863E+07	0.07	Poor	Under	0.35	**Good**	Under	60.44	Poor	Over
SW	PO-BETHEL	202	11	3.481E+07	4.727E+06	1.815E+05		3.491E+07	2.259E+07	1.535E+07	1.00	**Excellent**	Same	4.78	**Good**	Over	84.59	Poor	Over
SW	PO-WILKENS	31	20	4.824E+07	1.319E+07	1.289E+06		3.189E+07	2.669E+07	1.765E+07	0.66	**Excellent**	Under	2.02	**Good**	Over	13.70	Poor	Over

Streams

DSN	Score	
127	Fair	
87	Good	
193	Fair	
64	Poor	↓
58	Fair	
55	Fair	
94	Poor	↓
92	Poor	↑
149	Good	
57	Excellent	
93	Excellent	
210	Good	
187	Fair	
76	Fair	
73	Excellent	
81	Poor	↓
152	Poor	↓
74	Excellent	
6	Fair	

Stormwater

DSN	Score	
136	Good	
154	Poor	↓
7	Fair	
45		
158	Very Poor	↓
84		
195	Good	
167	Poor	↓
217	Excellent	
183	Fair	
11	Poor	↓
151	Poor	↓
143	Poor	↓
9	Excellent	
104	Excellent	
216	Good	
177	Very Poor	↓
16	Very Poor	↓
215	Good	
162	Fair	
199	Fair	
32	Poor	↓
202	Good	
31	Good	
169	Very Poor	↓
166	Very Poor	↓
38	Good	
99	Good	
27	Poor	↓
176	Fair	
170		
174	Very Poor	↓
175	Poor	↓

CH3D-FC Simulation

Mancini Equ added to model code to simulate FC die off:

$$C_t = C_0 e^{-kt}$$

Where:

C_t = surviving concentration

C_0 = initial concentration

t = time

k = bacterial death rate

$= [0.8 + 0.006(S)]1.07^{(t-20)} + I[1-e^{-K_E H}]/(K_E H)$

S = % seawater

I = incident radiation in langleys

T = Temperature °C

K_E = light extinction coefficient

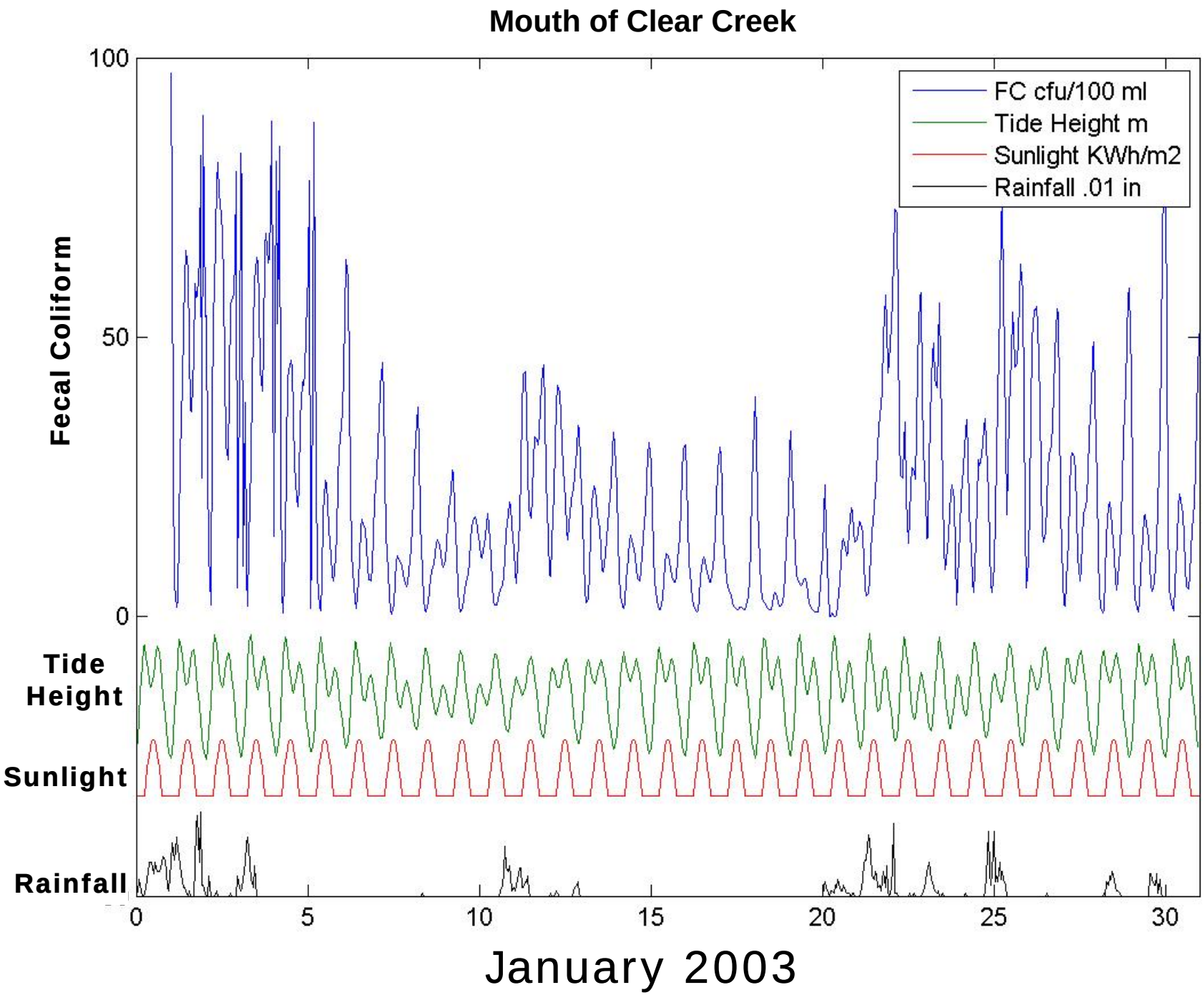
Mancini, J. L. 1978. Numerical estimates of coliform mortality rates under various conditions. J. Water Poll. Control Fed. 50:2477-2484.)

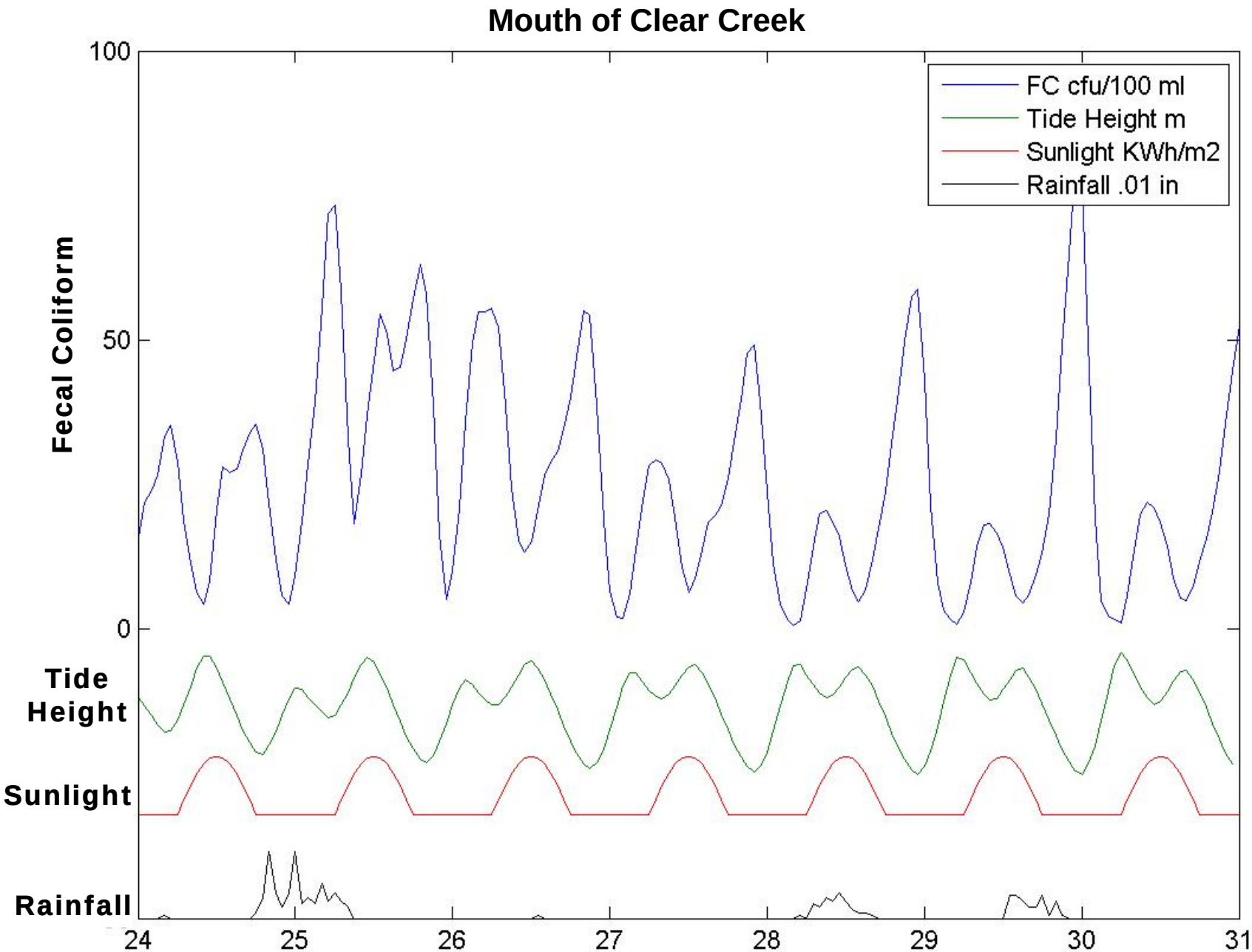
Model Limitations

- **Indirectly accounts for:**
  - **Failed septic systems**
  - **Upland Waterfowl and Wildlife**
- **Inputs do not include:**
  - **Marinas**
  - **Broken pipes**
  - **CSO Events**
  - **Nearshore waterfowl and marine mammals**
  - **Other unknown sources**

Identifying Critical Conditions

- **Spatial Considerations**
  - **Arial extent of plume**
  - **Depth of plume**
- **Temporal Considerations**
  - **Weather conditions**
  - **Tidal variations**
  - **Sunlight**
  - **Mixing processes**
- **Combination of Factors**
  - **Multiple sources**

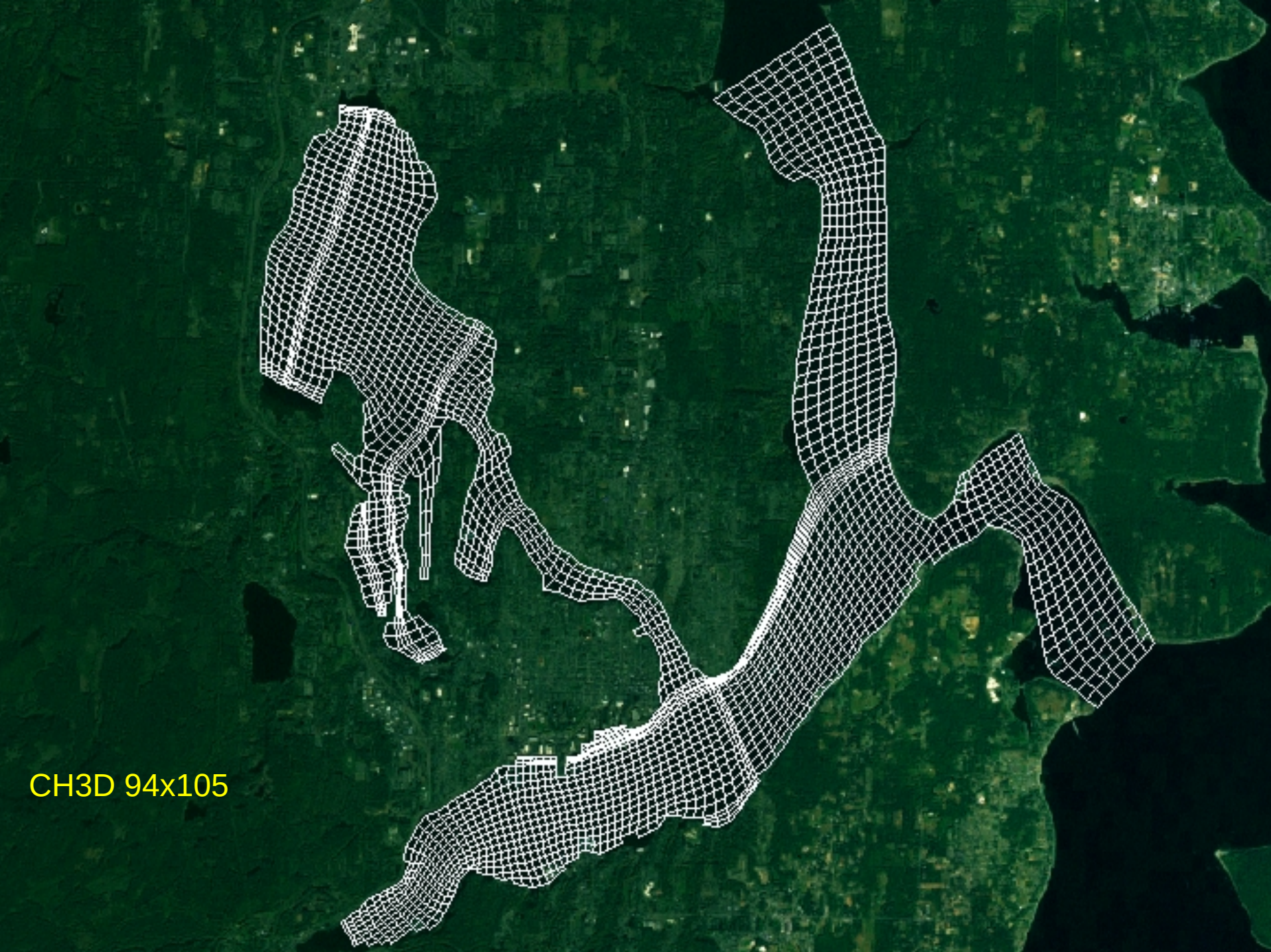

Mouth of Clear Creek
FC cfu/100 ml
Tide Height m
Sunlight KWh/m2
Rainfall .01 in
Fecal Coliform
100
50
0
Tide Height
Sunlight
Rainfall
0
5
10
15
20
25
30
January 2003



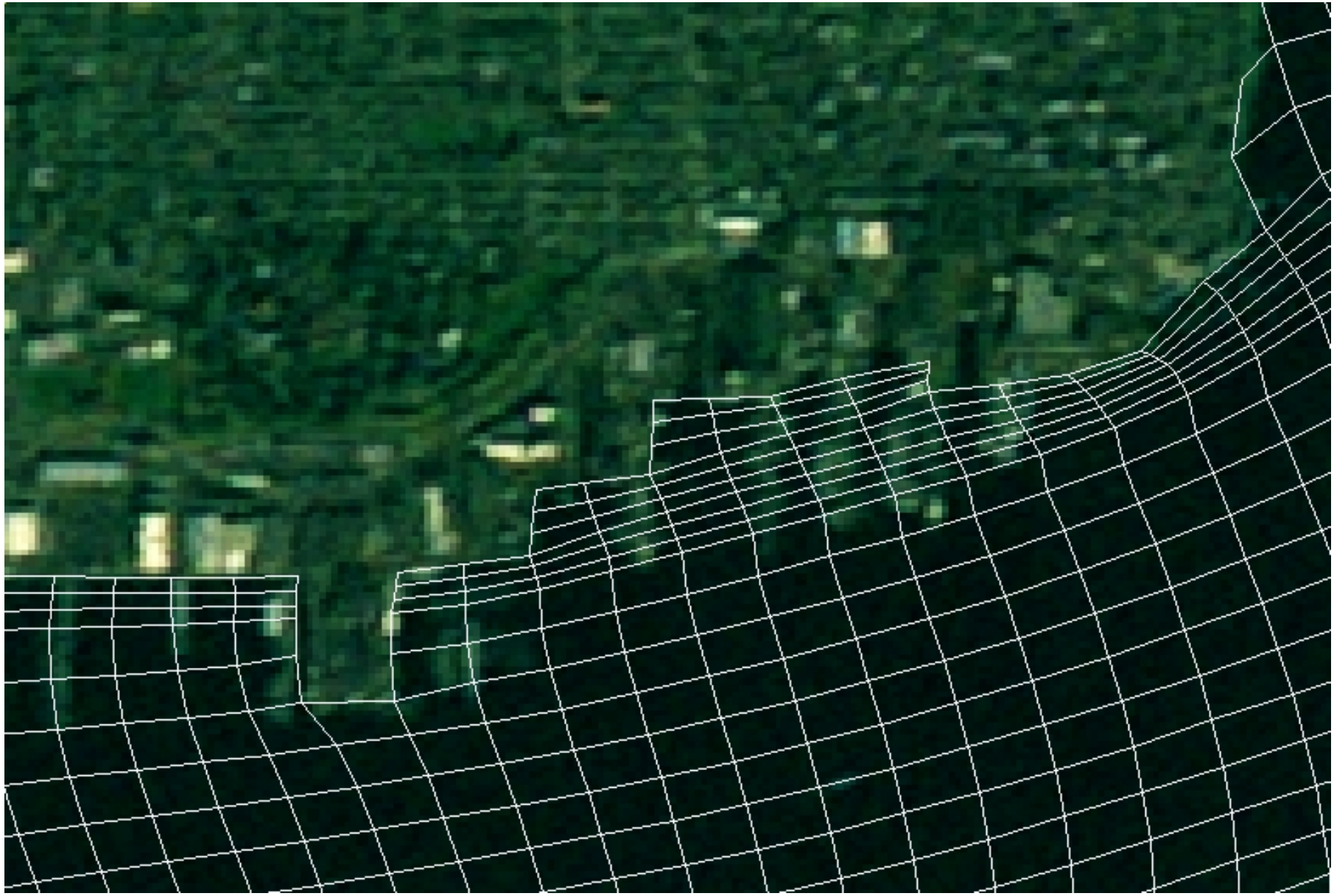
January 2003

CH3D-FC Simulations

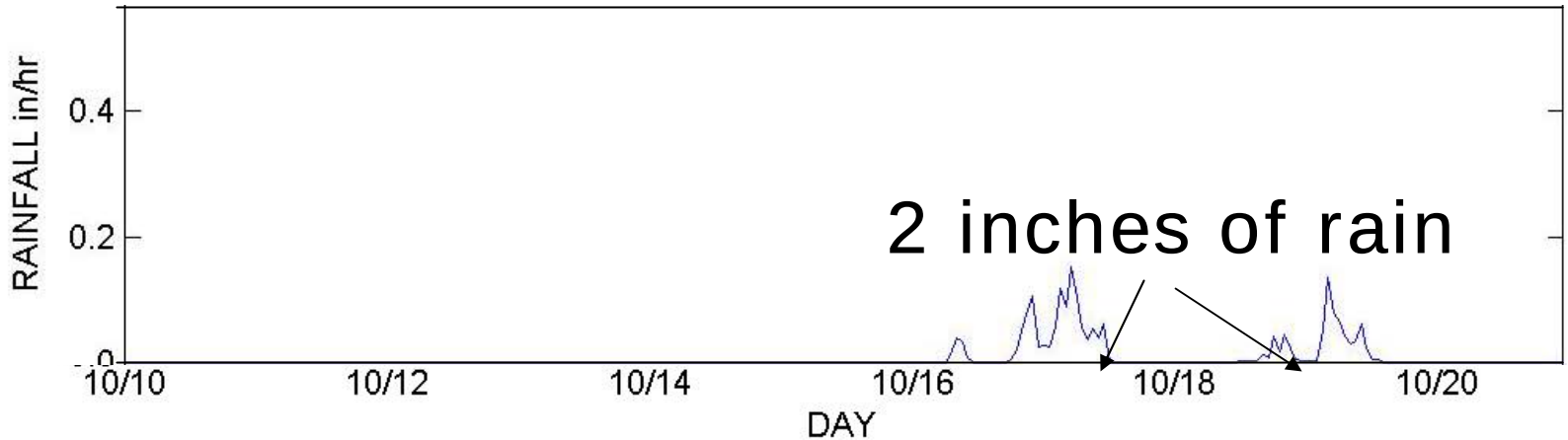
#	Simulation	Watershed Hydrology	FC Loading	Grid	Sensitivity	Purpose
1	April 19-20, 2004	1.00	25th Percentile	96x105		Verification
2	April 19-20, 2004	1.00	Geomean	96x105		Verification
3	April 19-20, 2004	1.00	75th Percentile	96x105		Verification
4	May 26-27, 2004	1.00	25th Percentile	96x105	Low Estimate for FC Loading	Verification
5	May 26-27, 2004	1.00	Geomean	96x105	**Base Model (average loading)**	Verification
6	May 26-27, 2004	1.00	75th Percentile	96x105	High Estimate for FC Loading	Verification
7	Oct 18-19, 2004	1.00	25th Percentile	96x105		Verification
8	Oct 18-19, 2004	1.00	Geomean	96x105		Verification
9	Oct 18-19, 2004	1.00	75th Percentile	96x105		Verification
10	WY2003	1.00	Geomean	96x105		Verification
11	WY2003	1.00	Geomean	91x94		Critical Conditions
12	WY2003:100/200	1.00	Geomean	91x94		Standard Part 1
13	WY2003:200/400	1.00	Geomean	91x94		Standard Part 2
14	May 26-27, 2004	1.20	Geomean	96x105	Increase Flow by 20%	Sensitivity
15	May 26-27, 2004	2.00	Geomean	96x105	Increase Flow by 100%	Sensitivity
16	May 26-27, 2004	1.00	Geomean	96x105	Wind	Sensitivity
17	May 26-27, 2004	1.00	Geomean	96x105	No FC dieoff	Sensitivity
18	May2020 Build Out	N. Dyes/1.00	N. Dyes Future/Geomean	96x105	Future Flow and average FC for N. Dyes	Future Conditions
19	May2020 Build Out	N. Dyes/1.00	N. Dyes Future/25th Percentile	96x105	Future Flow and low FC for N. Dyes	Future Conditions
20	May2020 Build Out	N. Dyes/1.00	N. Dyes Future/75th Percentile	96x105	Future Flow and high FC for N. Dyes	Future Conditions


CH3D 94x105

Finer Resolution Grid Near Shipyard ~30m



Example Model Simulation

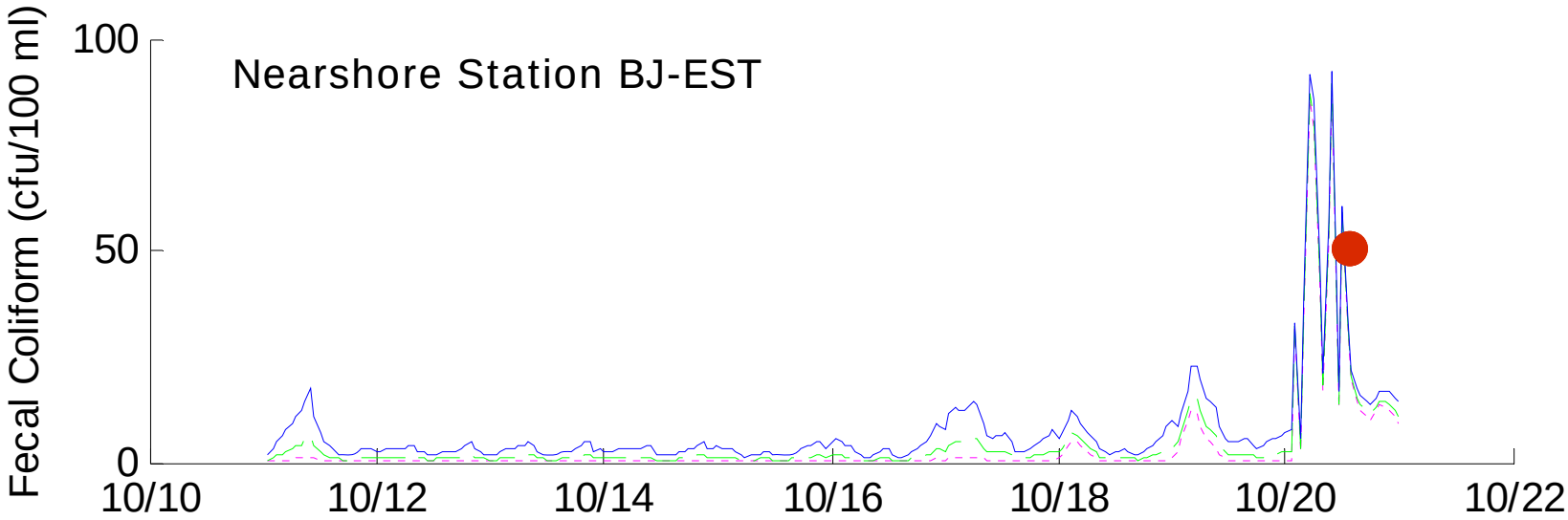


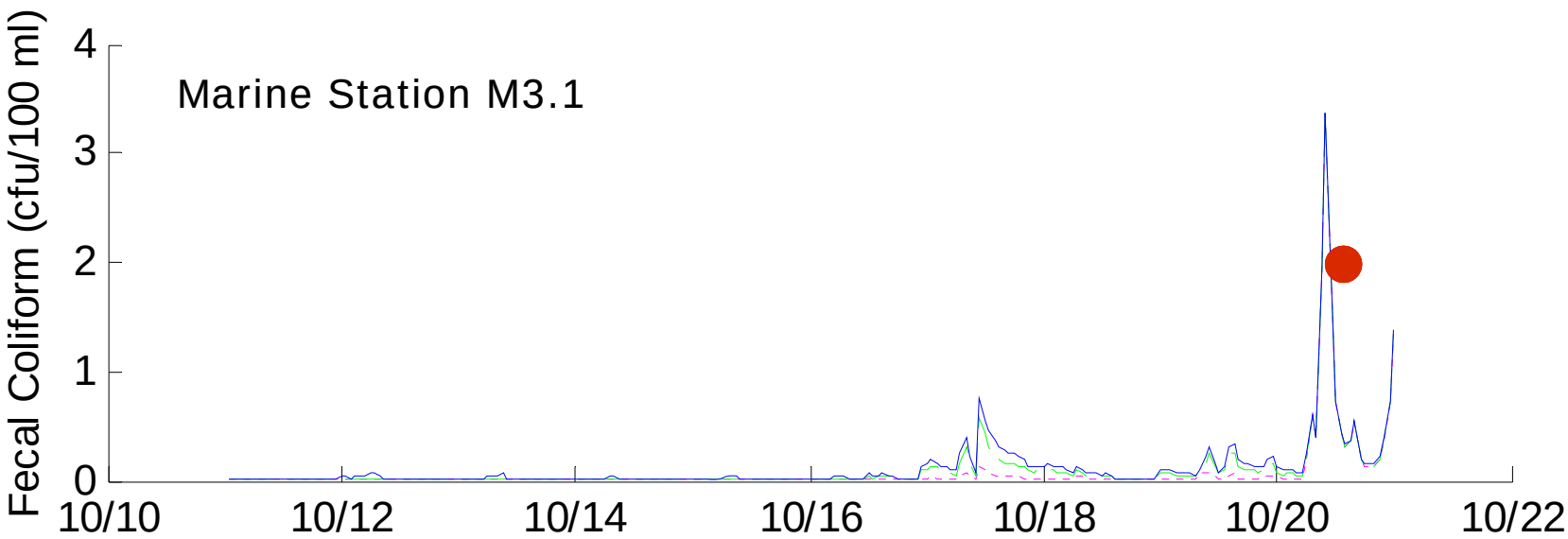
(Click to view animation)

October 2004 Storm Event (91x96grid)

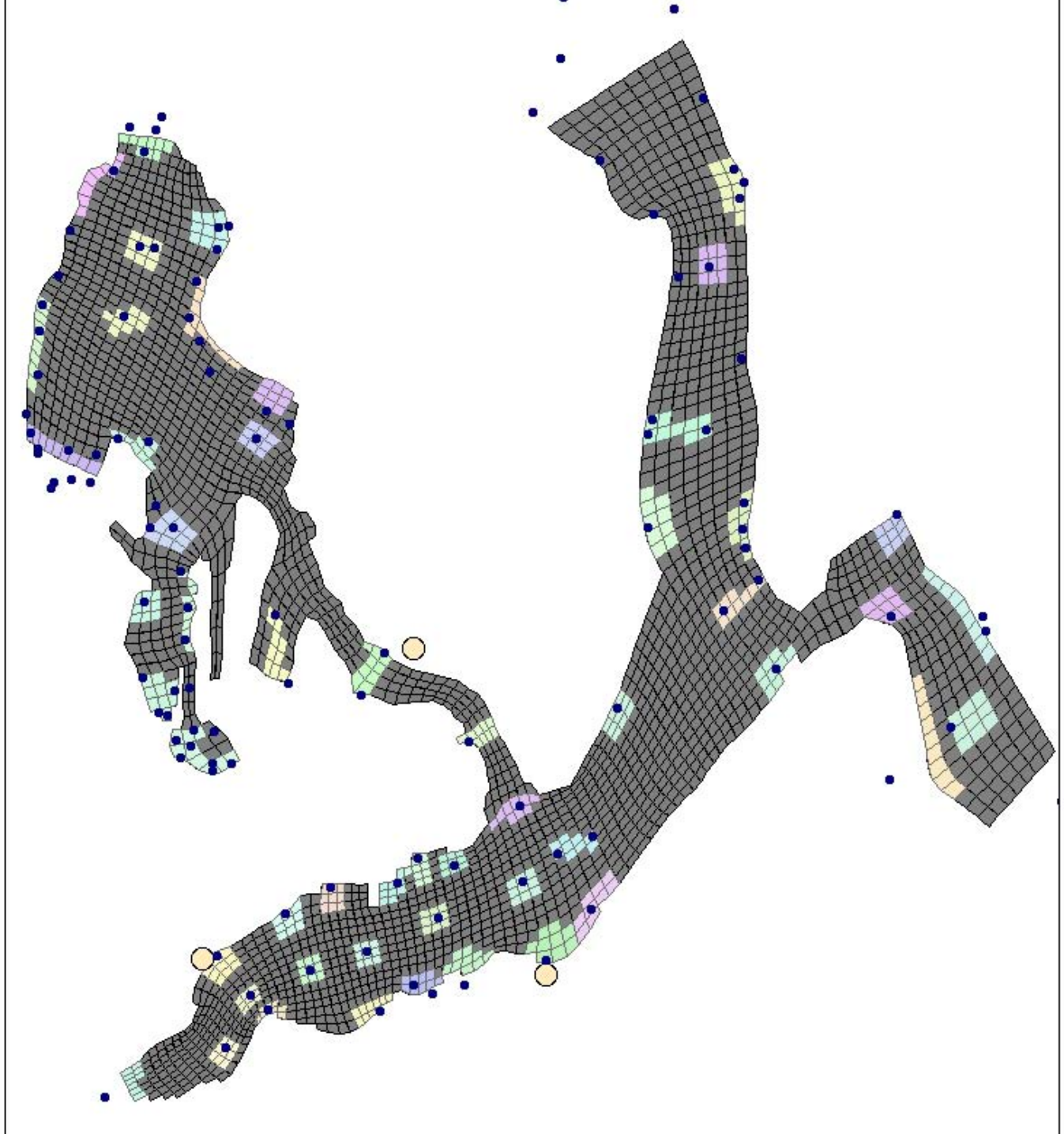
October 2004 Storm Event (94x105grid)

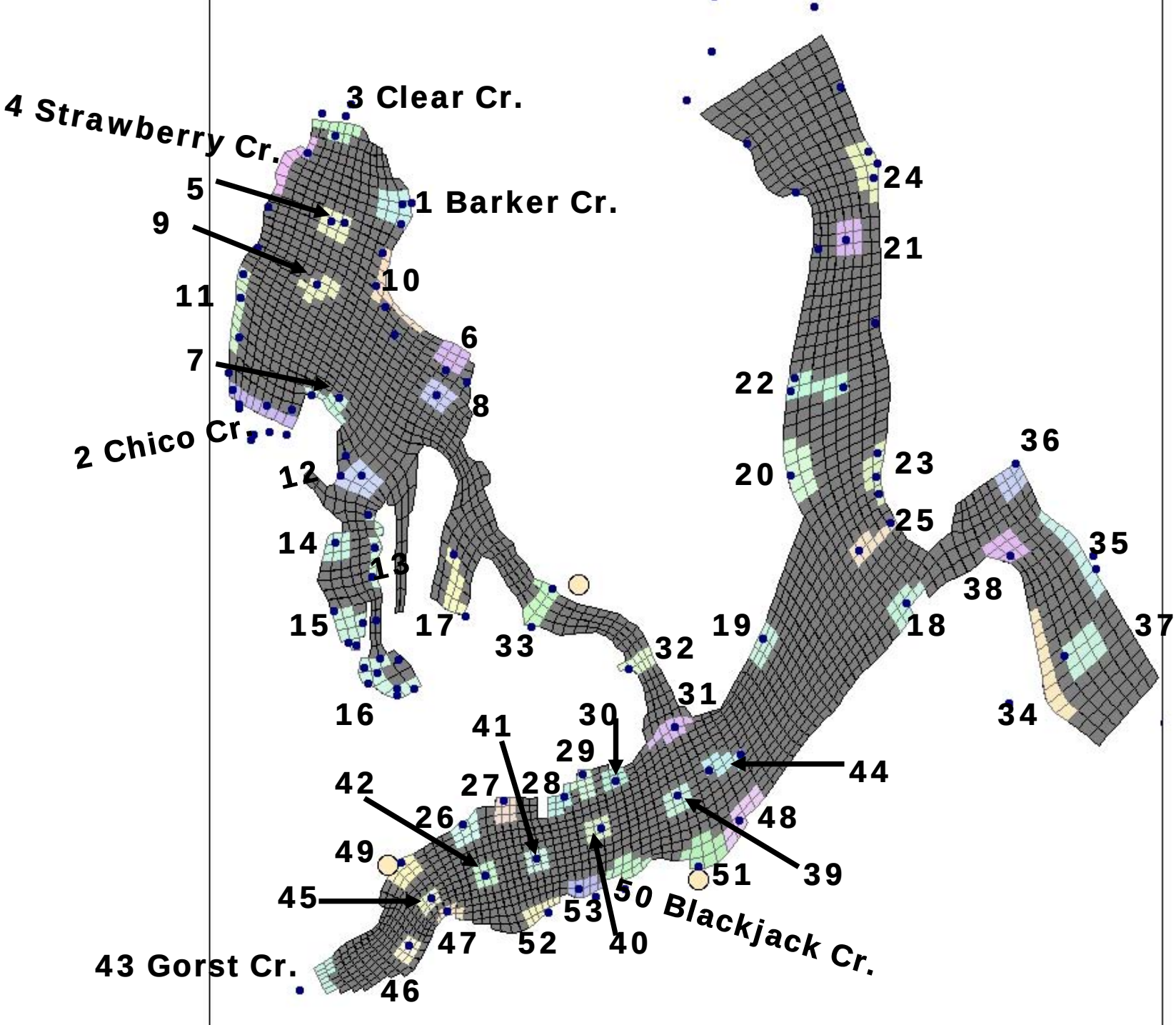
Predicted and Observed FC from Oct 2004 Storm Event





Canary Nodes (group of 9 grid cells) were selected based on available monitoring locations (blue dots). Output from the Canary Nodes were compared to the observed data.




4 Strawberry Cr.
3 Clear Cr.
1 Barker Cr.
2 Chico Cr.
43 Gorst Cr.
50 Blackjack Cr.
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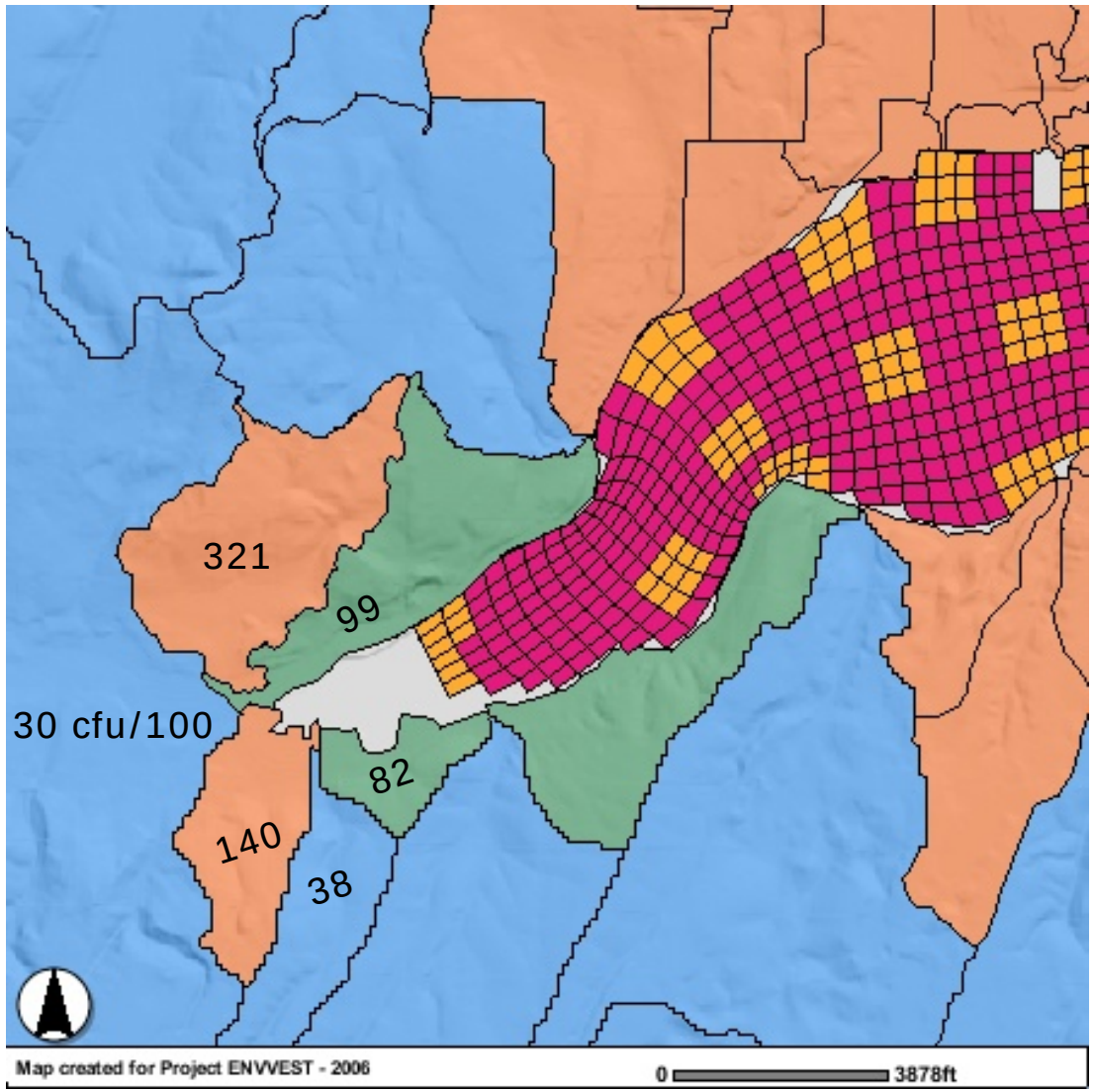
WY2003 Simulated FC For Gorst

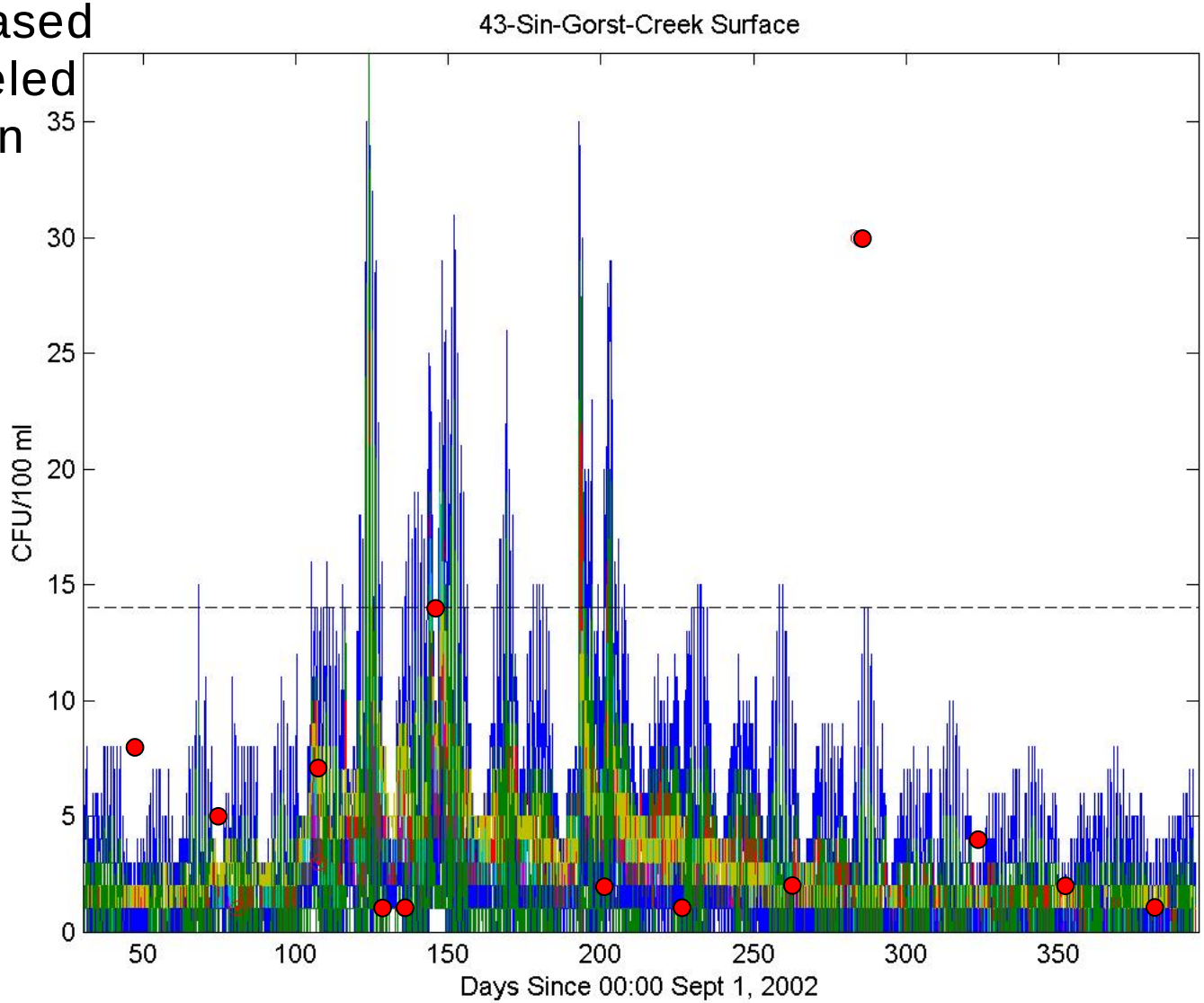
Model Output for Gorst Creek

Loads based on modeled Geomean

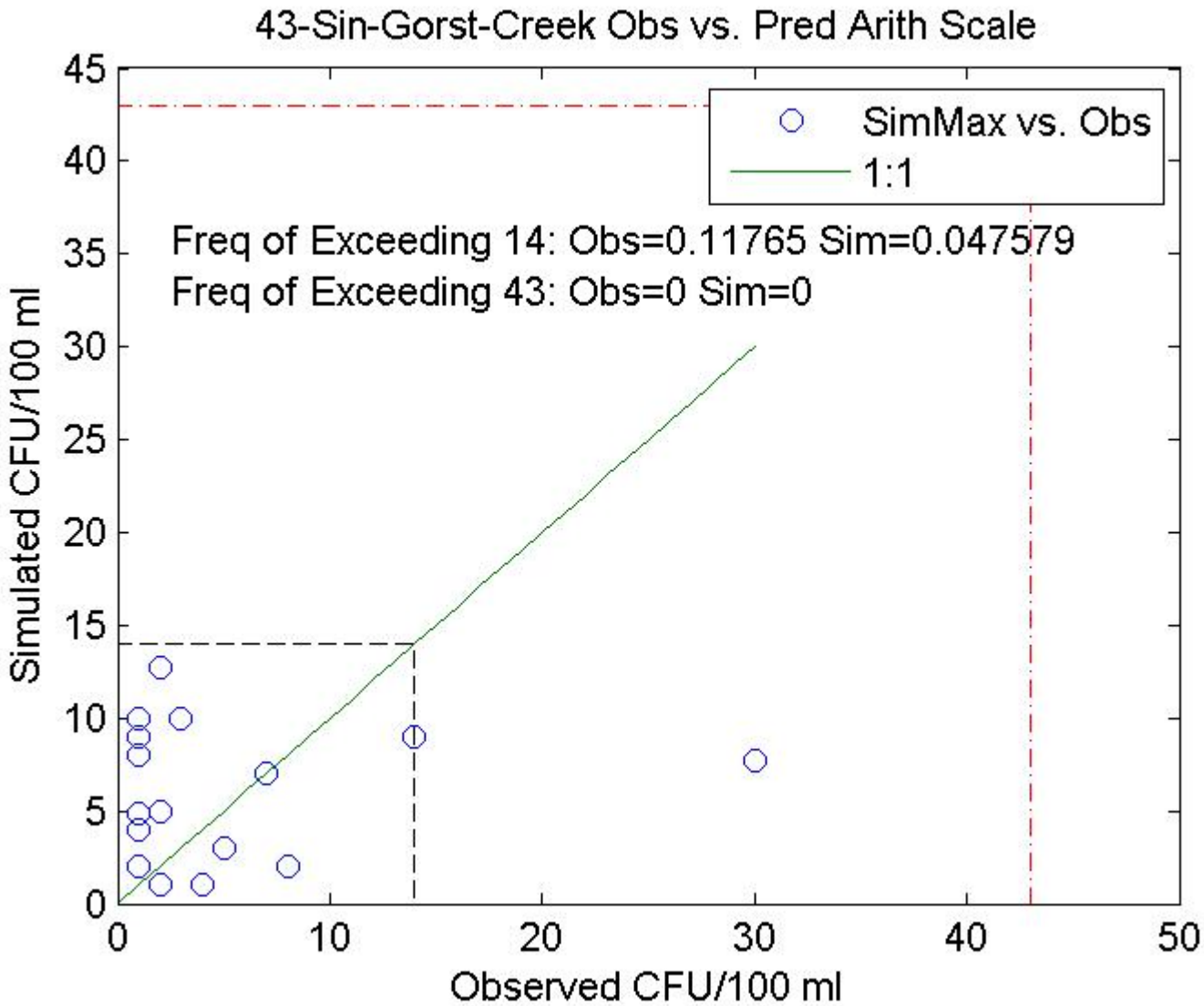


Gorst Cr. Simulated vs. Observed (WY2003 91x96 Grid)

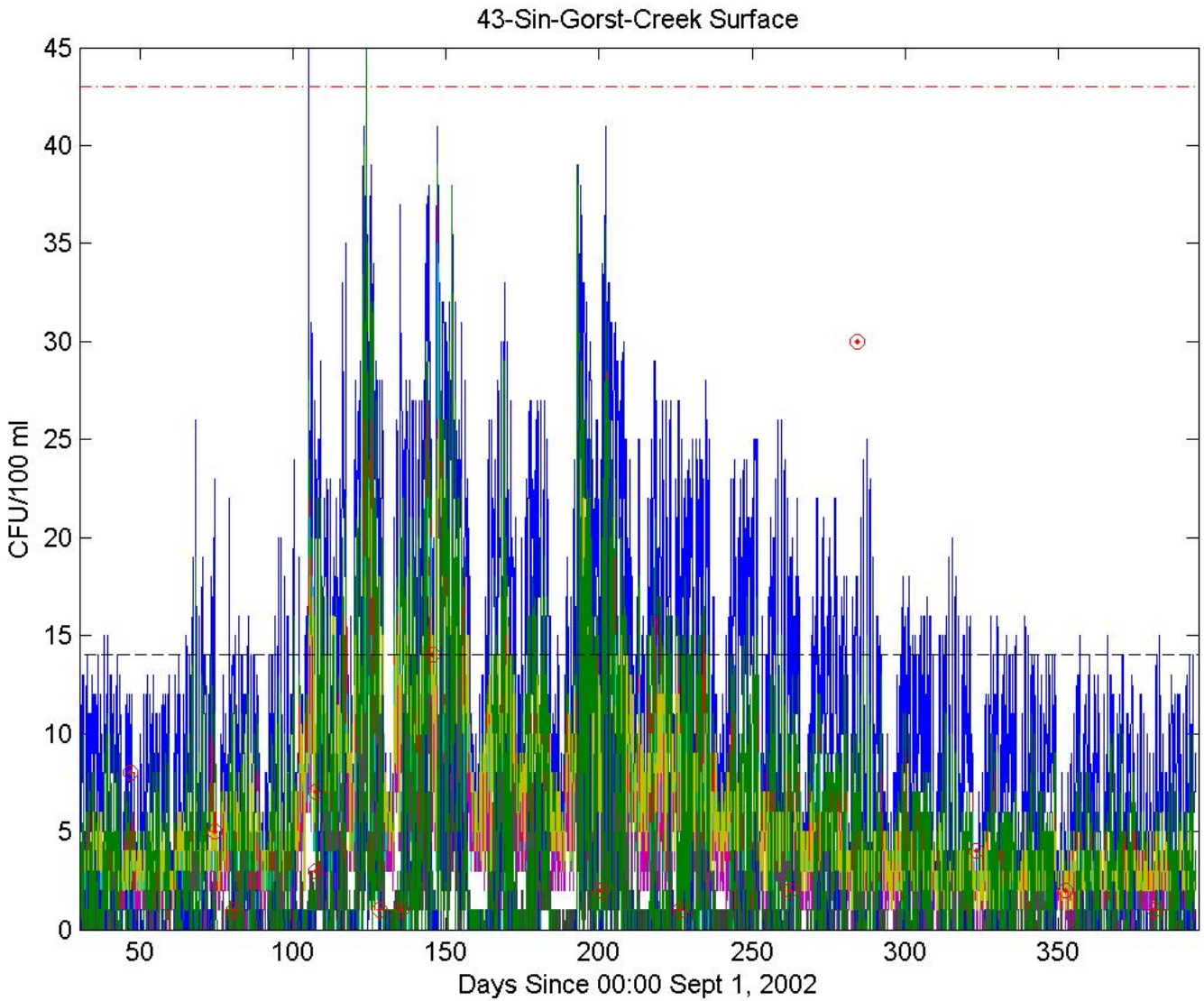
Loads based on modeled Geomean



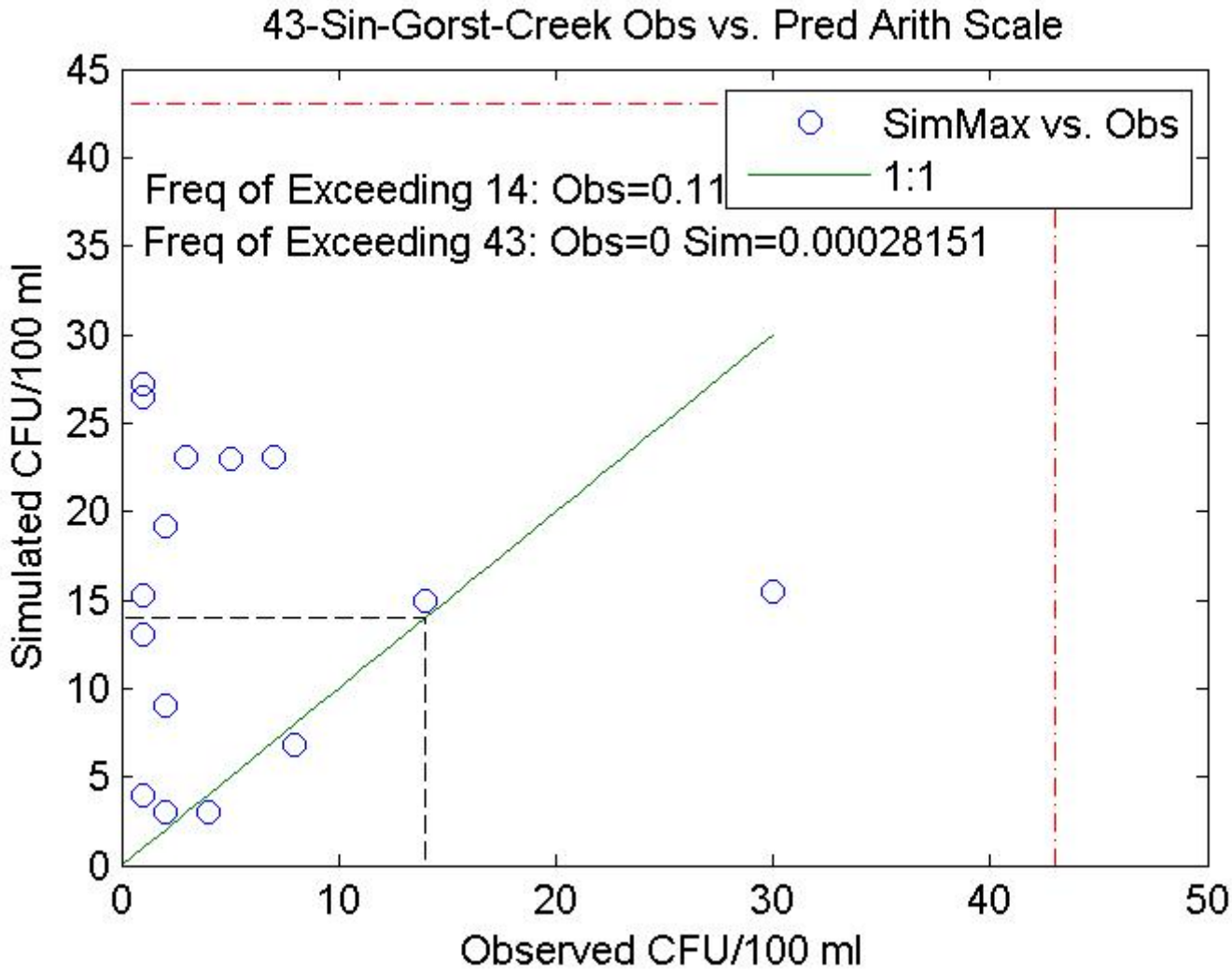
Gorst Creek 91x96 Grid



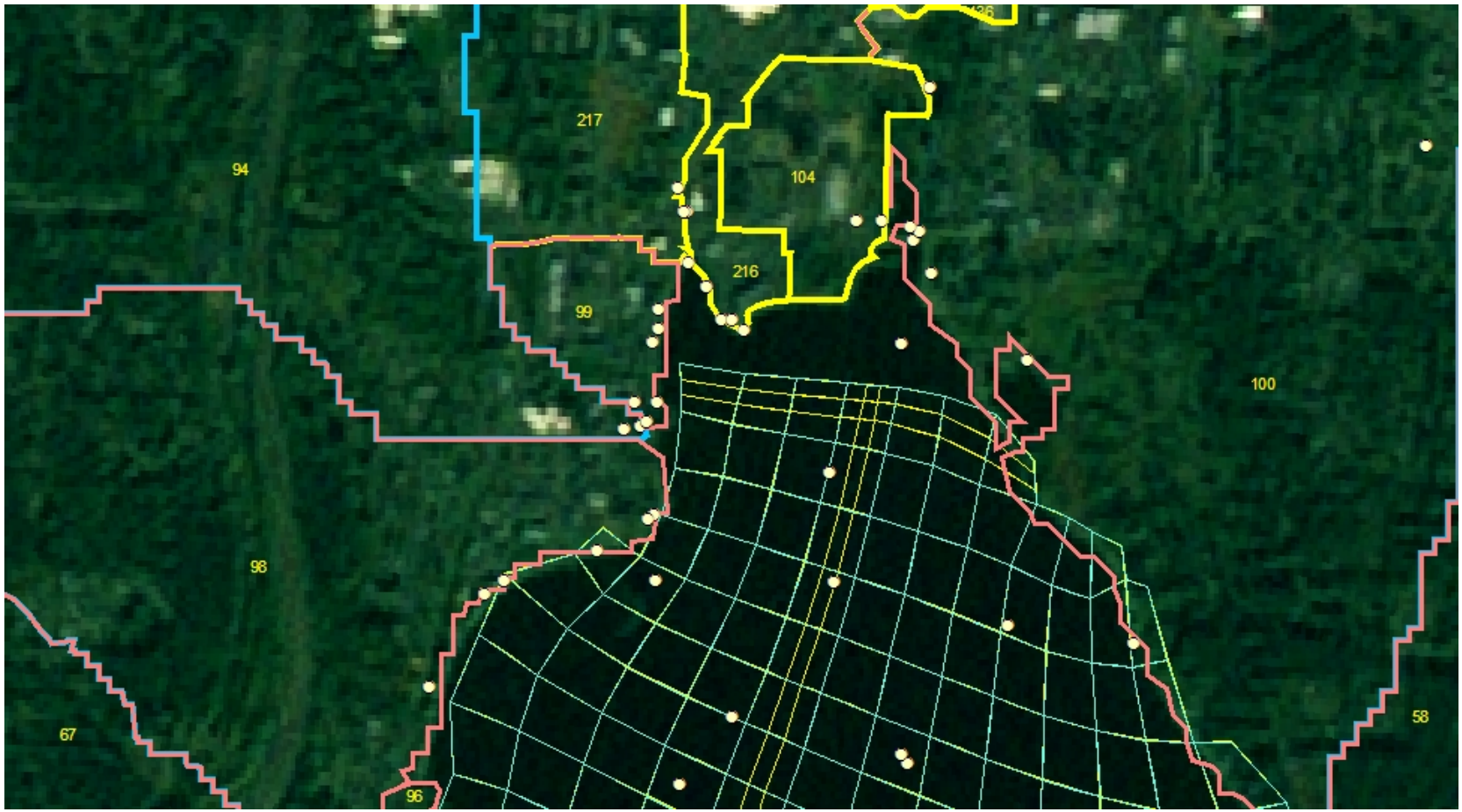
Gorst 94x105 Grid



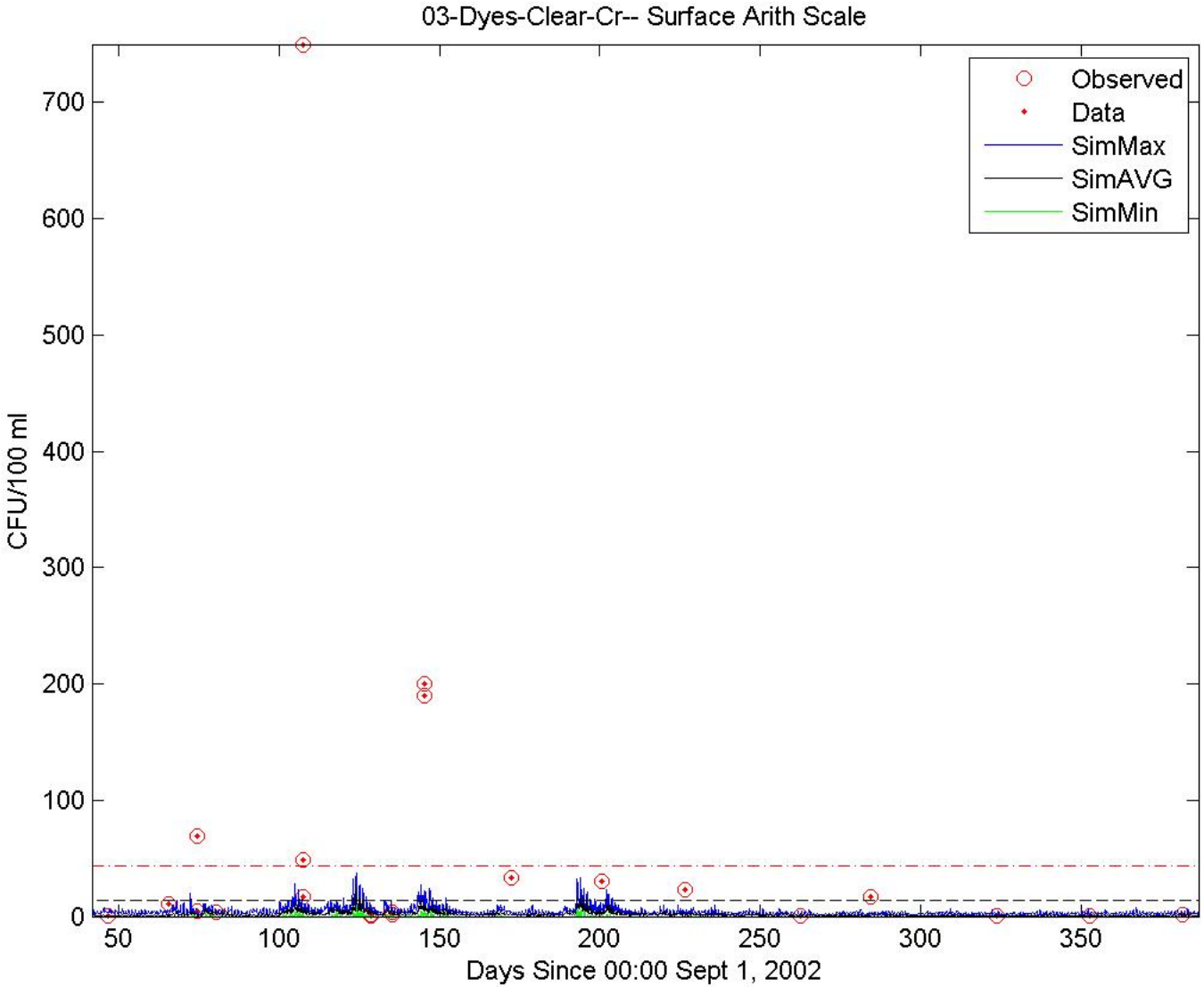
Gorst Creek 96x105 Grid



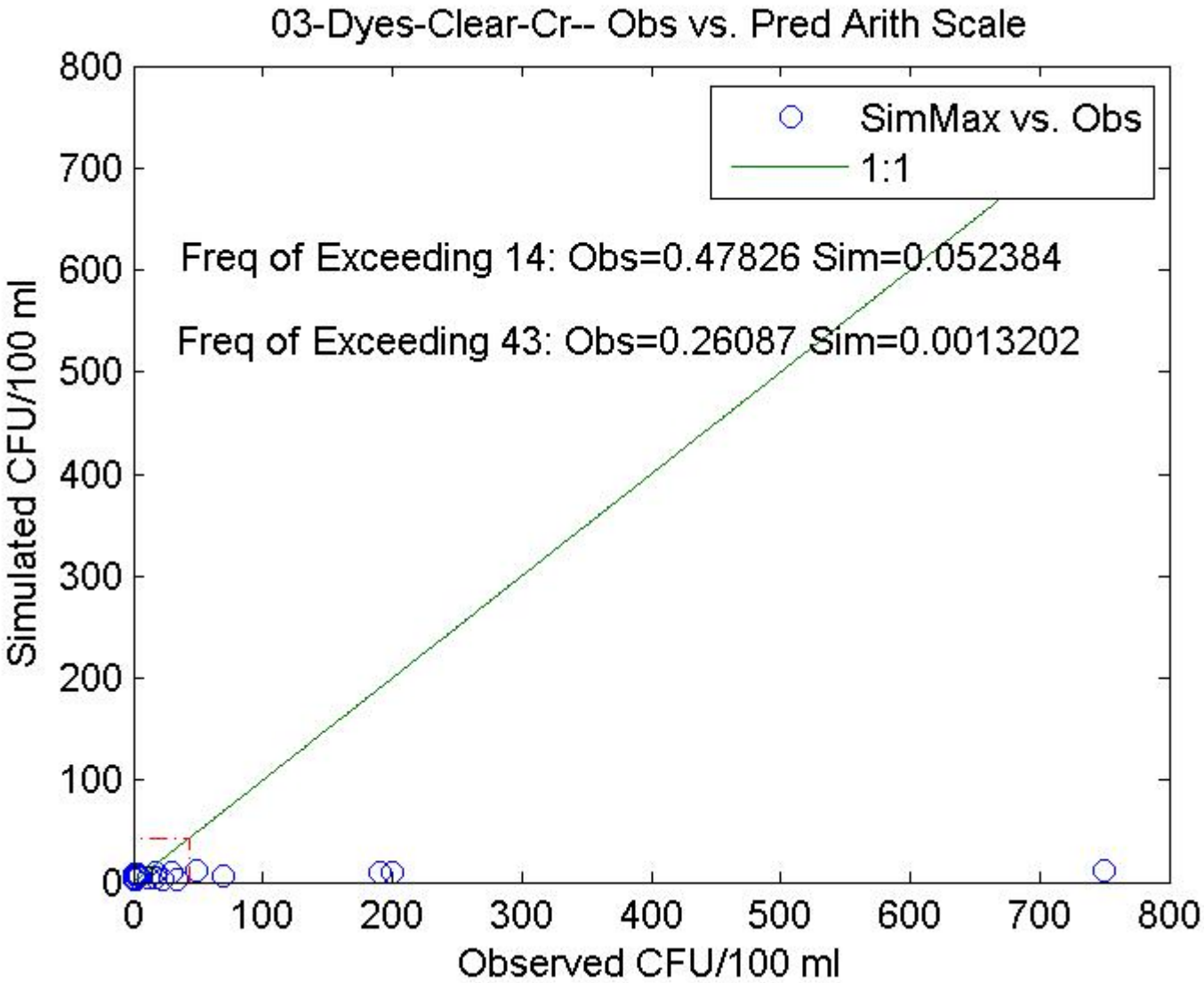
WY2003 Simulated FC For Clear Creek



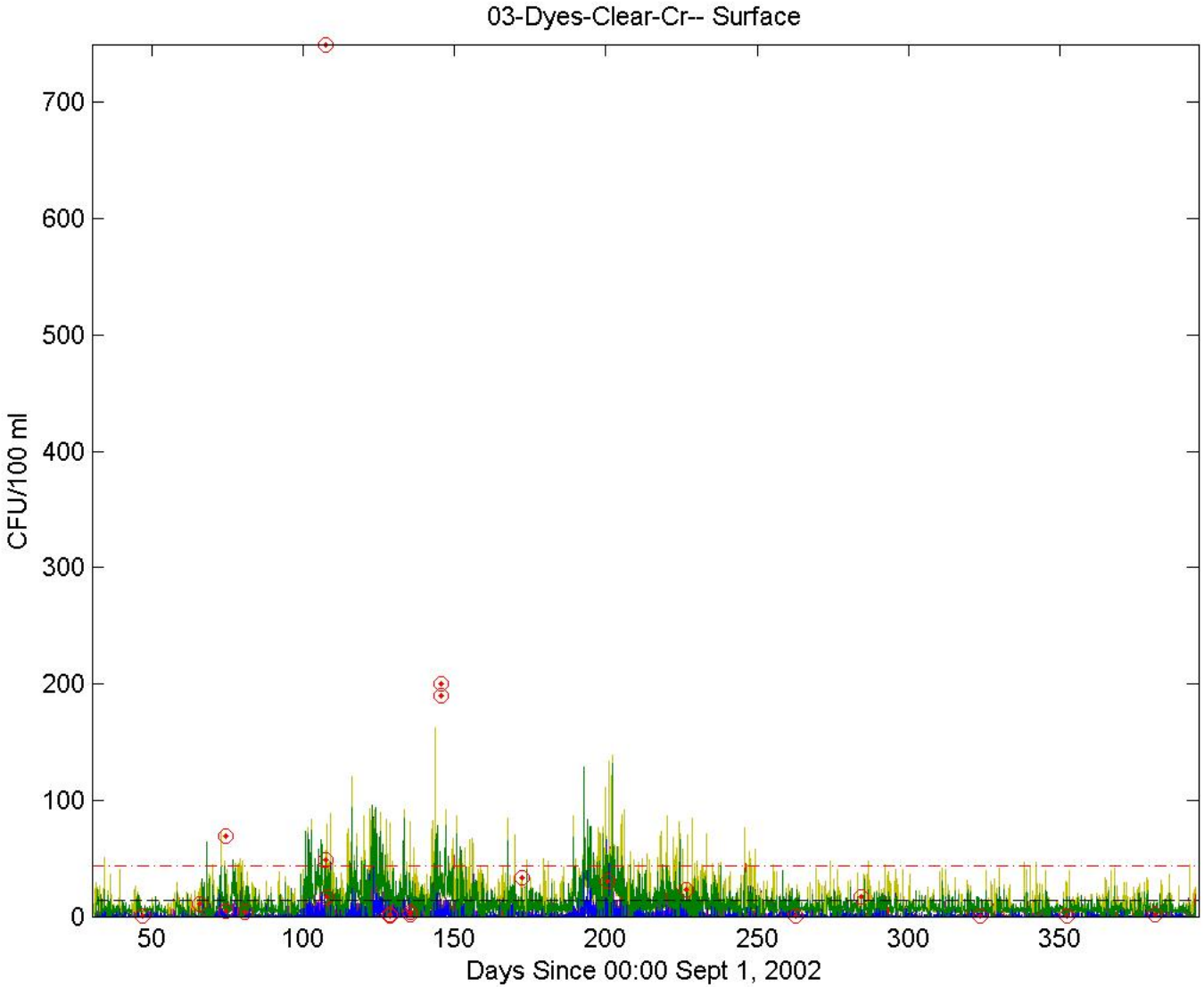
Clear Creek 91x96 Grid



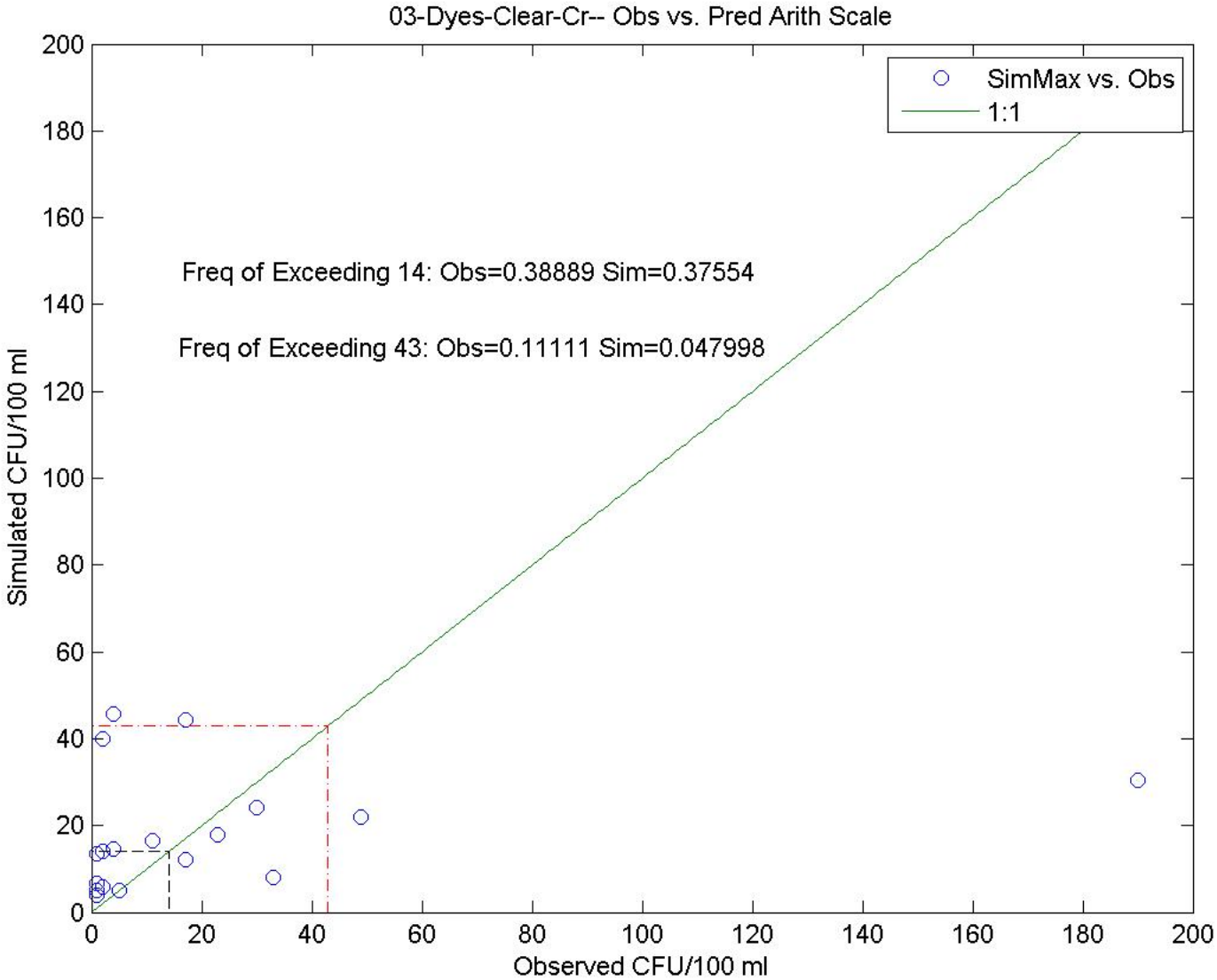
Clear Creek 91x96 Grid



Clear Creek 94x105 Grid

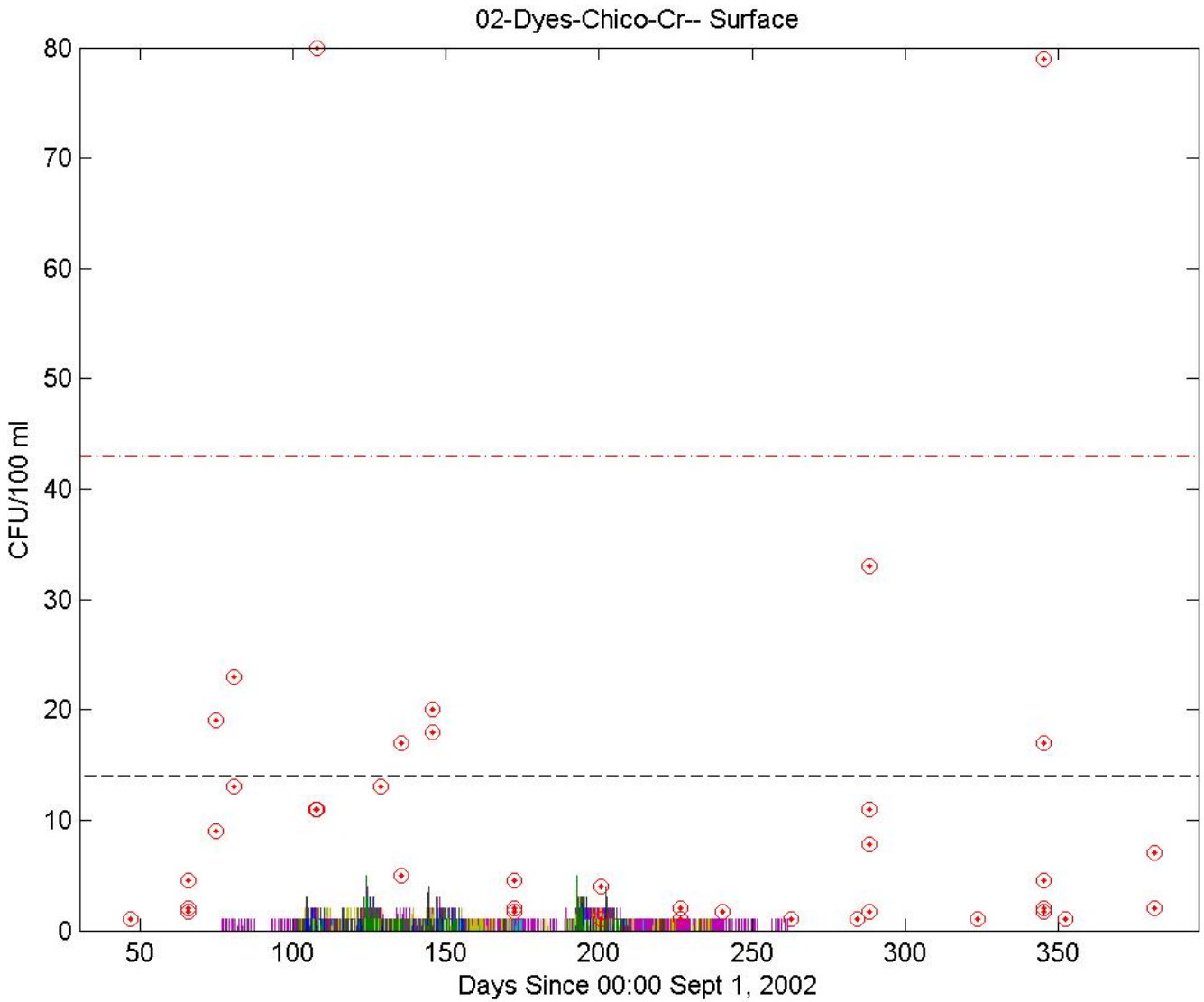


Clear Creek 94x105 Grid

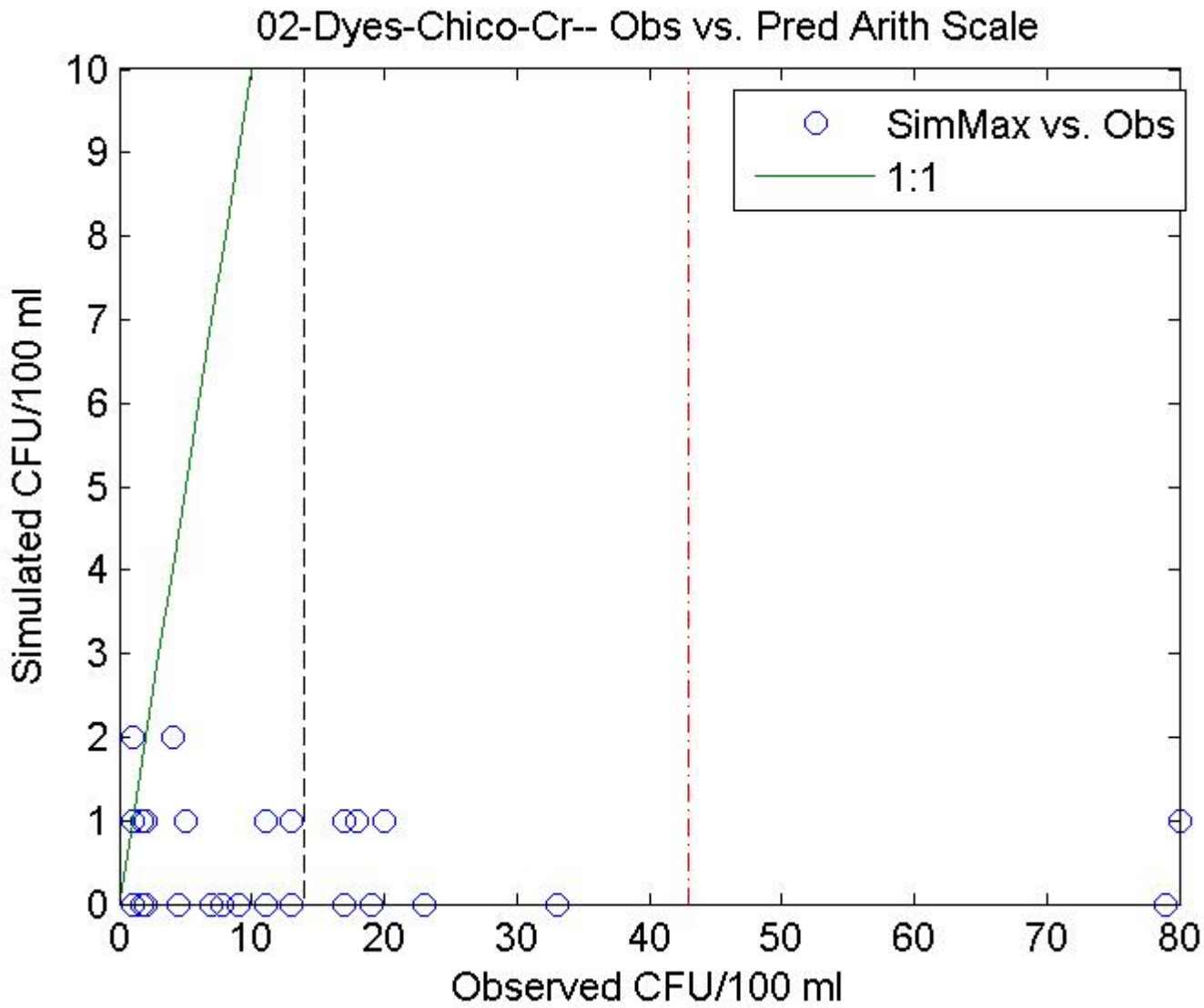


Chico Creek

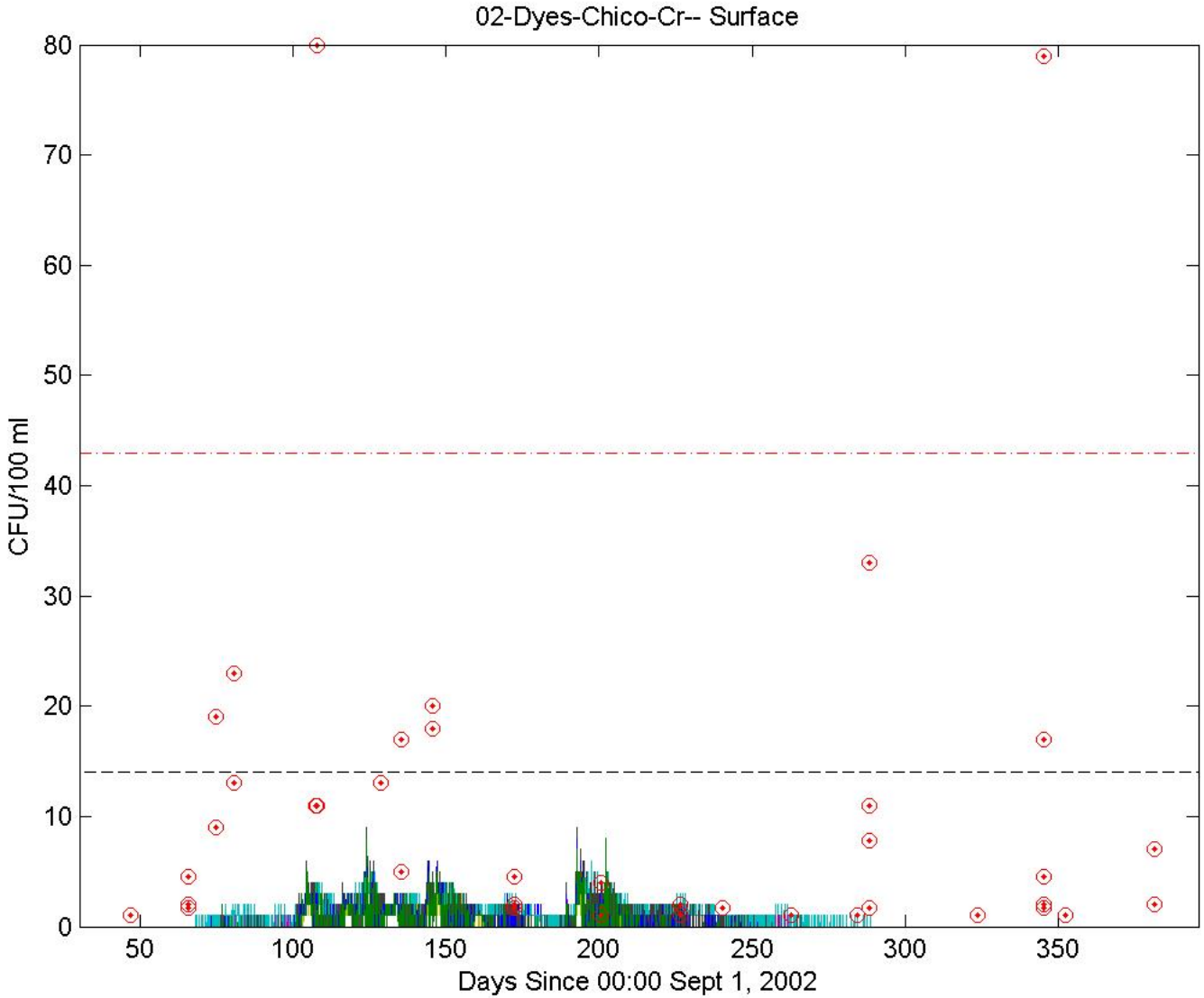
Chico Creek 91x96 Grid



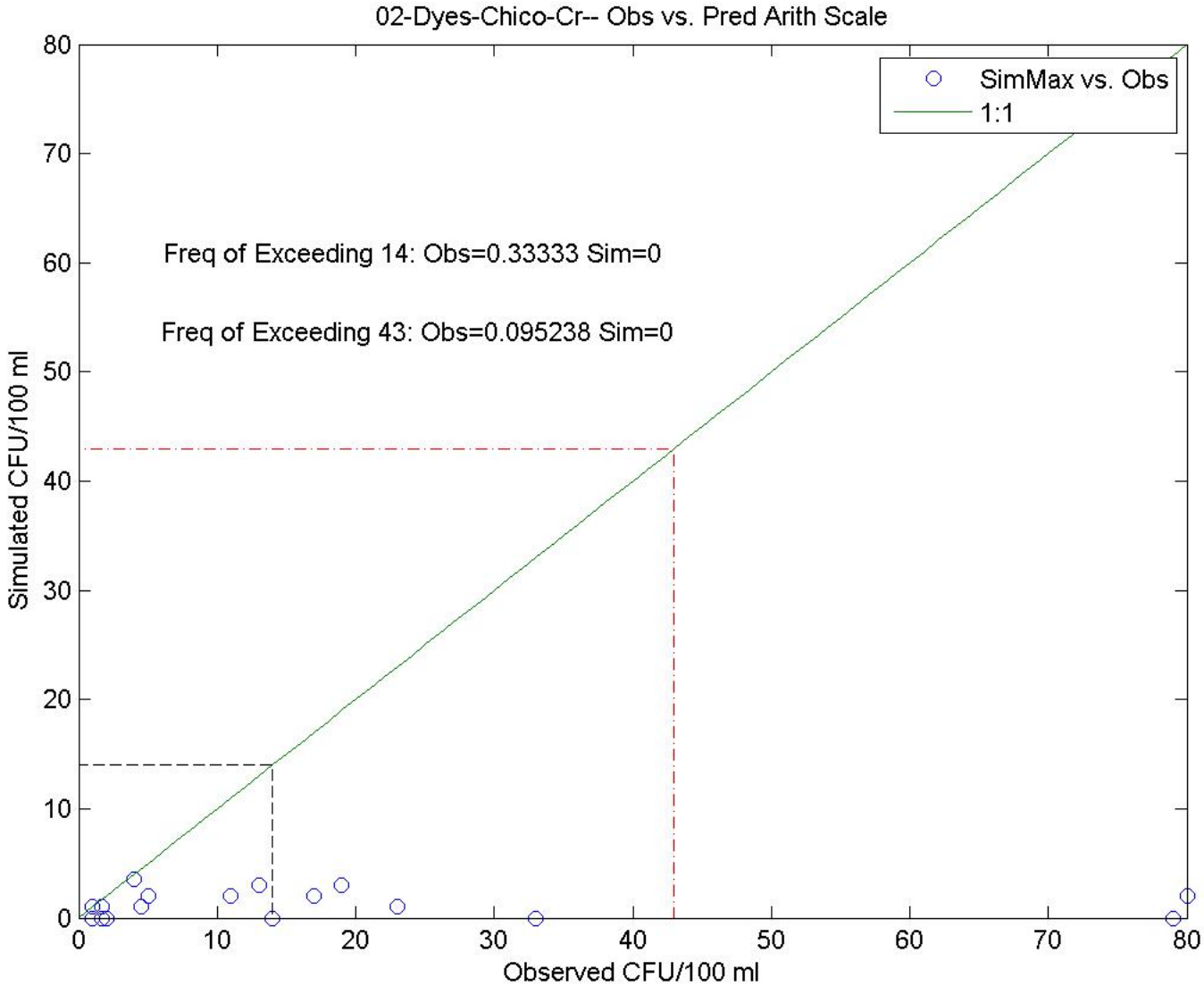
Chico Creek 91x96 Grid



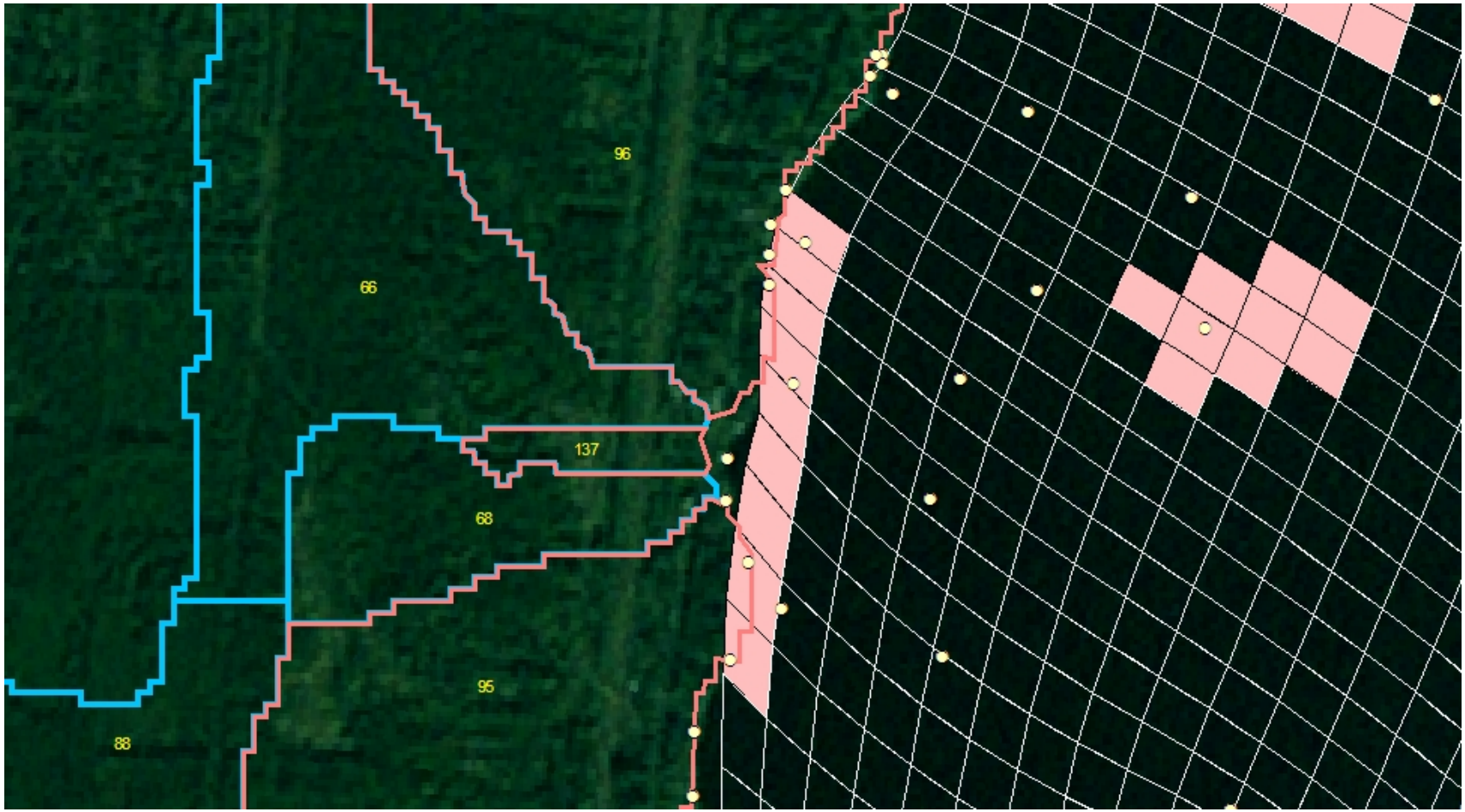
Chico 94x105 Grid



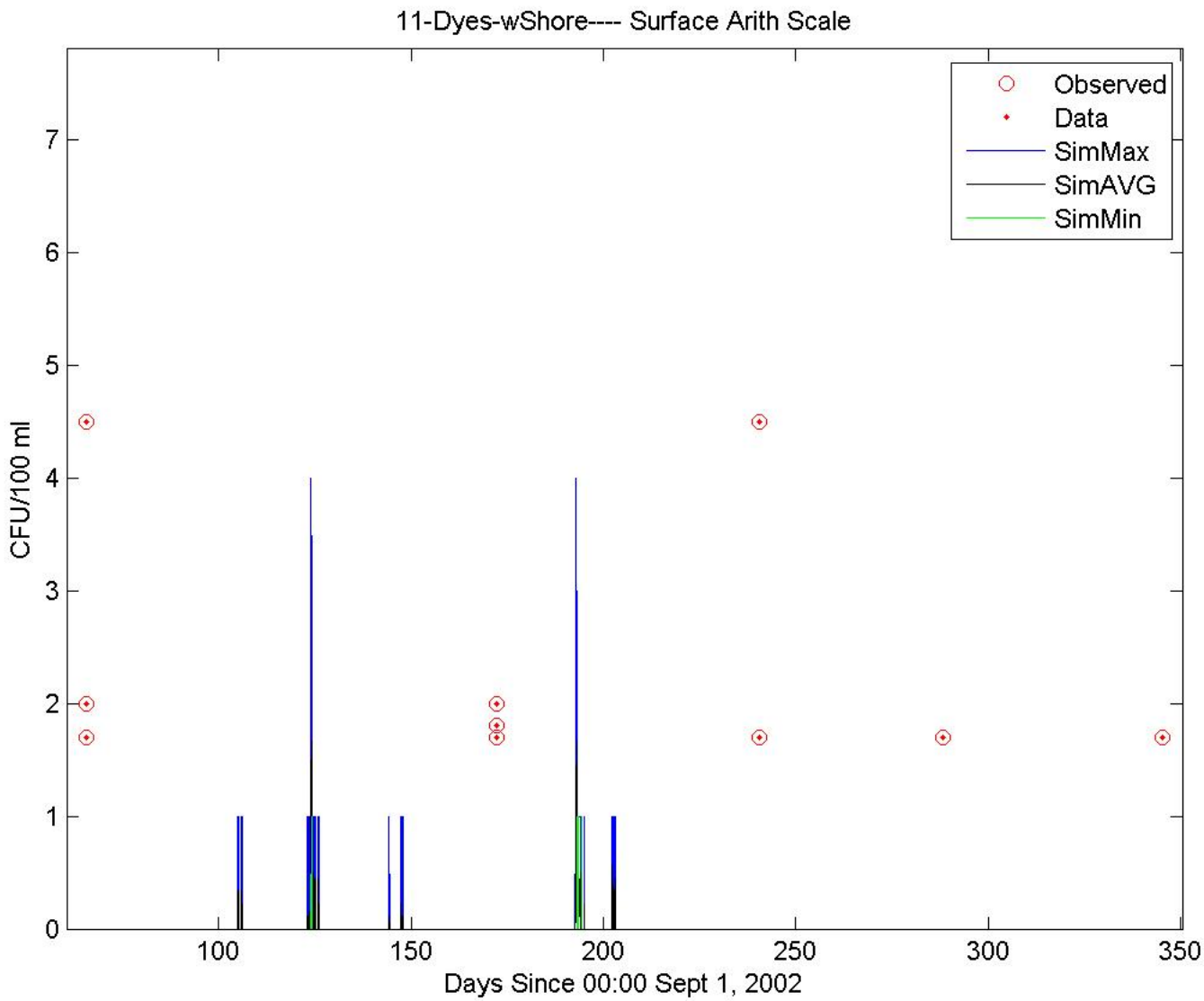
Chico 94x105 Grid



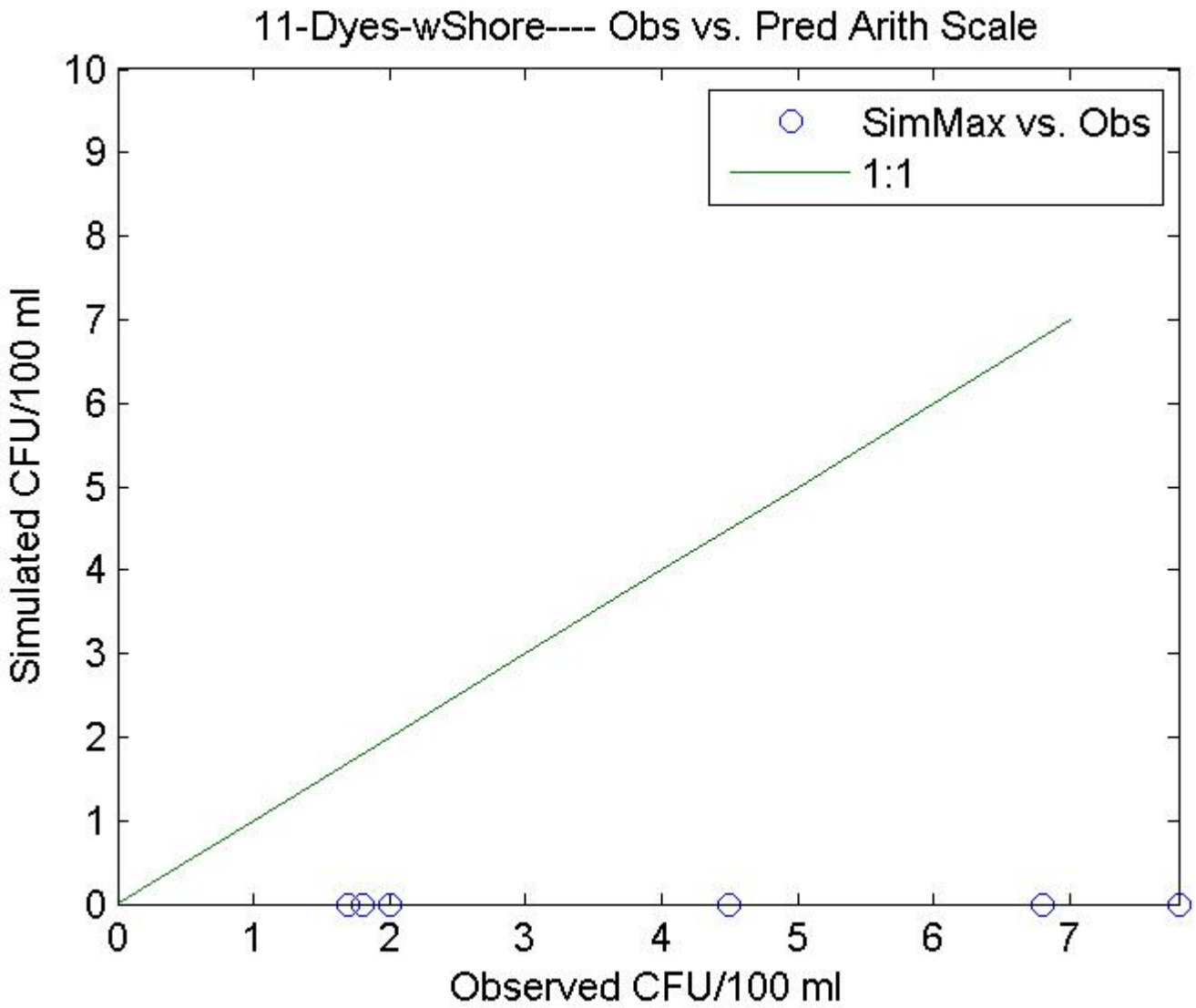
WY2003 Simulated FC For West Dyes Inlet



Dyes West Shore Grid 91x96



West Dyes 91x96 Grid



Evaluation Criteria for CH3D-FC Simulation of WY2003

Based on the observed data available to compare to the model output for the selected "canary" nodes.

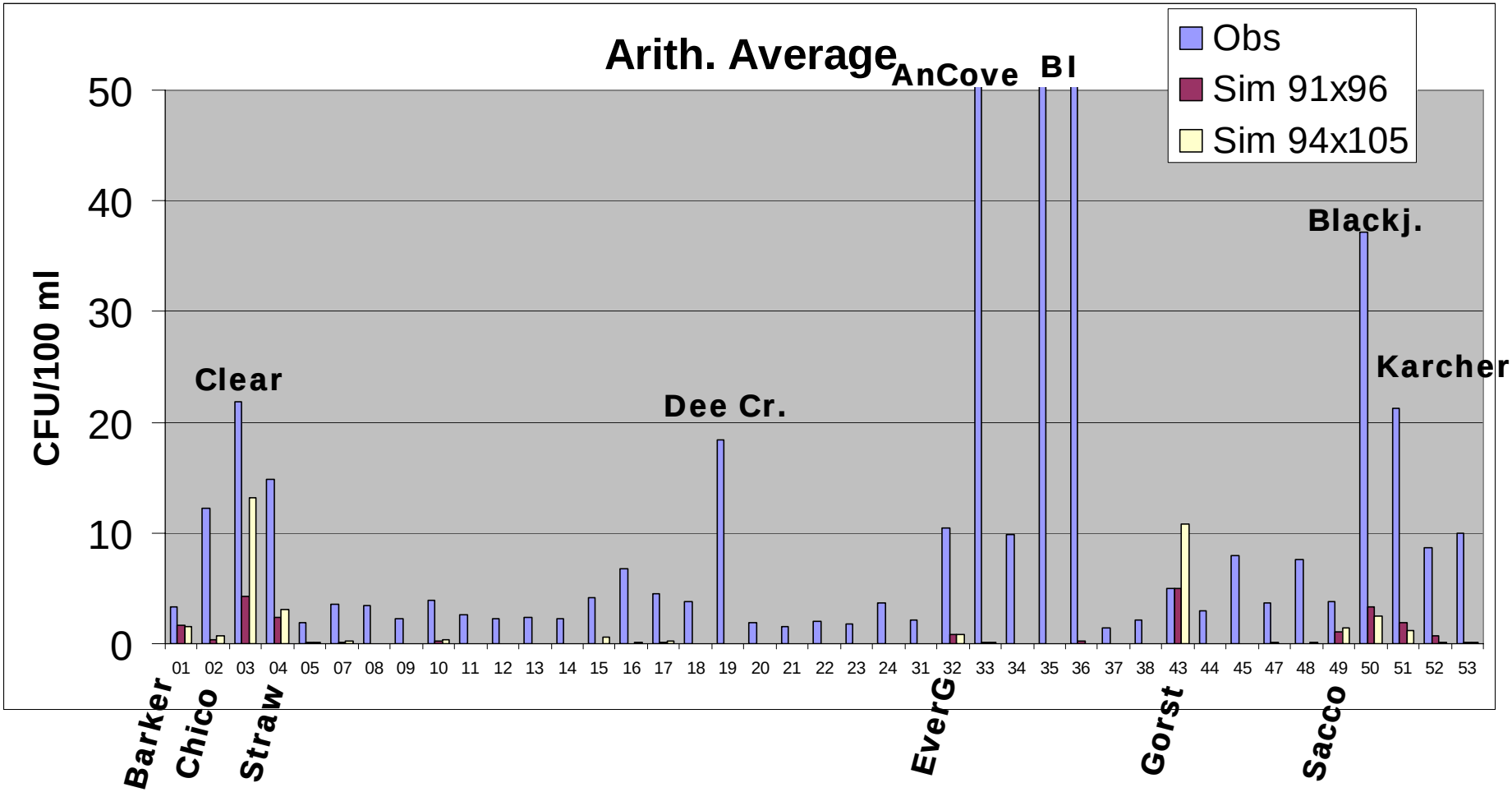
Comparison of Means between Observed and Predicted

Frequency of Exceeding Standard (14 cfu/100 ml; 43 cfu/100 ml)

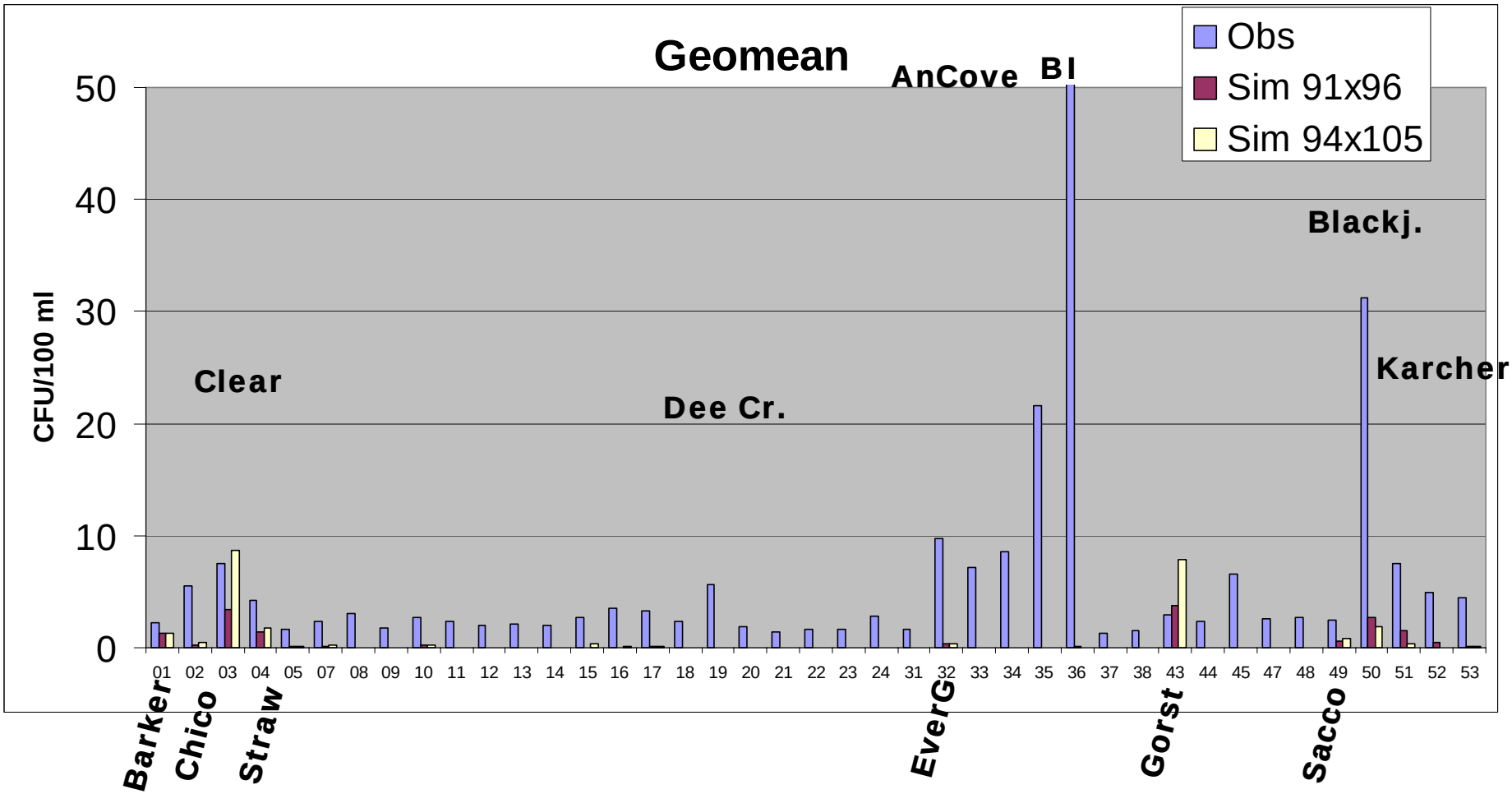
Comparison of Cumulative Density Function

Comparison of the root mean square error (RMSE) between the observed (Obs(i)) and predicted (Pred(i)) values averaged over the number of observations (n)

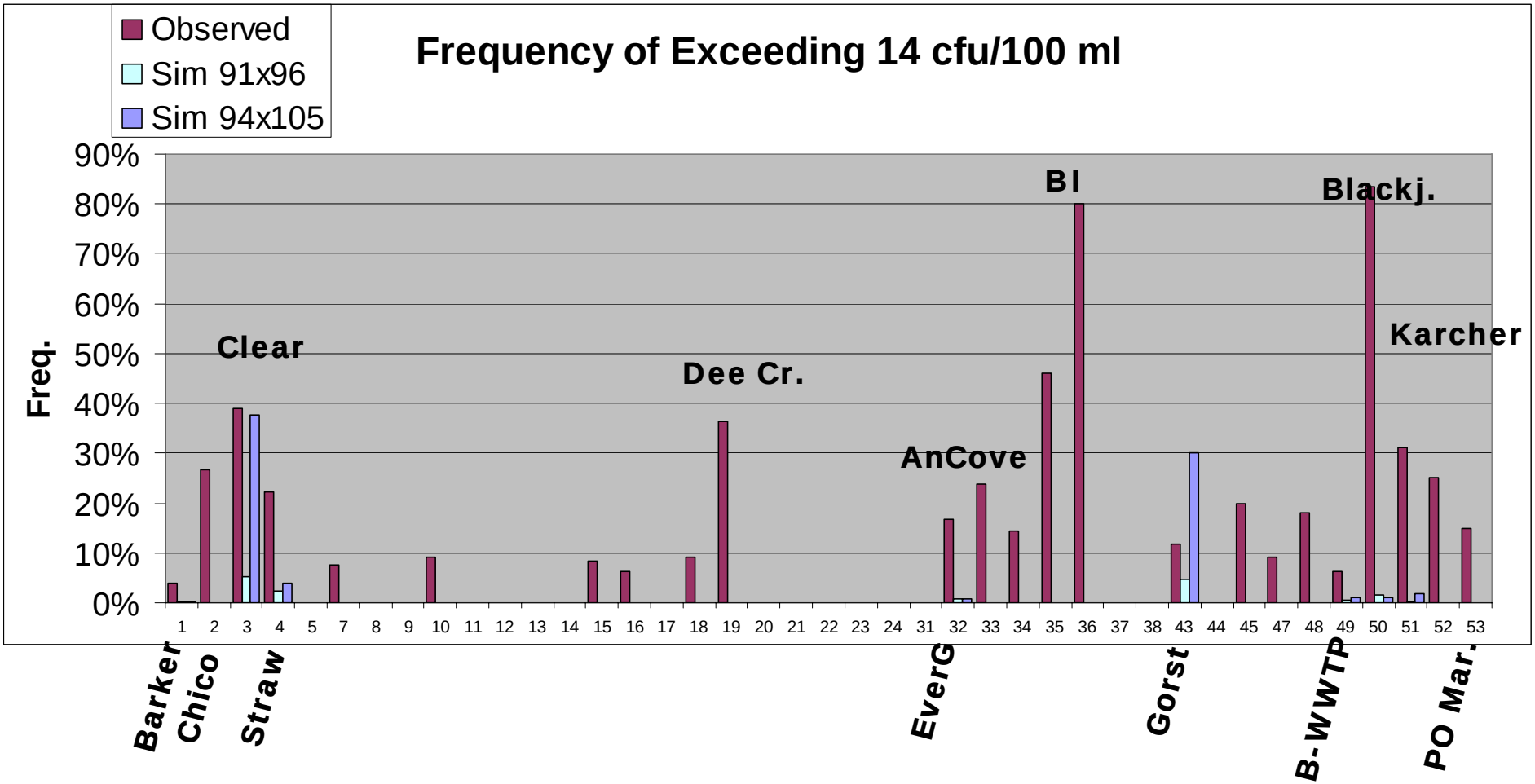
Comparison of Means



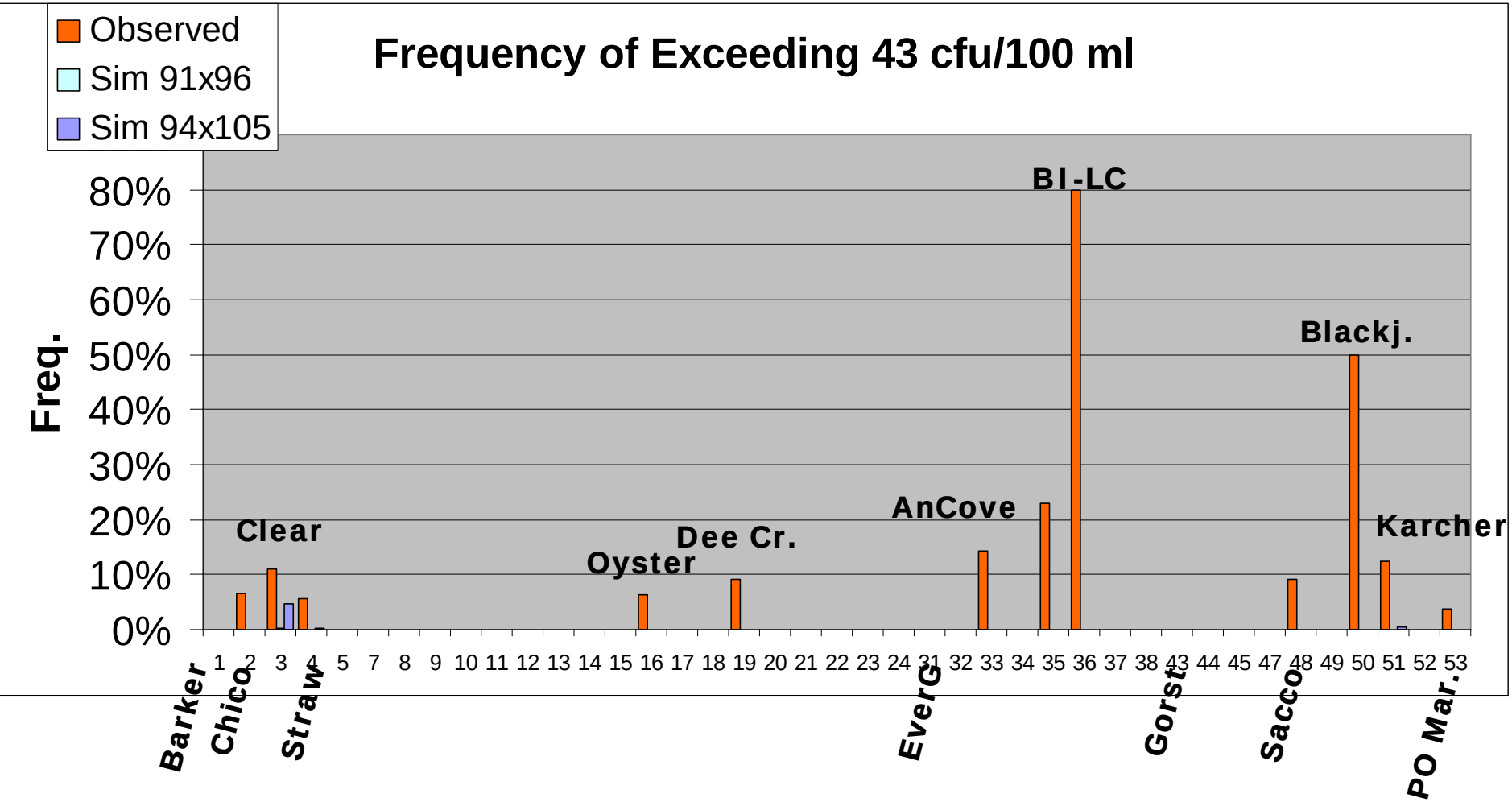
Comparison of Means



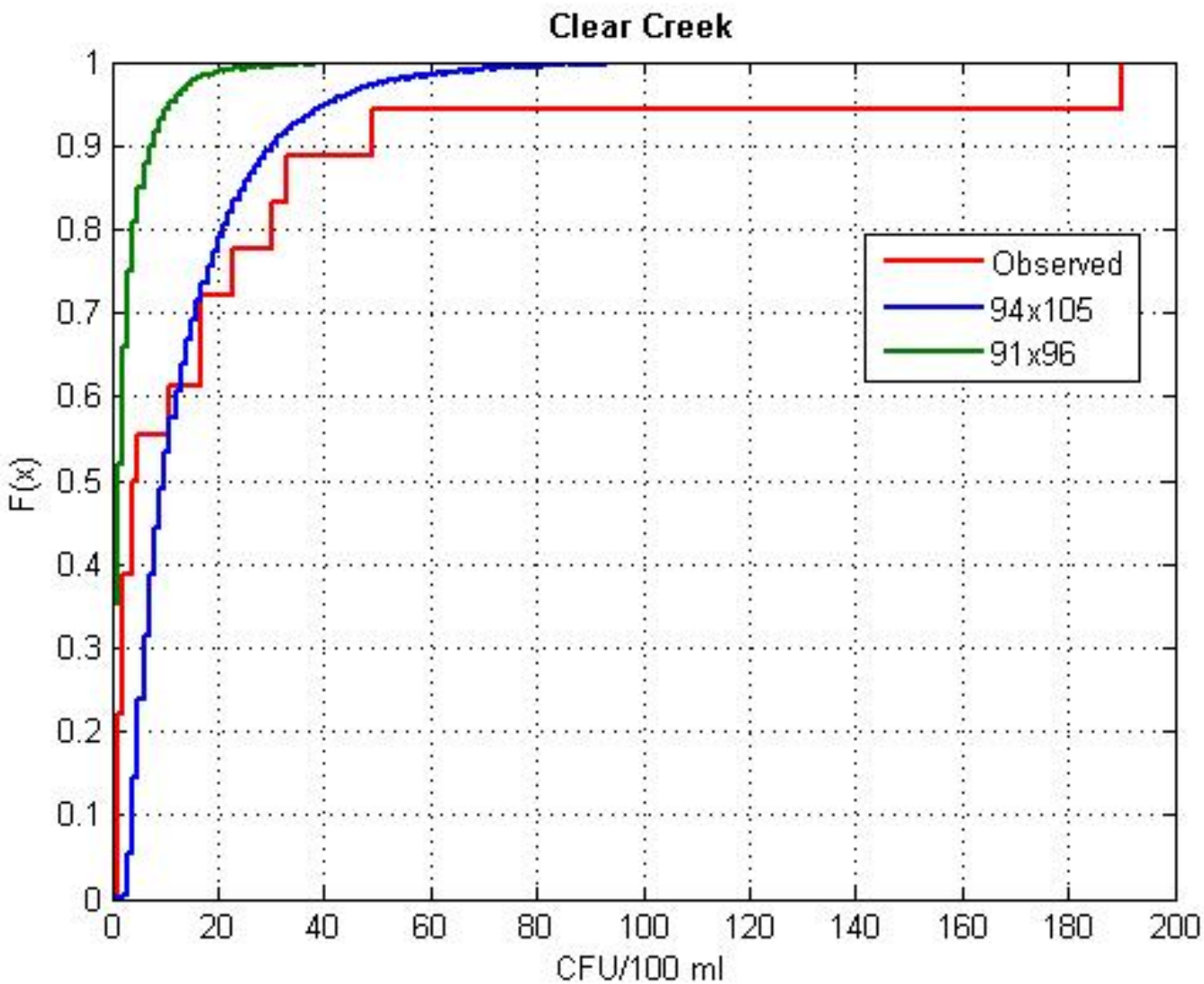
Frequency of Exceeding 14 cfu/100 ml



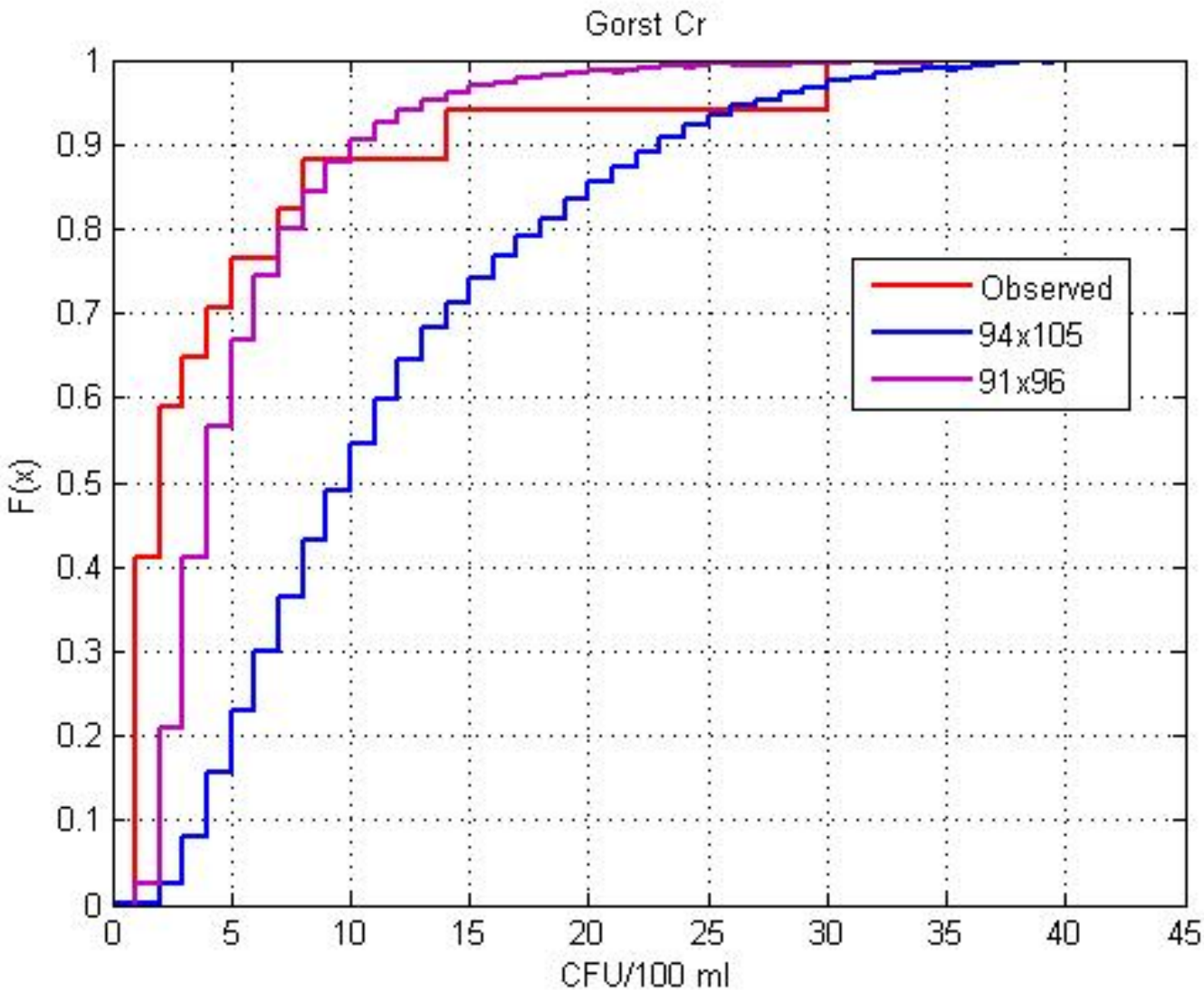
Frequency of Exceeding 43 cfu/100 ml



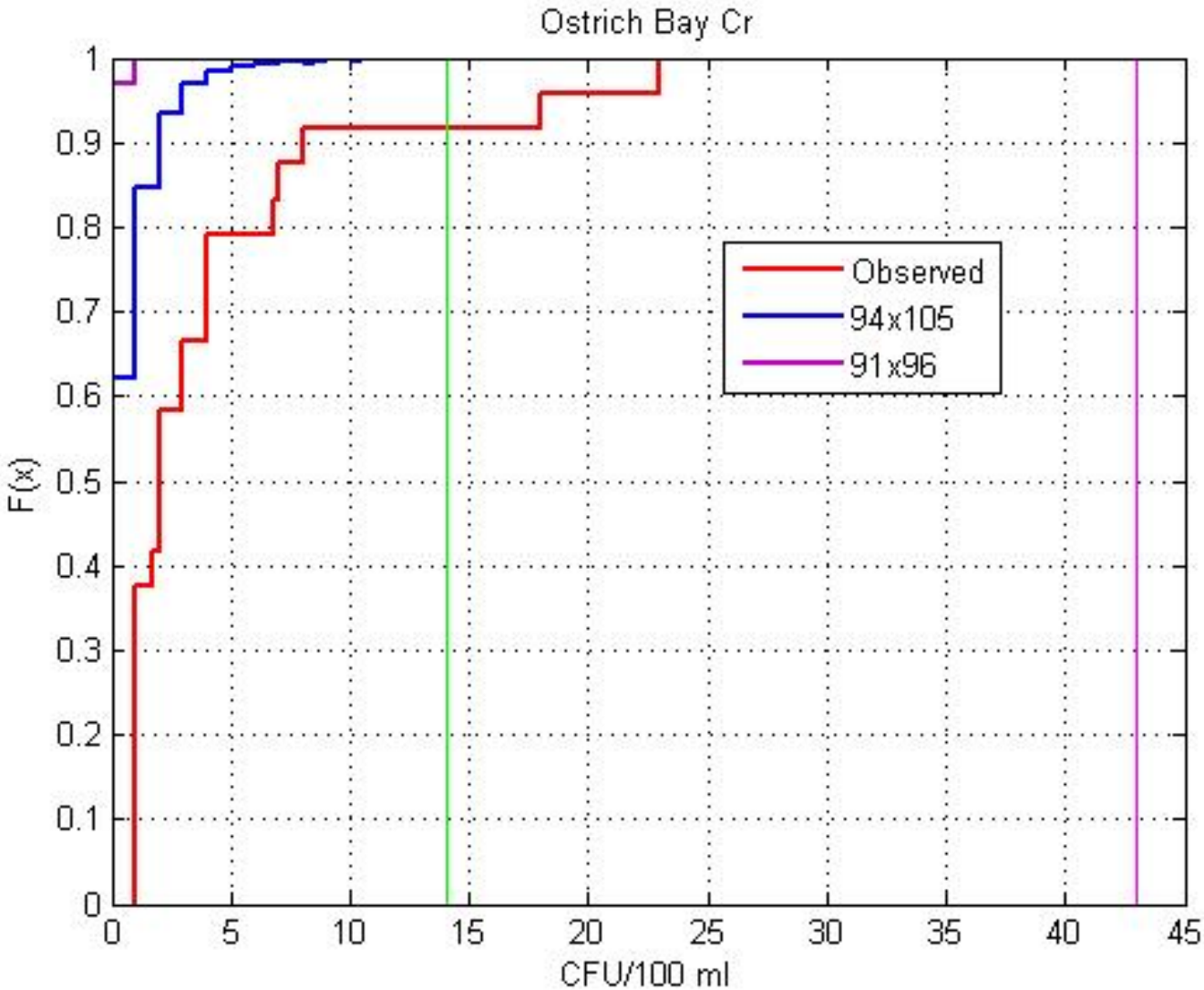
Cumulative Distribution Function – Clear Cr.



Gorst Creek


Gorst Cr
F(x)
CFU/100 ml
Observed
94x105
91x96
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35
40
45

Ostrich Bay Creek



Evaluation Criteria for CH3D-FC Simulation of WY2003

Based on the observed data available to compare to the model output for the selected "canary" nodes.

Comparison of Means between Observed and Predicted

Frequency of Exceeding Standard (14 cfu/100 ml; 43 cfu/100 ml)

Comparison of Cumulative Density Function

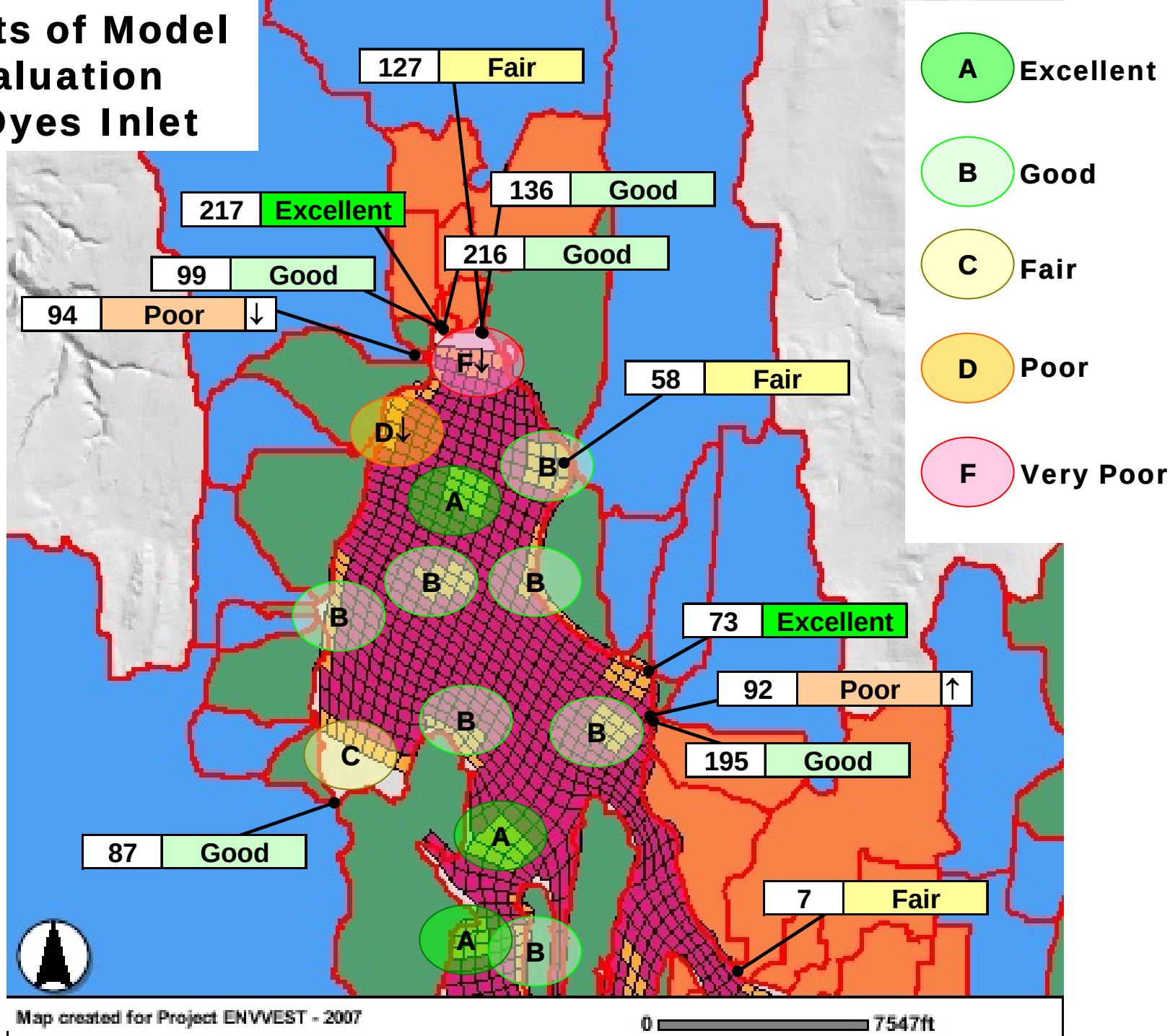
Comparison of the root mean square error (RMSE) between the observed (Obs(i)) and predicted (Pred(i)) values averaged over the number of observations (n)

The magnitude of the RMSE was used to evaluate the goodness of fit for those points by using cutoff values based on the geometric progression of e:

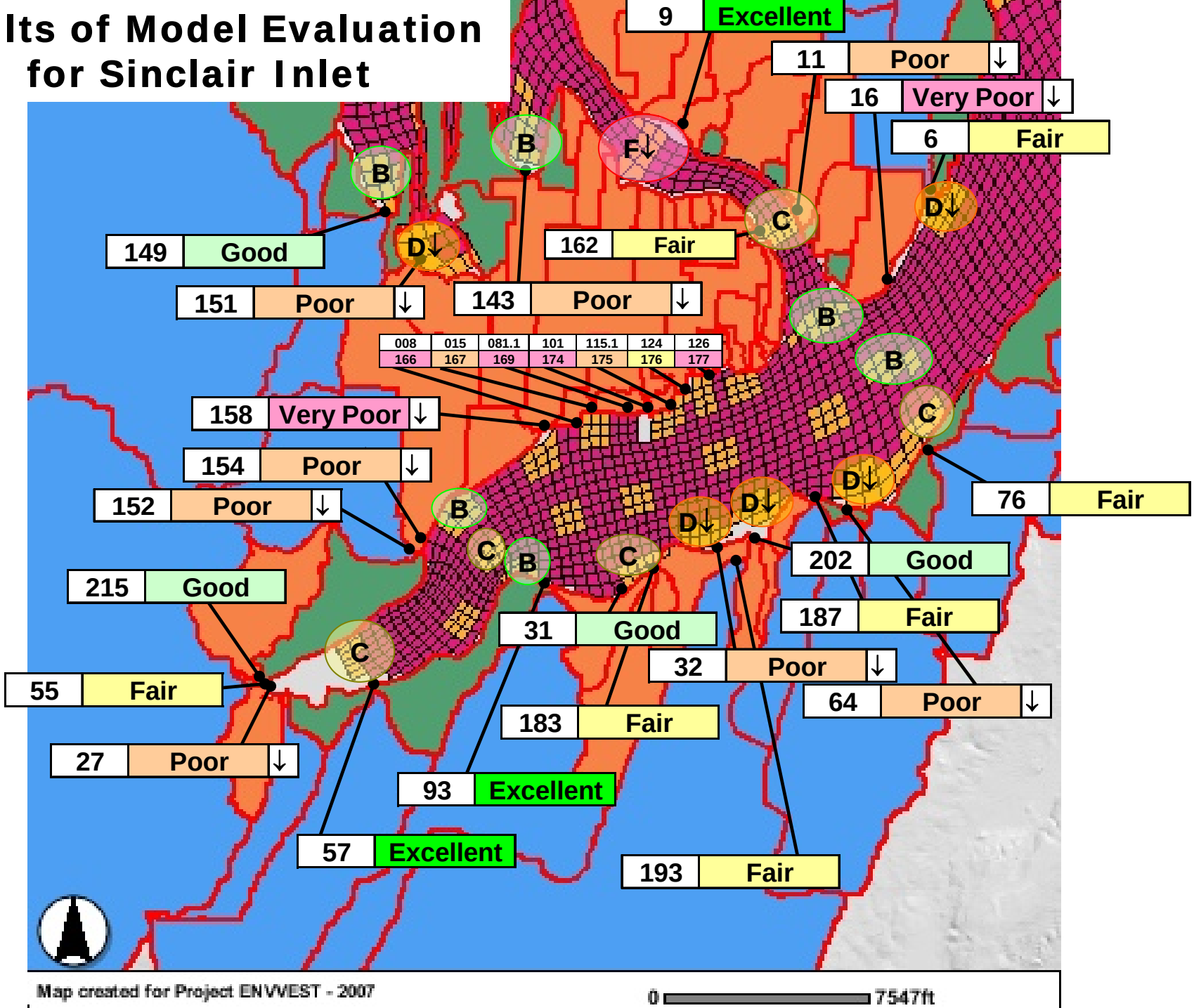
		RSME <=
EXCELLENT	e	2.72
GOOD	e^2	7.39
FAIR	e^3	20.09
POOR	e^4	54.60
VERY POOR	e^4	>54.60

	Predicted: Run08 91x96			Predicted: Run07 94x105			Comparison of Grids
	RMSE			RMSE			
	Avg of Error		Geomean	Avg of Error		Geomean	Comment
Group	arith		Predicts	arith	Rating	Predicts	result of finer resoultion grid
01-Dyes-Barker-Cr-	5.5	GOOD	SAME	5.38	GOOD	SAME	no change
02-Dyes-Chico-Cr--	16.9	FAIR	UNDER	26.84	POOR	UNDER	worsened slightly
03-Dyes-Clear-Cr--	170.5	VERY POOR	UNDER	45.17	POOR	SAME	very improved
04-Dyes-DY24-Straw	40.9	POOR	UNDER	39.96	POOR	SAME	no change
05-Dyes-DY28-ClamI	2.5	EXCELLENT	SAME	2.35	EXCELLENT	SAME	no change
07-Dyes-ErlandsPt-	6.7	GOOD	SAME	6.68	GOOD	SAME	no change
08-Dyes-M5-RockyPt	3.7	GOOD	UNDER	3.69	GOOD	UNDER	no change
09-Dyes-M7-MidWind	2.7	GOOD	SAME	2.92	GOOD	SAME	no change
10-Dyes-Windy-Pt--	7.0	GOOD	SAME	6.98	GOOD	SAME	no change
11-Dyes-wShore----	3.3	GOOD	SAME	3.17	GOOD	SAME	no change
12-Ostrich-Bay-M6-	2.5	EXCELLENT	SAME	2.78	GOOD	SAME	no change
13-Ostrich-eShore-	2.8	GOOD	SAME	2.82	GOOD	SAME	no change
14-Ostrich-JackPar	2.4	EXCELLENT	SAME	2.41	EXCELLENT	SAME	no change
15-Ostrich-OBCreek	6.4	GOOD	UNDER	6.33	GOOD	SAME	no change
16-OysterBay-all--	27.2	POOR	UNDER	13.27	FAIR	UNDER	improved
17-PhinnyBay-sEnd-	4.8	GOOD	UNDER	5.85	GOOD	UNDER	no change
18-POP-SN17-Waterm	6.3	GOOD	SAME	6.32	GOOD	SAME	no change
19-POP-Dee-Cr-----	40.6	POOR	UNDER	40.61	POOR	UNDER	no change
20-POP-IllaheeSPCr	1.9	EXCELLENT	SAME	1.86	EXCELLENT	SAME	no change
21-POP-M1-MidChann	4.4	GOOD	SAME	2.00	EXCELLENT	SAME	improved slightly
22-POP-PO11-------	3.1	GOOD	SAME	3.06	GOOD	SAME	no change
23-POPASS-PO12----	2.1	EXCELLENT	SAME	2.05	EXCELLENT	SAME	no change
24-POP-SpringBroCr	5.0	GOOD	UNDER	5.00	GOOD	UNDER	no change
31-PWN-DY01-mouth-	2.9	GOOD	SAME	2.92	GOOD	SAME	no change
32-PWN-EvergrnPark	10.1	FAIR	UNDER	10.09	FAIR	UNDER	no change
33-PWN-AnCov-PineR	436.9	VERY POOR	UNDER	436.84	VERY POOR	UNDER	no change
34-RPass-ClamBay--	11.4	FAIR	UNDER	11.38	FAIR	UNDER	no change
35-RPass-FortWard-	374.9	VERY POOR	UNDER	374.92	VERY POOR	UNDER	no change
36-RPass-LynhwoodC	107.6	VERY POOR	UNDER	107.71	VERY POOR	UNDER	no change
37-RPass-M2-midChn	1.6	EXCELLENT	SAME	1.62	EXCELLENT	SAME	no change
38-RPas-SN18-Entra	4.1	GOOD	SAME	4.07	GOOD	SAME	no change
43-Sin-Gorst-Creek	7.9	FAIR	SAME	10.65	FAIR	OVER	worsened slightly
44-Sinclair-M3-mid	4.3	GOOD	SAME	4.33	GOOD	SAME	no change
45-Sinclair-M4-mid	9.3	FAIR	UNDER	9.80	FAIR	UNDER	no change
47-Sin-RossPt-SN08	5.7	GOOD	SAME	5.74	GOOD	SAME	no change
48-Sinclair-SaccoC	16.5	FAIR	SAME	16.47	FAIR	SAME	no change
49-Sin-SN03-PTOW--	6.0	GOOD	SAME	6.14	GOOD	SAME	no change
50-SinPO-BlackJ-Cr	41.4	POOR	UNDER	41.96	POOR	UNDER	no change
51-SinPO-KarcherCr	39.3	POOR	UNDER	39.83	POOR	UNDER	no change
52-SinPO-SN10-wfro	12.9	FAIR	UNDER	13.40	FAIR	UNDER	no change
53-Sin-SN11-12mari	20.4	POOR	UNDER	20.48	POOR	UNDER	no change

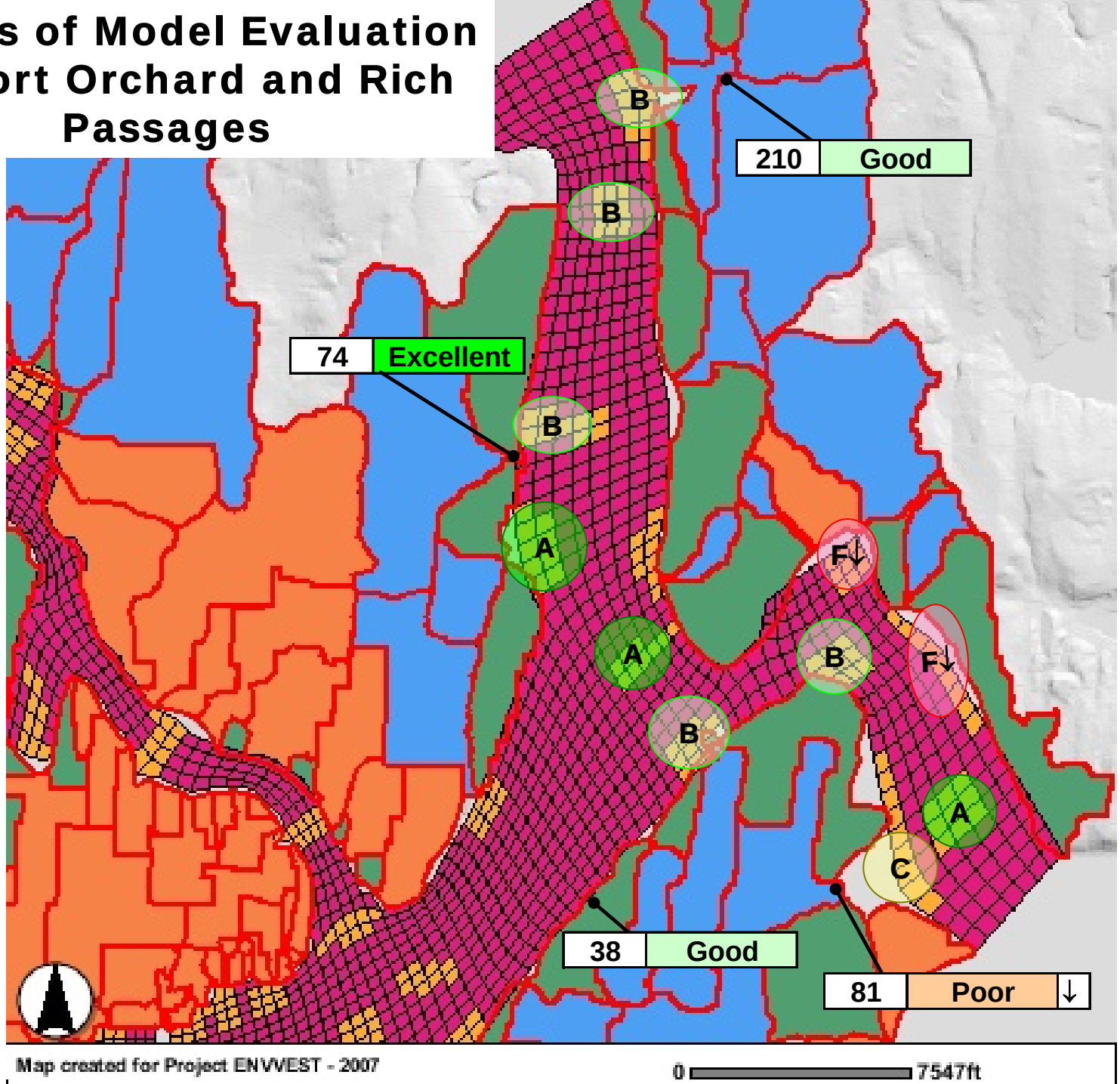
Results of Model Evaluation for Dyes Inlet



Results of Model Evaluation for Sinclair Inlet



Results of Model Evaluation for Port Orchard and Rich Passages



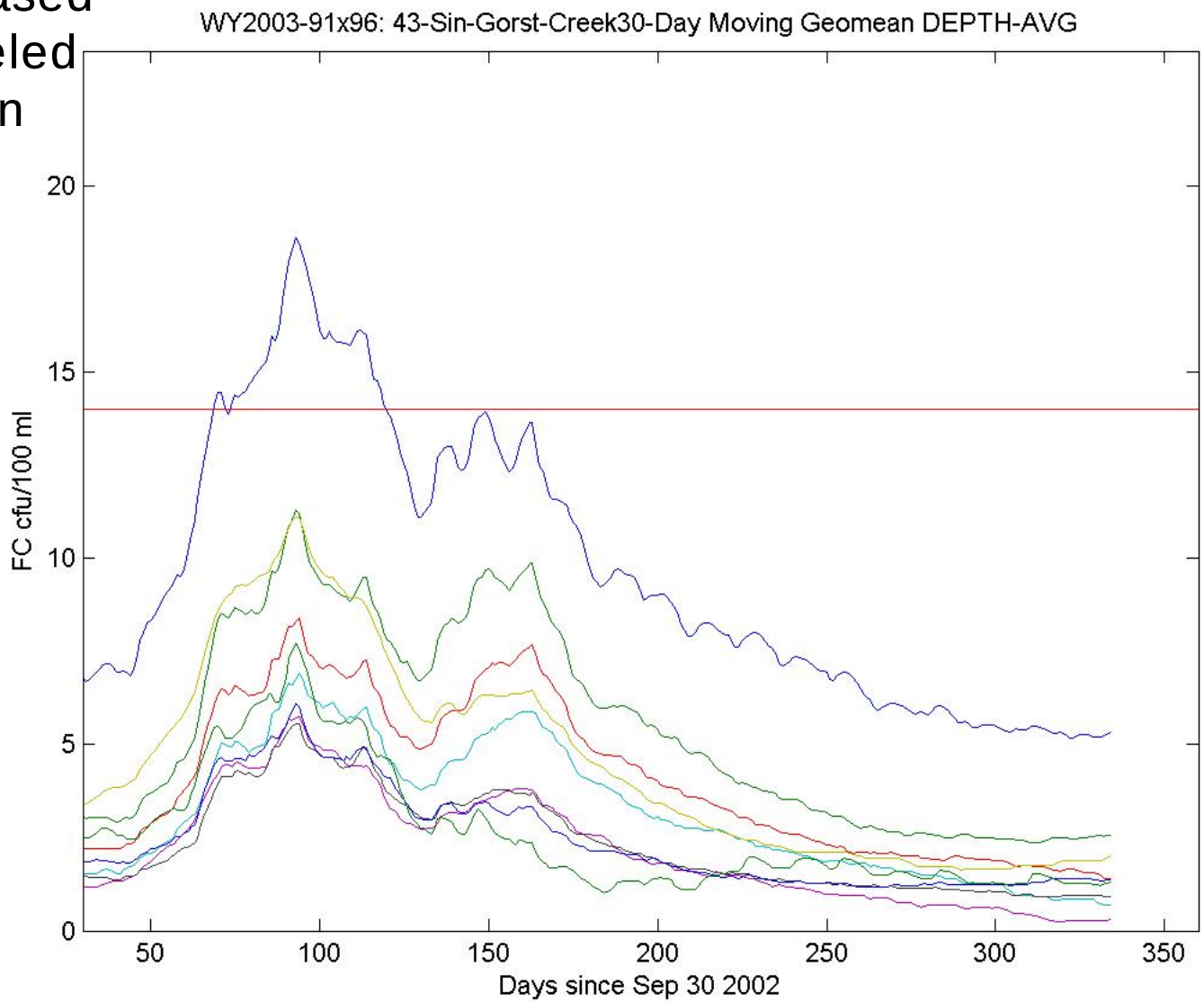
Model Runs Completed

Simulation	FC Loading	Grid	Purpose
April 19-20, 2004	25th Percentile	96x105	Verification
April 19-20, 2004	Geomean	96x105	Verification
April 19-20, 2004	75th Percentile	96x105	Verification
May 26-27, 2004	25th Percentile	96x105	Verification
May 26-27, 2004	Geomean	96x105	Verification
May 26-27, 2004	75th Percentile	96x105	Verification
Oct 18-19, 2004	25th Percentile	96x105	Verification
Oct 18-19, 2004	Geomean	96x105	Verification
Oct 18-19, 2004	75th Percentile	96x105	Verification
WY2003	Geomean	96x105	Verification
WY2003	Geomean	91x94	Critical Conditions
WY2003:100/200	Geomean	91x94	Standard Part 1
WY2003:200/400	Geomean	91x94	Standard Part 2

- Sensitivity Analysis
- Future Scenario

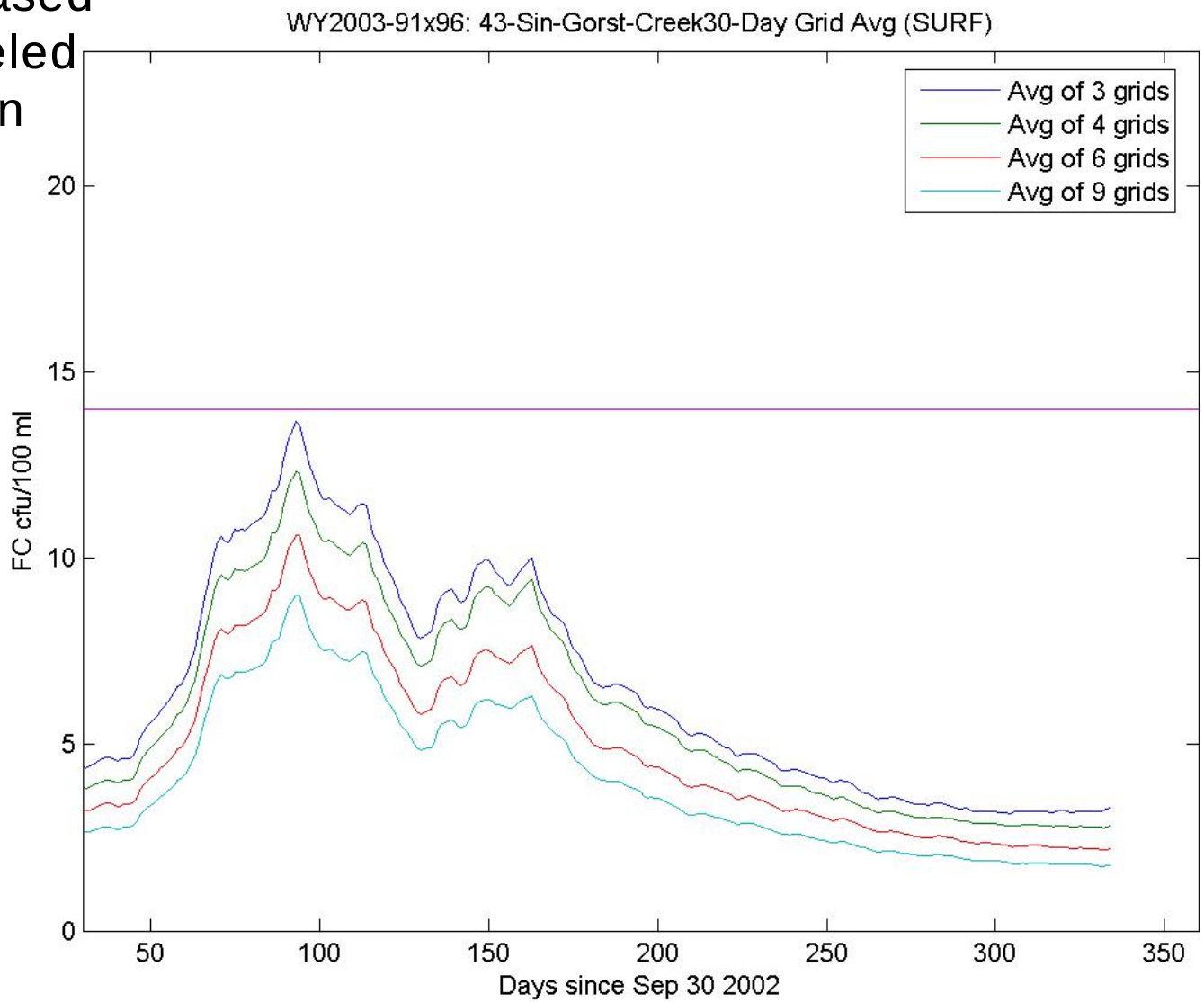
Gorst Creek 30-day Geomean
(WY2003 Simulated)

Loads based on modeled Geomean



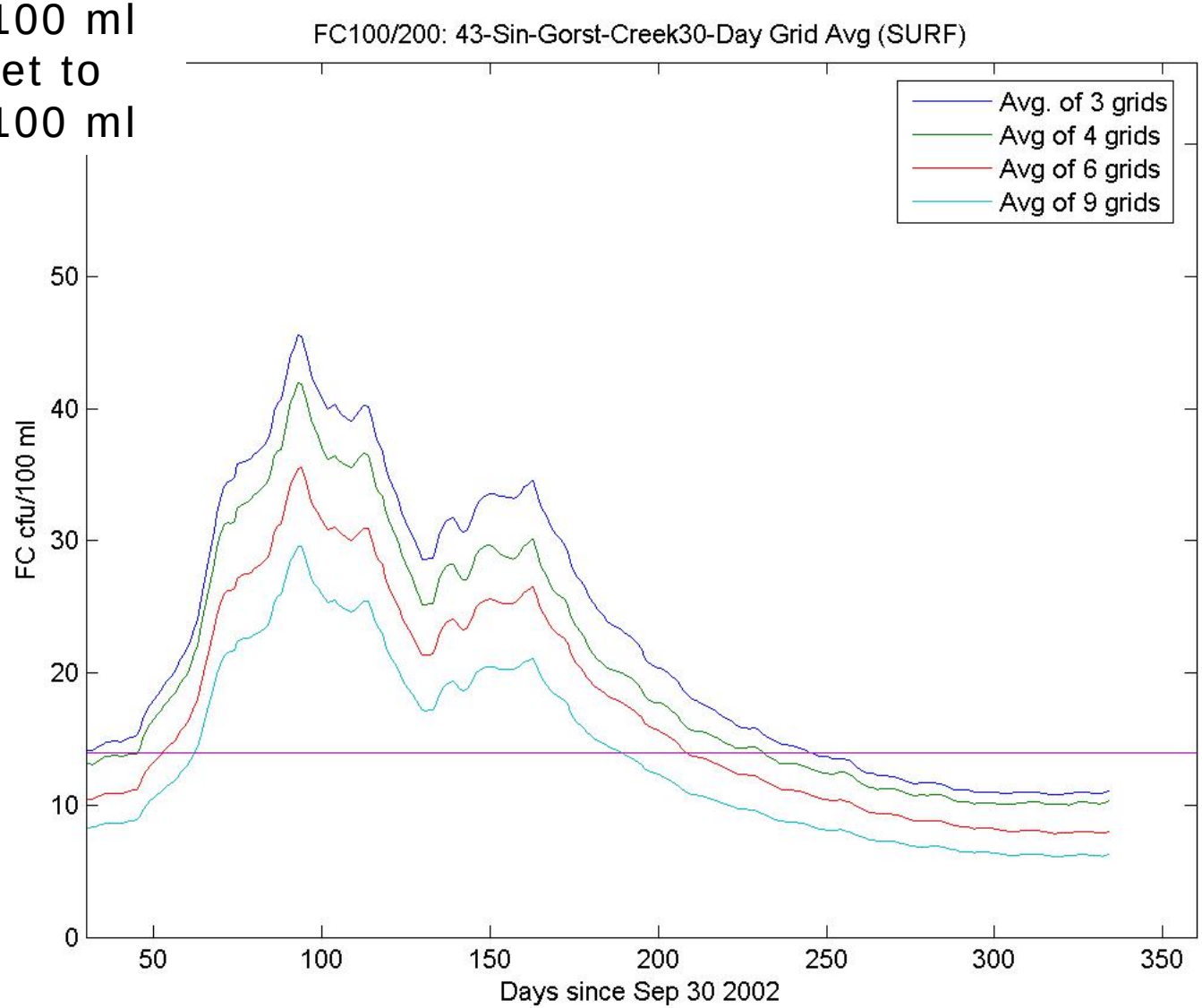
Gorst Creek 30-day Geomean
(WY2003 Simulated – Average by Grids)

Loads based on modeled Geomean



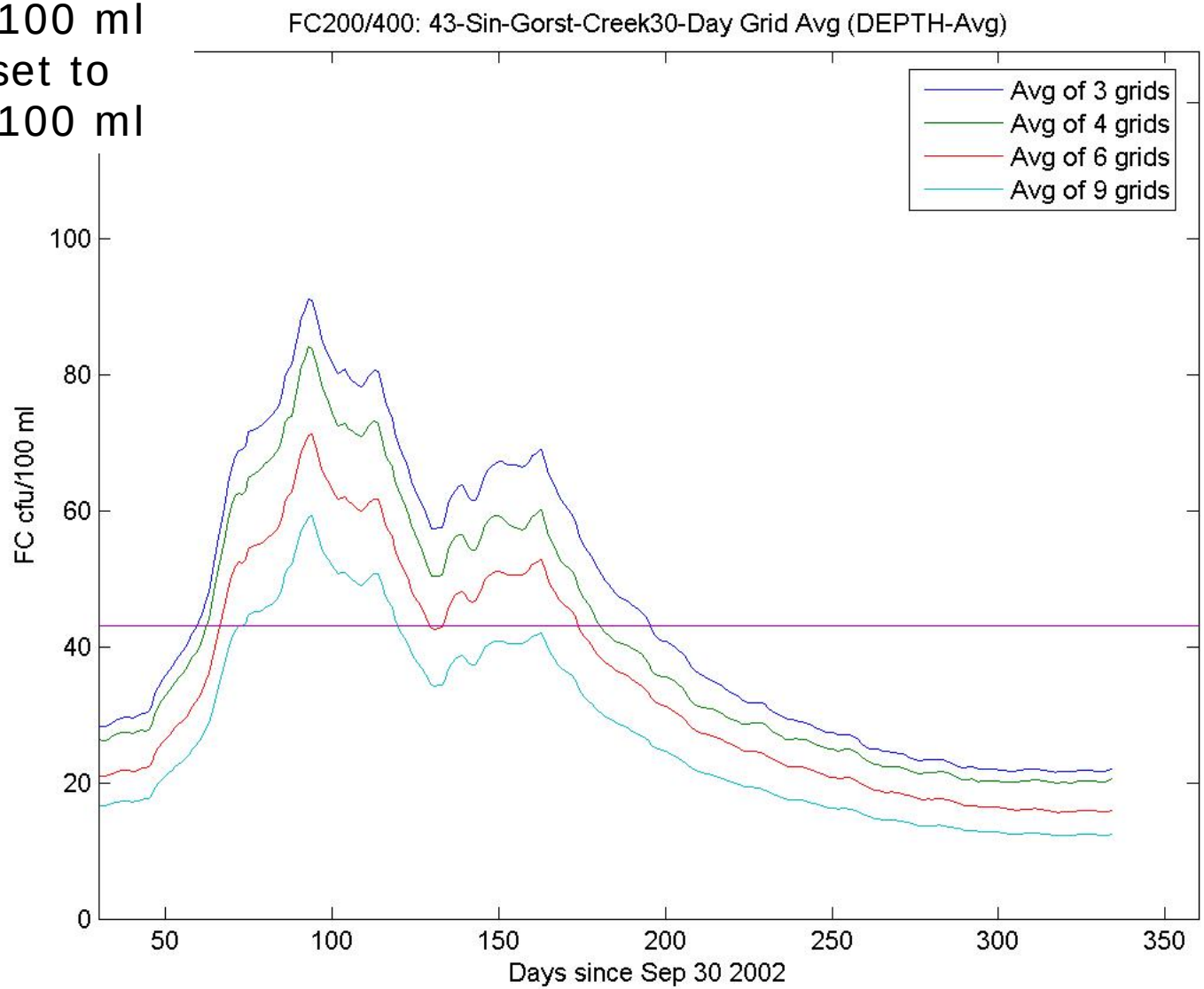
Gorst Creek 30-day Geomean (WY2003_100/200 Simulated)

Steams set to 100 cfu/100 ml
WWTPs set to 200 cfu/100 ml



Gorst Creek 30-day 90th Percentile (WY2003_200/400 Simulated)

Steams set to 200 cfu/100 ml
WWTPs set to 400 cfu/100 ml



Next Steps

- **Model Results are Under Review**
  - **Ecology**
  - **Technical Stakeholders**
- **Complete Analysis of Model Results for TMDL**
- **Sensitivity Analysis**
- **Uncertainty Analysis**
- **Complete Modeling Study Report**

CH3D-FC Simulations

#	Simulation	Watershed Hydrology	FC Loading	Grid	Sensitivity	Purpose
1	April 19-20, 2004	1.00	25th Percentile	96x105		Verification
2	April 19-20, 2004	1.00	Geomean	96x105		Verification
3	April 19-20, 2004	1.00	75th Percentile	96x105		Verification
4	May 26-27, 2004	1.00	25th Percentile	96x105	Low Estimate for FC Loading	Verification
5	May 26-27, 2004	1.00	Geomean	96x105	**Base Model (average loading)**	Verification
6	May 26-27, 2004	1.00	75th Percentile	96x105	High Estimate for FC Loading	Verification
7	Oct 18-19, 2004	1.00	25th Percentile	96x105		Verification
8	Oct 18-19, 2004	1.00	Geomean	96x105		Verification
9	Oct 18-19, 2004	1.00	75th Percentile	96x105		Verification
10	WY2003	1.00	Geomean	96x105		Verification
11	WY2003	1.00	Geomean	91x94		Critical Conditions
12	WY2003:100/200	1.00	Geomean	91x94		Standard Part 1
13	WY2003:200/400	1.00	Geomean	91x94		Standard Part 2
14	May 26-27, 2004	1.20	Geomean	96x105	Increase Flow by 20%	Sensitivity
15	May 26-27, 2004	2.00	Geomean	96x105	Increase Flow by 100%	Sensitivity
16	May 26-27, 2004	1.00	Geomean	96x105	Wind	Sensitivity
17	May 26-27, 2004	1.00	Geomean	96x105	No FC dieoff	Sensitivity
18	May2020 Build Out	N. Dyes/1.00	N. Dyes Future/Geomean	96x105	Future Flow and average FC for N. Dyes	Future Conditions
19	May2020 Build Out	N. Dyes/1.00	N. Dyes Future/25th Percentile	96x105	Future Flow and low FC for N. Dyes	Future Conditions
20	May2020 Build Out	N. Dyes/1.00	N. Dyes Future/75th Percentile	96x105	Future Flow and high FC for N. Dyes	Future Conditions

Acknowledgements

Thank You!

Brian Skahill, ERDC
Chris May & Valerie Cullinan, BMSL
PF Wang, Woohee Choi, Erin Carlson, Amy Blake, Ken Richter, Marissa Brand, & Chris Kyburg SSC-SD
Vickie Whitney, Dwight Leisle, Bruce Beckwith, & Jerry Sherrell PSNS&IMF
Mindy Roberts, Ecology
And other members of the ENVVEST Technical Working Group

Links

Link to CH3D-FC Simulation Results Page

https://www.mesodat.org/envvest/Modelling/Sinclair_Dyes/CH3D-FC/01_FC_Simulations.html

Link to ENVVEST Spatial Viewer

https://boris.mesodat.org/website/development

Link to Ecology's Sinclair/Dyes Inlet Web Site

http://www.ecy.wa.gov/programs/wq/tmdl/sinclair-dyes_inlets/index.html