

Model Archive Summary for Hardness at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the hardness (HARD) model developed to compute hourly HARD from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas; Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 1, 1998 to August 7, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 220 concurrent measurements of hardness, streamflow, and SC collected from May 1, 1998 through August 7, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions.

Summary statistics and the complete model-calibration data set are provided below. None of the samples were below laboratory reporting levels. Potential outliers were identified where Studentized residuals were greater than 3 or less than negative 3 and Cook's D values exceeded the outlier test criteria. A sample collected June 9, 2005 was deemed an outlier and was removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating hardness. A variety of models that predict HARD and models that predict $\log_{10}(\text{HARD})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted HARD were

examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{HARD})$.

Specific conductance was selected as the best predictor of HARD based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for hardness at site number 07144100.

Hardness-based model:

$$\log_{10}(\text{HARD}) = 1.04 \times \log_{10}(\text{SC}) - 0.607,$$

where

HARD = hardness in milligrams per liter as calcium carbonate (mg/L CaCO_3); and,

SC = specific conductance, in microsiemens per centimeter ($\mu\text{S}/\text{cm}$) at 25 degrees Celsius.

Specific conductance makes physical and statistical sense as an explanatory variable for hardness. It makes physical sense because hardness, in this case, is reported as a concentration of calcium carbonate (CaCO_3). CaCO_3 is composed of major ions, which affect the conductivity of water. This correlates well with SC because SC is a measure of the conductivity of water. Specific conductance makes statistical sense as an explanatory variable because it resulted in a model with low standard error, Mallows' C_p and $PRESS$ values, and high R^2 values. The multiple-linear regression model with SC and Q as explanatory variables was considered but, ultimately, discarded because the model only reduced the model standard error 5 percent.

The log-transformed model may be retransformed to the original units so that HARD can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.01. The retransformed model, accounting for BCF is:

$$\text{HARD} = 0.2496 \times \text{SC}^{1.04}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\text{HARD} = 0.318 \times \text{SC} + 0.442$
2.0	2007	--	$\log_{10}(\text{HARD}) = 1.04 \times \log_{10}(\text{SC}) - 0.607$

Hardness Record

The HARD record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

Computed: Patrick Eslick

Model Statistics, Data, and Plots

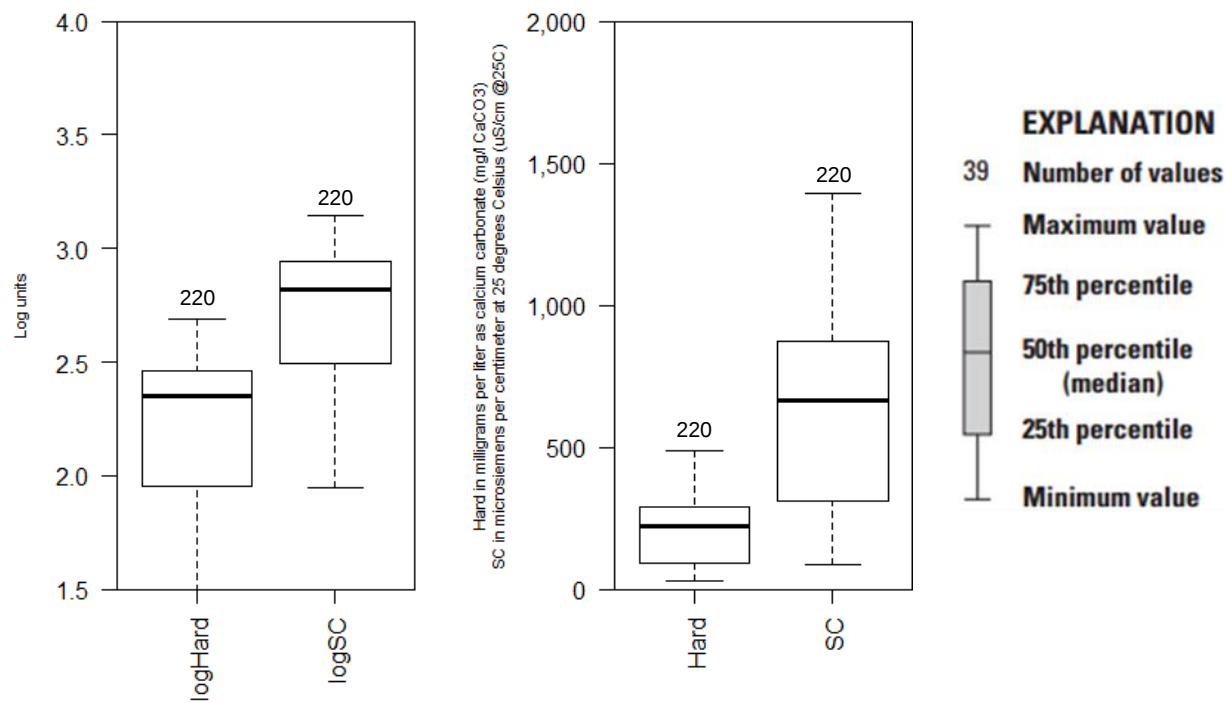
Model

$$\text{logHard} = + 1.04 * \text{logSC} + -0.607$$

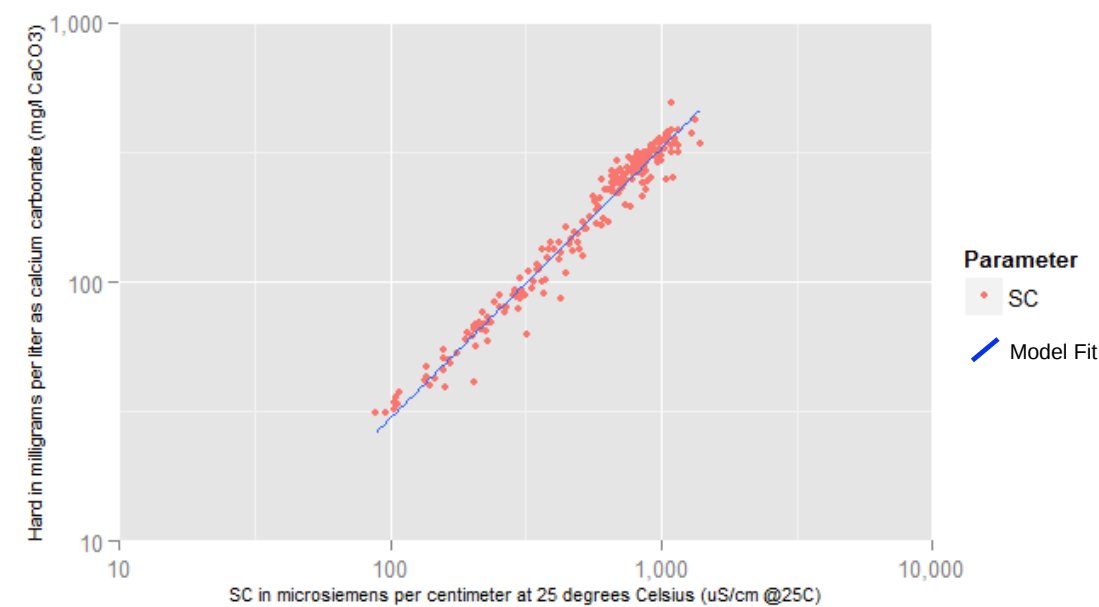
Variable Summary Statistics

	logHard	logSC	Hard	SC
Minimum	1.49	1.95	31.0	88.2
1st Quartile	1.96	2.49	90.4	311.0
Median	2.35	2.82	224.0	663.0
Mean	2.22	2.71	202.0	618.0
3rd Quartile	2.46	2.94	292.0	872.0
Maximum	2.69	3.14	487.0	1390.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	220
Standard error (RMSE)	0.0534
Upper Model standard percentage error (MSPE)	13.1
Lower Model standard percentage error (MSPE)	11.6
Coefficient of determination (R ²)	0.969
Adjusted Coefficient of Determination (Adj. R ²)	0.969
Bias Correction Factor (BCF)	1.01

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-0.607	0.0344	-17.7	6.44e-44
logSC	1.040	0.0126	82.7	1.50e-166

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.994
E.vars	-0.994	1.000

Outlier Test Criteria

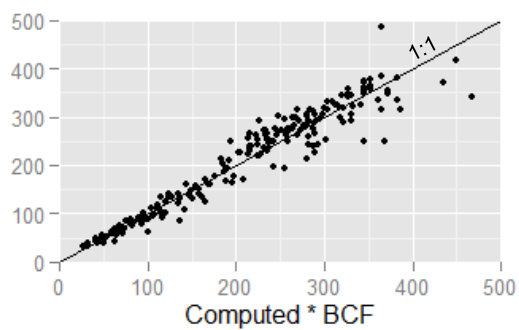
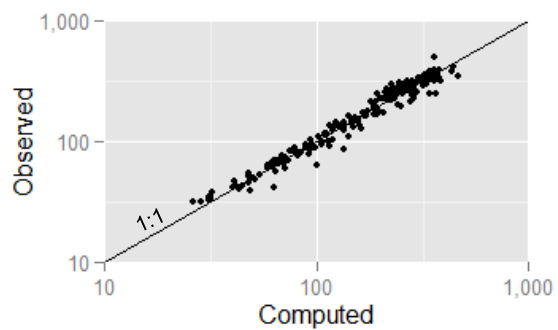
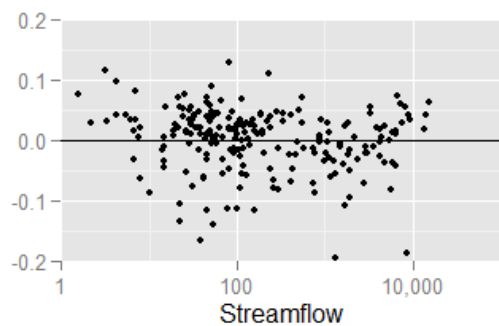
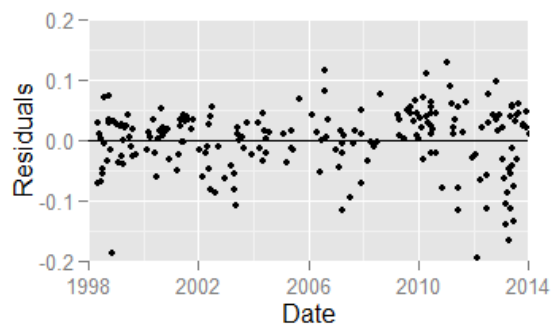
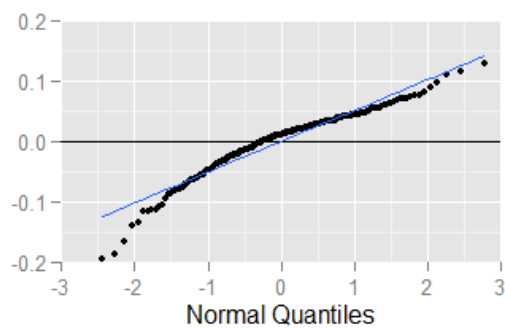
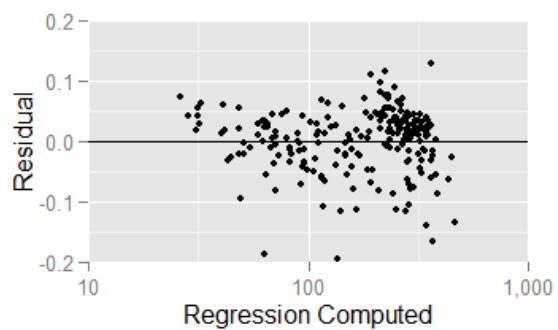
Leverage	Cook's D	DFFITS
0.01363636	0.10541122	0.13483997

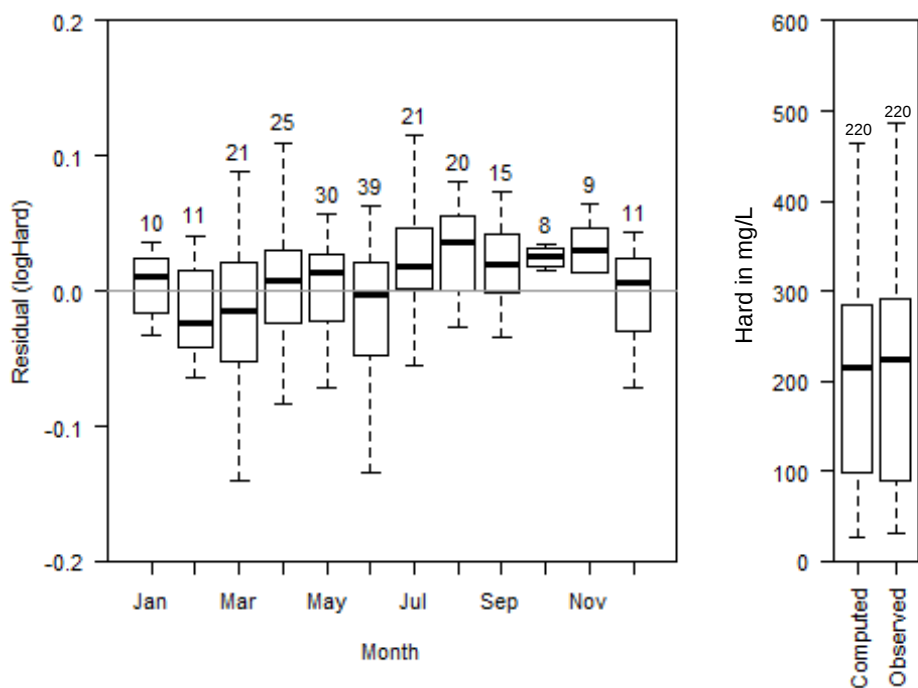
Flagged Observations

	logHard	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
5/14/1998 9:26	1.799	2.000	-0.200400		-3.76500		-3.88500	0.006983	4.984e-02	-0.325800
9/22/1998 10:16	1.829	1.796	0.033570		0.63270		0.63180	0.013680	2.776e-03	0.074410
9/25/1998 10:11	1.491	1.419	0.072840		1.39000		1.39300	0.037310	3.741e-02	0.274100

10/5/1998 10:21	1.530	1.503	0.027520	0.52330	0.52240	0.030770	4.347e-03	0.093090
11/5/1998 13:45	1.612	1.799	-0.187100	-3.52600	-3.62200	0.013550	8.536e-02	-0.424500
3/16/1999 13:41	2.621	2.649	-0.027590	-0.52010	-0.51930	0.014070	1.930e-03	-0.062030
4/16/1999 11:16	1.788	1.790	-0.001803	-0.03399	-0.03391	0.013930	8.162e-06	-0.004031
7/20/1999 10:46	1.722	1.733	-0.011130	-0.21000	-0.20960	0.016600	3.724e-04	-0.027230
8/3/1999 11:51	1.624	1.650	-0.026200	-0.49570	-0.49480	0.021050	2.642e-03	-0.072560
6/6/2001 10:11	1.497	1.456	0.040870	0.77850	0.77780	0.034300	1.076e-02	0.146600
6/23/2001 11:16	1.700	1.703	-0.003410	-0.06441	-0.06427	0.018120	3.829e-05	-0.008731
9/20/2001 10:21	1.633	1.617	0.016650	0.31530	0.31460	0.023070	1.173e-03	0.048340
6/13/2002 9:31	1.768	1.850	-0.082250	-1.54900	-1.55400	0.011480	1.392e-02	-0.167400
12/18/2002 10:36	2.571	2.635	-0.064520	-1.21600	-1.21700	0.013470	1.010e-02	-0.142300
5/14/2003 10:01	1.957	2.065	-0.107400	-2.01600	-2.03000	0.005750	1.175e-02	-0.154400
10/14/2003 11:01	1.801	1.773	0.028010	0.52830	0.52740	0.014700	2.082e-03	0.064430
7/27/2004 9:46	1.619	1.607	0.012190	0.23090	0.23040	0.023680	6.466e-04	0.035880
7/27/2006 11:16	2.465	2.350	0.114900	2.15700	2.17500	0.005448	1.274e-02	0.161000
3/27/2007 11:46	2.033	2.149	-0.115600	-2.17000	-2.18800	0.004788	1.132e-02	-0.151800
4/2/2007 11:51	1.686	1.707	-0.021500	-0.40610	-0.40530	0.017910	1.504e-03	-0.054740
7/11/2007 12:11	1.594	1.690	-0.095270	-1.80000	-1.81000	0.018850	3.113e-02	-0.250800
9/9/2009 12:01	1.737	1.682	0.054900	1.03800	1.03800	0.019250	1.057e-02	0.145400
4/23/2010 10:01	2.396	2.286	0.110100	2.06600	2.08100	0.004785	1.026e-02	0.144300
6/9/2010 9:46	1.660	1.682	-0.021960	-0.41500	-0.41420	0.019270	1.693e-03	-0.058070
6/13/2010 15:21	1.553	1.499	0.053960	1.02600	1.02600	0.031060	1.687e-02	0.183700
6/14/2010 9:41	1.574	1.512	0.062340	1.18500	1.18600	0.030110	2.179e-02	0.209000
6/15/2010 9:21	1.777	1.768	0.008878	0.16740	0.16710	0.014930	2.124e-04	0.020570
6/16/2010 9:11	1.819	1.797	0.022170	0.41780	0.41700	0.013640	1.206e-03	0.049030
7/6/2010 9:01	1.511	1.493	0.017580	0.33430	0.33360	0.031490	1.817e-03	0.060160
1/19/2011 11:41	2.688	2.560	0.128000	2.40800	2.43600	0.010530	3.088e-02	0.251300
6/22/2011 10:21	2.326	2.443	-0.116900	-2.19600	-2.21500	0.007151	1.736e-02	-0.188000
3/1/2012 12:01	1.936	2.131	-0.195000	-3.66000	-3.76900	0.004931	3.319e-02	-0.265300
6/19/2012 9:01	2.100	2.215	-0.114500	-2.14800	-2.16700	0.004546	1.054e-02	-0.146400
3/12/2013 11:00	2.352	2.459	-0.106500	-2.00000	-2.01400	0.007520	1.516e-02	-0.175300
3/13/2013 9:16	2.394	2.535	-0.140900	-2.65000	-2.68700	0.009715	3.444e-02	-0.266200
3/27/2013 11:36	2.497	2.584	-0.086620	-1.63100	-1.63700	0.011400	1.534e-02	-0.175800
4/15/2013 9:00	2.398	2.564	-0.165700	-3.11800	-3.18300	0.010680	5.247e-02	-0.330600
5/6/2013 11:00	2.290	2.402	-0.112300	-2.10900	-2.12600	0.006292	1.409e-02	-0.169200
6/24/2013 9:40	2.533	2.666	-0.133700	-2.52100	-2.55200	0.014870	4.793e-02	-0.313500
7/29/2013 10:40	1.599	1.632	-0.033000	-0.62470	-0.62380	0.022160	4.421e-03	-0.093900
8/7/2013 9:46	1.534	1.493	0.040640	0.77300	0.77230	0.031460	9.704e-03	0.139200
8/15/2013 9:10	1.675	1.614	0.060460	1.14500	1.14600	0.023220	1.558e-02	0.176700
6/12/2014 11:40	1.703	1.682	0.021100	0.39870	0.39800	0.019260	1.561e-03	0.055760

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logHard ~ logSC	1	0.05343	96.91	96.89	28.56	0.6333	1 ± 12	
logHard ~ SC	1	0.101	88.95	88.9	657.8	2.283	1 ± 23	
logHard ~ logQ	1	0.1602	72.2	72.07	1983	5.704	1 ± 38	
logHard ~ logQ + logSC	2	0.05057	97.24	97.22	4.128	0.57	3.221 ± 12	
logHard ~ logSC + SC	2	0.05355	96.91	96.88	30.55	0.6419	12.27 ± 12	
logHard ~ Q + logSC	2	0.05355	96.91	96.88	30.56	0.6415	2.191 ± 12	
logHard ~ Q + logQ + logSC	3	0.05032	97.28	97.24	3	0.5669	2.457 ± 12	
logHard ~ logQ + logSC + SC	3	0.05058	97.25	97.22	5.183	0.5755	3.36 ± 12	
logHard ~ Q + logSC + SC	3	0.05367	96.91	96.87	32.55	0.6517	3.222 ± 12	
logHard ~ Q + logQ + logSC + SC	4	0.05044	97.28	97.23	5	0.5759	3.466 ± 12	

Model-Calibration Data Set

0	Date	logHard	logSC	Hard	SC	Computed logHard	Computed Hard	Residual	Normal Quantiles	Censored Values
1	1998-05-01	2.382	2.94	241	871.2	2.454	286.6	-0.0721	-1.32	--
2	1998-05-06	2.447	2.906	280	804.5	2.418	263.8	0.0291	0.53	--
3	1998-05-11	2.502	2.96	318	912	2.475	300.6	0.0276	0.492	--
4	1998-05-14	1.799	2.504	63	318.9	2	100.7	-0.2	-2.78	--
5	1998-05-27	2.45	2.926	282	844	2.44	277.3	0.0105	-0.0285	--
6	1998-06-16	2.461	2.943	289	877.9	2.458	288.9	0.00335	-0.189	--
7	1998-06-24	2.217	2.779	165	601.2	2.286	194.8	-0.0689	-1.27	--
8	1998-07-10	1.748	2.315	56	206.7	1.804	64.1	-0.0556	-1.08	--
9	1998-07-13	1.947	2.5	88.6	316	1.996	99.7	-0.0482	-0.988	--
10	1998-07-20	2.328	2.751	213	564.1	2.258	182.3	0.0708	1.71	--

11	1998-08-06	2.422	2.914	264	819.7	2.427	268.9	-0.00494	-0.342	--
12	1998-09-15	2.413	2.933	259	857.4	2.447	281.8	-0.0336	-0.817	--
13	1998-09-22	1.829	2.308	67.5	203.1	1.796	62.93	0.0336	0.667	--
14	1998-09-25	1.491	1.945	31	88.18	1.419	26.4	0.0728	1.76	--
15	1998-10-05	1.53	2.026	33.9	106.2	1.503	32.05	0.0275	0.466	--
16	1998-10-22	2.114	2.629	130	425.9	2.13	136	-0.0166	-0.517	--
17	1998-11-05	1.612	2.311	40.9	204.5	1.799	63.38	-0.187	-2.26	--
18	1998-12-04	2.403	2.862	253	728.3	2.373	237.8	0.03	0.544	--
19	1999-01-12	2.584	3.041	384	1100	2.56	365.3	0.0248	0.391	--
20	1999-02-01	1.943	2.486	87.8	306.3	1.981	96.52	-0.038	-0.882	--
21	1999-02-19	2.558	3.017	361	1040	2.534	344.6	0.0233	0.367	--
22	1999-03-16	2.621	3.127	418	1340	2.649	448.6	-0.0276	-0.725	--
23	1999-03-23	2.584	3.041	384	1100	2.56	365.3	0.0248	0.403	--
24	1999-04-07	2.086	2.625	122	421.7	2.126	134.6	-0.0397	-0.899	--
25	1999-04-16	1.788	2.302	61.4	200.5	1.79	62.1	-0.0018	-0.271	--
26	1999-05-05	2.438	2.905	274	804.1	2.418	263.6	0.0199	0.259	--
27	1999-05-24	1.837	2.324	68.7	211	1.813	65.48	0.024	0.379	--
28	1999-06-18	2.013	2.477	103	300.3	1.972	94.54	0.0404	0.849	--
29	1999-06-21	1.839	2.344	69	220.7	1.833	68.61	0.00558	-0.143	--
30	1999-07-20	1.722	2.247	52.7	176.8	1.733	54.46	-0.0111	-0.403	--
31	1999-08-03	1.624	2.168	42.1	147.3	1.65	45.04	-0.0262	-0.71	--
32	1999-08-19	2.498	2.965	315	921.9	2.48	303.9	0.0187	0.201	--
33	1999-09-28	1.841	2.375	69.3	237.2	1.866	73.98	-0.0252	-0.695	--
34	2000-02-09	2.55	3.049	355	1118	2.567	371.7	-0.0168	-0.544	--
35	2000-03-07	1.965	2.458	92.3	287.4	1.953	90.33	0.0125	0.0285	--
36	2000-03-28	1.904	2.407	80.2	255.5	1.9	79.92	0.00462	-0.177	--
37	2000-05-19	2.575	3.025	376	1060	2.543	351.5	0.0324	0.611	--
38	2000-05-31	2.143	2.662	139	459.6	2.165	147.3	-0.0219	-0.625	--
39	2000-06-28	2	2.562	100	364.9	2.061	115.8	-0.0606	-1.17	--
40	2000-07-20	2.373	2.86	236	724.9	2.371	236.7	0.0019	-0.224	--
41	2000-07-28	2.061	2.548	115	353	2.046	111.9	0.015	0.143	--
42	2000-08-16	2.438	2.874	274	749	2.386	244.8	0.052	1.22	--
43	2000-09-08	2.447	2.927	280	846	2.441	277.9	0.00633	-0.108	--
44	2000-09-25	2.465	2.932	292	855.9	2.446	281.3	0.0193	0.224	--
45	2000-10-26	1.863	2.358	72.9	228	1.848	70.98	0.0147	0.108	--
46	2000-11-08	2.233	2.711	171	514.6	2.216	165.6	0.0169	0.177	--
47	2000-12-04	2.524	3.037	334	1088	2.555	361.2	-0.0309	-0.755	--
48	2001-03-14	1.971	2.525	93.5	335.3	2.022	106.1	-0.0516	-1.03	--
49	2001-04-13	2.207	2.725	161	531.3	2.231	171.3	-0.0237	-0.653	--
50	2001-04-26	2.533	2.994	341	986.6	2.51	326.2	0.0224	0.342	--
51	2001-05-08	2.364	2.821	231	662.5	2.33	215.5	0.0333	0.653	--
52	2001-06-04	1.956	2.465	90.3	291.9	1.96	91.81	-0.00408	-0.306	--
53	2001-06-06	1.497	1.981	31.4	95.82	1.456	28.79	0.0409	0.916	--
54	2001-06-23	1.7	2.219	50.1	165.5	1.703	50.86	-0.00341	-0.294	--
55	2001-07-11	2.452	2.909	283	811.1	2.422	266	0.03	0.557	--
56	2001-08-02	2.436	2.885	273	767.3	2.397	251.1	0.0395	0.817	--
57	2001-08-28	2.442	2.897	277	789	2.409	258.5	0.0332	0.638	--
58	2001-09-20	1.633	2.136	43	136.7	1.617	41.68	0.0166	0.166	--
59	2001-10-31	2.479	2.931	301	853	2.445	280.3	0.034	0.695	--
60	2002-01-10	2.513	3.014	326	1032	2.531	341.9	-0.0176	-0.557	--
61	2002-02-21	2.5	3.041	316	1100	2.56	365.3	-0.0599	-1.15	--
62	2002-04-09	2.477	2.983	300	960.7	2.498	317.3	-0.0212	-0.584	--

63	2002-04-22	1.904	2.423	80.2	264.9	1.916	82.98	-0.0117	-0.416	--
64	2002-05-13	2.246	2.786	176	611.6	2.294	198.3	-0.0486	-1.01	--
65	2002-05-22	2.152	2.625	142	422	2.126	134.8	0.0259	0.441	--
66	2002-06-06	2.127	2.589	134	388.1	2.088	123.5	0.0386	0.77	--
67	2002-06-13	1.768	2.36	58.6	229.1	1.85	71.33	-0.0823	-1.44	--
68	2002-07-09	2.423	2.857	265	720	2.368	235	0.0553	1.35	--
69	2002-08-15	2.294	2.872	197	744	2.383	243.1	-0.0883	-1.54	--
70	2002-09-19	2.358	2.857	228	720	2.368	235	-0.00998	-0.391	--
71	2002-12-18	2.571	3.114	372	1300	2.635	434.7	-0.0645	-1.22	--
72	2003-03-20	1.932	2.479	85.5	301.5	1.974	94.95	-0.0424	-0.916	--
73	2003-04-17	2.524	3.061	334	1150	2.58	382.6	-0.0559	-1.11	--
74	2003-04-23	2.233	2.808	171	642	2.316	208.5	-0.0831	-1.47	--
75	2003-05-14	1.957	2.566	90.6	368	2.065	116.9	-0.107	-1.66	--
76	2003-05-29	2.193	2.68	156	479	2.184	153.8	0.00942	-0.0512	--
77	2003-06-11	2.346	2.817	222	656	2.326	213.3	0.0205	0.271	--
78	2003-06-24	2.502	2.988	318	972	2.504	321.2	-0.00116	-0.247	--
79	2003-07-30	2.47	2.951	295	892.6	2.465	293.9	0.00475	-0.166	--
80	2003-09-03	1.904	2.425	80.2	265.9	1.917	83.29	-0.0133	-0.453	--
81	2003-10-14	1.801	2.286	63.2	193	1.773	59.68	0.028	0.517	--
82	2003-12-11	2.543	3.049	349	1120	2.568	372.2	-0.0249	-0.681	--
83	2004-03-09	1.844	2.328	69.9	212.8	1.817	66.08	0.0276	0.479	--
84	2004-03-30	2.505	3.003	320	1007	2.519	333.1	-0.0143	-0.479	--
85	2004-04-26	2.554	2.994	358	986.3	2.51	326.1	0.0437	1.01	--
86	2004-05-13	1.88	2.421	75.8	263.6	1.914	82.56	-0.034	-0.833	--
87	2004-05-26	2.549	3.017	354	1040	2.534	344.6	0.0148	0.12	--
88	2004-06-16	2.436	2.92	273	832	2.433	273.2	0.00287	-0.201	--
89	2004-06-22	1.905	2.433	80.3	270.8	1.926	84.89	-0.021	-0.57	--
90	2004-07-27	1.619	2.126	41.6	133.8	1.607	40.74	0.0122	0.0171	--
91	2005-01-27	2.049	2.542	112	348.7	2.04	110.5	0.00914	-0.0626	--
92	2005-03-23	1.807	2.355	64.1	226.3	1.845	70.44	-0.0378	-0.865	--
93	2005-05-10	2.29	2.769	195	587	2.276	190	0.0145	0.0969	--
94	2005-05-27	1.965	2.484	92.2	305	1.98	96.09	-0.0148	-0.492	--
95	2005-06-06	1.942	2.464	87.5	291.3	1.959	91.62	-0.0168	-0.53	--
96	2005-08-31	2.127	2.561	134	364	2.06	115.5	0.0675	1.58	--
97	2006-02-09	2.496	2.941	313	872	2.455	286.8	0.041	0.933	--
98	2006-05-02	2.394	2.87	248	741.9	2.381	242.4	0.013	0.0626	--
99	2006-06-08	2.464	3	291	1000	2.516	330.8	-0.0526	-1.04	--
100	2006-06-26	1.95	2.457	89.1	286.7	1.952	90.09	-0.00169	-0.259	--
101	2006-07-27	2.465	2.841	292	692.7	2.35	225.7	0.115	2.44	--
102	2006-08-15	2.408	2.818	256	658	2.327	214	0.081	1.95	--
103	2006-08-23	2.274	2.762	188	578.2	2.269	187	0.00544	-0.154	--
104	2006-09-27	2.422	2.876	264	750.9	2.387	245.5	0.0347	0.74	--
105	2007-01-10	2.439	2.941	275	873	2.455	287.2	-0.0157	-0.504	--
106	2007-02-05	2.459	2.989	288	974	2.505	321.9	-0.0451	-0.951	--
107	2007-03-12	2.375	2.85	237	708	2.36	230.9	0.0144	0.0855	--
108	2007-03-21	2.348	2.844	223	698	2.354	227.5	-0.00558	-0.354	--
109	2007-03-27	2.033	2.647	108	443.7	2.149	142	-0.116	-1.82	--
110	2007-04-02	1.686	2.223	48.5	167	1.707	51.33	-0.0215	-0.597	--
111	2007-04-18	1.862	2.364	72.8	231	1.854	71.95	0.00821	-0.0855	--
112	2007-07-11	1.594	2.206	39.3	160.6	1.69	49.29	-0.0953	-1.58	--
113	2007-08-16	2.34	2.837	219	686.4	2.346	223.6	-0.00587	-0.367	--
114	2007-09-06	2.511	2.979	324	952	2.494	314.3	0.0163	0.154	--

115	2007-11-26	2.474	2.911	298	815	2.424	267.3	0.0503	1.19	--
116	2007-12-06	2.483	2.957	304	906	2.472	298.5	0.0111	-0.0171	--
117	2007-12-13	1.895	2.472	78.6	296.5	1.967	93.3	-0.0713	-1.29	--
118	2008-03-06	1.944	2.485	88	305.2	1.98	96.15	-0.0353	-0.849	--
119	2008-04-14	2.164	2.666	146	463.5	2.169	148.6	-0.00443	-0.318	--
120	2008-05-29	1.814	2.336	65.1	216.8	1.825	67.36	-0.0117	-0.428	--
121	2008-06-30	2.045	2.55	111	355.2	2.048	112.6	-0.00312	-0.283	--
122	2008-08-05	2.435	2.85	272	707.5	2.36	230.7	0.0746	1.82	--
123	2009-04-06	2.377	2.825	238	668.2	2.334	217.4	0.0424	0.951	--
124	2009-04-13	2.25	2.737	178	545.4	2.242	176	0.00805	-0.0969	--
125	2009-04-28	1.836	2.314	68.6	206	1.802	63.86	0.0342	0.71	--
126	2009-06-16	2.188	2.683	154	481.9	2.186	154.7	0.0011	-0.236	--
127	2009-07-30	1.947	2.407	88.6	255.4	1.899	79.88	0.0481	1.17	--
128	2009-09-09	1.737	2.199	54.6	158	1.682	48.46	0.0549	1.32	--
129	2009-09-24	1.922	2.387	83.6	243.7	1.878	76.06	0.0442	1.03	--
130	2009-11-03	2.041	2.514	110	326.7	2.011	103.2	0.0308	0.584	--
131	2009-11-19	2.468	2.892	294	780	2.404	255.4	0.0642	1.54	--
132	2009-12-01	2.522	2.964	333	920.6	2.479	303.5	0.0434	0.969	--
133	2009-12-17	2.54	3.017	347	1040	2.534	344.5	0.0063	-0.12	--
134	2010-01-06	2.582	3.061	382	1150	2.58	382.6	0.00243	-0.212	--
135	2010-01-19	2.571	3.017	372	1040	2.534	344.6	0.0364	0.755	--
136	2010-02-04	2.512	2.977	325	948.6	2.493	313.1	0.0193	0.212	--
137	2010-02-23	2.483	2.999	304	997	2.515	329.8	-0.0322	-0.77	--
138	2010-03-10	2.433	2.853	271	713	2.364	232.6	0.0695	1.62	--
139	2010-04-14	2.573	3.017	374	1040	2.534	344.6	0.0387	0.785	--
140	2010-04-23	2.396	2.779	249	600.8	2.286	194.6	0.11	2.26	--
141	2010-05-13	2.068	2.543	117	349	2.04	110.6	0.0277	0.504	--
142	2010-06-09	1.66	2.198	45.7	157.9	1.682	48.42	-0.022	-0.638	--
143	2010-06-10	1.879	2.344	75.7	221	1.834	68.71	0.0452	1.06	--
144	2010-06-13	1.553	2.022	35.7	105.3	1.499	31.76	0.054	1.27	--
145	2010-06-14	1.574	2.035	37.5	108.4	1.512	32.72	0.0623	1.5	--
146	2010-06-15	1.777	2.281	59.8	190.9	1.768	59.01	0.00888	-0.0741	--
147	2010-06-16	1.819	2.309	65.9	203.5	1.797	63.07	0.0222	0.33	--
148	2010-07-06	1.511	2.017	32.4	104	1.493	31.34	0.0176	0.189	--
149	2010-08-19	2.354	2.801	226	633.1	2.31	205.5	0.0444	1.04	--
150	2010-08-25	2.201	2.718	159	522.7	2.223	168.3	-0.0217	-0.611	--
151	2010-11-16	2.124	2.699	133	500.5	2.204	160.9	-0.0797	-1.41	--
152	2011-01-19	2.688	3.041	487	1100	2.56	365.3	0.128	2.78	--
153	2011-03-07	2.48	2.88	302	759	2.392	248.3	0.0882	2.04	--
154	2011-03-16	2.477	2.906	300	805.2	2.418	264	0.0586	1.41	--
155	2011-04-06	2.507	2.981	321	957	2.497	316	0.00993	-0.0399	--
156	2011-04-18	2.512	2.976	325	946	2.491	312.2	0.0205	0.283	--
157	2011-05-02	2.52	2.972	331	936.9	2.487	309.1	0.0329	0.625	--
158	2011-06-07	2.403	2.839	253	691	2.349	225.1	0.0538	1.24	--
159	2011-06-21	2.386	2.95	243	890.5	2.464	293.2	-0.0784	-1.38	--
160	2011-06-22	2.326	2.93	212	850.5	2.443	279.5	-0.117	-1.88	--
161	2011-08-15	2.09	2.578	123	378.3	2.077	120.2	0.013	0.0512	--
162	2011-09-22	2.152	2.591	142	390.2	2.091	124.2	0.0613	1.47	--
163	2011-12-20	1.998	2.53	99.5	339	2.027	107.3	-0.0295	-0.74	--
164	2012-02-06	2.143	2.665	139	461.9	2.167	148	-0.0242	-0.667	--
165	2012-03-01	1.936	2.63	86.3	426.4	2.131	136.2	-0.195	-2.44	--
166	2012-04-07	2.009	2.576	102	376.9	2.075	119.8	-0.0666	-1.24	--

167	2012-04-17	2.391	2.86	246	725	2.371	236.7	0.0199	0.247	--
168	2012-06-18	2	2.559	99.9	362.4	2.058	115	-0.0579	-1.13	--
169	2012-06-19	2.1	2.71	126	513.3	2.215	165.2	-0.115	-1.76	--
170	2012-07-12	2.433	2.894	271	782.7	2.406	256.3	0.0273	0.453	--
171	2012-07-19	2.422	2.836	264	685	2.345	223.1	0.0762	1.88	--
172	2012-09-11	2.387	2.837	244	687.5	2.347	223.9	0.0404	0.865	--
173	2012-10-24	2.425	2.82	266	661	2.329	215	0.0956	2.14	--
174	2012-11-07	2.464	2.917	291	825.8	2.43	271	0.034	0.681	--
175	2012-11-14	2.462	2.934	290	859.7	2.448	282.6	0.0143	0.0741	--
176	2012-12-12	2.486	2.931	306	854	2.445	280.7	0.0406	0.882	--
177	2013-01-16	2.427	2.945	267	880.5	2.459	289.8	-0.0324	-0.785	--
178	2013-01-29	2.431	2.898	270	791	2.41	259.2	0.0209	0.294	--
179	2013-02-13	2.384	2.934	242	860	2.448	282.7	-0.0644	-1.19	--
180	2013-03-12	2.352	2.944	225	880	2.459	289.6	-0.106	-1.62	--
181	2013-03-13	2.394	3.018	248	1043	2.535	345.5	-0.141	-2.04	--
182	2013-03-27	2.497	3.064	314	1160	2.584	386.1	-0.0866	-1.5	--
183	2013-04-15	2.398	3.045	250	1110	2.564	368.8	-0.166	-2.14	--
184	2013-04-24	2.223	2.764	167	580.8	2.271	187.9	-0.0481	-0.969	--
185	2013-05-06	2.29	2.89	195	777	2.402	254.4	-0.112	-1.71	--
186	2013-05-09	2.121	2.672	132	470.2	2.175	150.8	-0.0547	-1.06	--
187	2013-05-15	2.322	2.775	210	595.7	2.282	192.9	0.04	0.833	--
188	2013-05-21	2.21	2.65	162	447.1	2.152	143.1	0.057	1.38	--
189	2013-05-28	2.418	2.854	262	714.2	2.364	233	0.0541	1.29	--
190	2013-06-05	2.152	2.692	142	491.9	2.196	158.1	-0.0434	-0.933	--
191	2013-06-05	2.182	2.691	152	491	2.195	157.7	-0.013	-0.441	--
192	2013-06-13	2.4	2.962	251	915.3	2.476	301.7	-0.0768	-1.35	--
193	2013-06-24	2.533	3.144	341	1393	2.666	467.2	-0.134	-1.95	--
194	2013-07-09	2.4	2.858	251	721.4	2.369	235.5	0.0308	0.597	--
195	2013-07-29	1.599	2.15	39.7	141.3	1.632	43.14	-0.033	-0.801	--
196	2013-08-07	1.534	2.017	34.2	104.1	1.493	31.37	0.0406	0.899	--
197	2013-08-15	1.675	2.134	47.3	136	1.614	41.45	0.0605	1.44	--
198	2013-08-29	2.375	2.822	237	664	2.331	216	0.0434	0.988	--
199	2013-10-24	2.483	2.943	304	878	2.458	288.9	0.0253	0.428	--
200	2013-10-30	2.127	2.604	134	402.1	2.105	128.1	0.0225	0.354	--
201	2013-11-25	2.497	2.936	314	863	2.45	283.8	0.0471	1.11	--
202	2013-12-11	2.562	3.025	365	1060	2.543	351.5	0.0195	0.236	--
203	2014-01-14	2.554	3.025	358	1060	2.543	351.5	0.0111	-0.00569	--
204	2014-02-20	2.545	3.017	351	1040	2.534	344.6	0.0111	0.00569	--
205	2014-03-17	2.537	2.999	344	997	2.515	329.8	0.0215	0.318	--
206	2014-04-09	2.543	2.996	349	990.5	2.512	327.5	0.0307	0.57	--
207	2014-04-14	2.535	2.985	343	966.3	2.501	319.2	0.0343	0.725	--
208	2014-05-14	2.288	2.766	194	583.5	2.273	188.8	0.0149	0.131	--
209	2014-05-15	2.394	2.896	248	787	2.408	257.8	-0.0137	-0.466	--
210	2014-05-29	2.465	2.945	292	882	2.46	290.3	0.00572	-0.131	--
211	2014-06-03	2.352	2.796	225	625.4	2.304	202.9	0.0479	1.15	--
212	2014-06-05	2.342	2.842	220	695.3	2.352	226.6	-0.00973	-0.379	--
213	2014-06-09	1.843	2.358	69.7	228.1	1.848	71.01	-0.00494	-0.33	--
214	2014-06-12	1.703	2.199	50.5	158	1.682	48.45	0.0211	0.306	--
215	2014-06-24	2.31	2.757	204	571	2.263	184.6	0.0465	1.08	--
216	2014-07-10	2.378	2.822	239	663.7	2.331	215.9	0.0473	1.13	--
217	2014-07-15	2.43	2.879	269	757.4	2.391	247.7	0.039	0.801	--
218	2014-07-24	2.418	2.893	262	782.2	2.405	256.1	0.0129	0.0399	--

219	2014-08-04	2.498	2.915	315	821.7	2.428	269.6	0.0707	1.66	--
220	2014-08-07	2.43	2.893	269	781	2.405	255.7	0.0251	0.416	--

Definitions

Hard: Total hardness -- SDWA NPDWR in mg/l CaCO₃ (00900)

SC: Specific conductance in uS/cm @25C (00095)

Model Archive Summary for Total Dissolved Solids at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the total dissolved solids (DS) model developed to compute hourly DS from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 1, 1998 to October 16, 2015

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 215 concurrent measurements of total dissolved solids, streamflow, and specific conductance collected from May 1, 1998 through October 16, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. There were no samples below laboratory reporting levels. Summary statistics and the complete model-calibration dataset are provided below. Samples with Cook's D values greater than the Outlier Test Criteria and studentized residual values greater than 3 or less than negative 3 were considered outliers. Samples collected October 14, 2003; June 9, 2005; and January 19, 2011 were deemed outliers and were removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating total dissolved solids. A variety of models that predict DS and models that predict $\log_{10}(\text{DS})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted DS were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the

range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated DS.

Specific conductance was selected as the best predictor of DS based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for total dissolved solids at site number 07144100.

Total dissolved solids-based model:

$$DS = 0.576 \times SC + 13.2$$

where

DS = total dissolved solids in milligrams per liter (mg/L); and,

SC = specific conductance in microsiemens per centimeter at 25 degrees Celsius ($\mu S/cm$).

Specific conductance makes physical and statistical sense as an explanatory variable for dissolved solids. It makes physical sense because dissolved solids are partially comprised of ions and salts, which affect the conductivity of the water. This correlates well with SC because SC is a measure of the conductivity of water. Specific conductance makes statistical sense as an explanatory variable because it resulted in a model with low standard error, Mallows' C_p and $PRESS$ values, and high R^2 values. The model selected was the simplest model (one explanatory variable) even though some of the other models were marginally better statistically.

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$DS = 0.562 \times SC + 17.2$
1.1	2007	--	$DS = 0.576 \times SC + 13.2$

Total Dissolved Solids Record

The DS record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick

Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

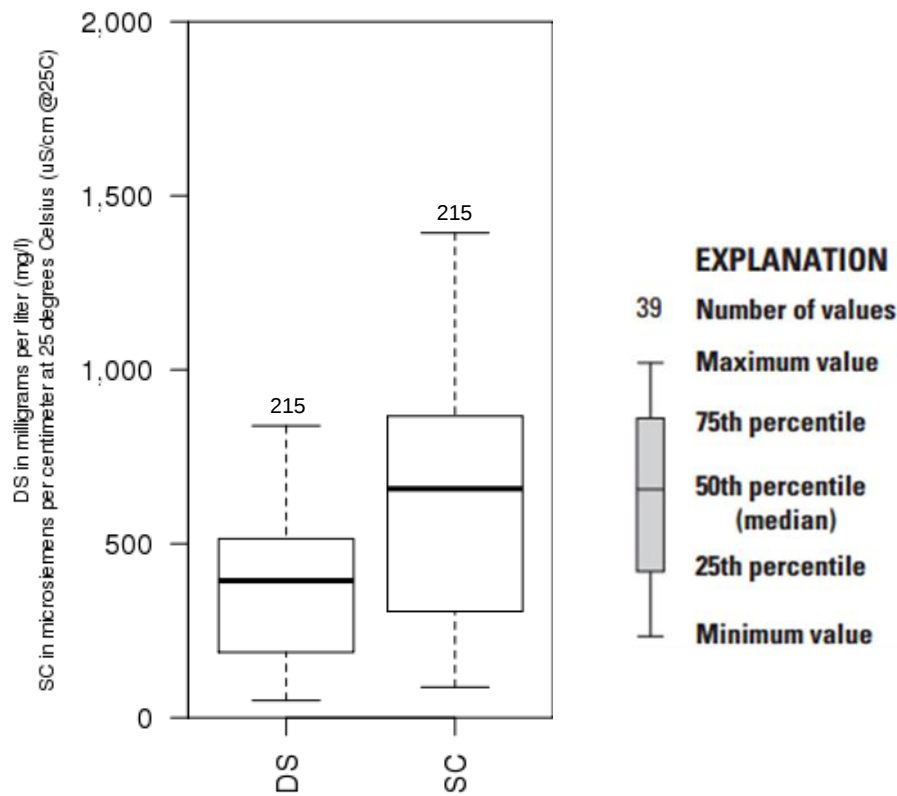
Model

$$DS = + 0.576 * SC + 13.2$$

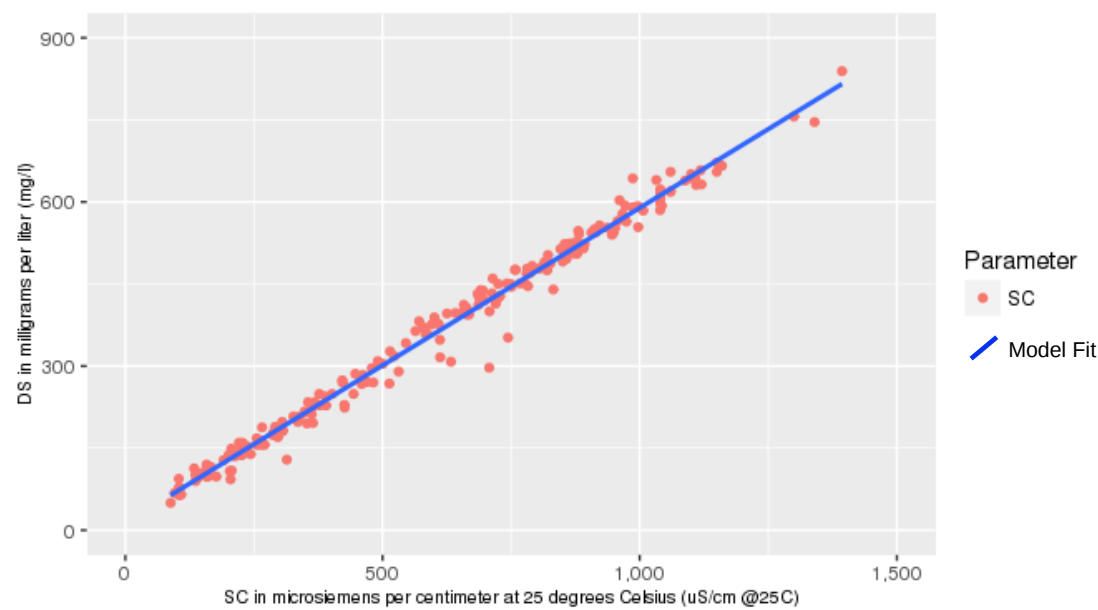
Variable Summary Statistics

	DS	SC
Minimum	50	88
1st Quartile	188	305
Median	394	658
Mean	366	613
3rd Quartile	515	871
Maximum	839	1390

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	215
Standard error (RMSE)	20.4
Upper Model standard percentage error (MSPE)	5.58
Lower Model standard percentage error (MSPE)	5.58
Coefficient of determination (R ²)	0.988
Adjusted Coefficient of Determination (Adj. R ²)	0.988

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	13.200	3.0300	4.37	1.95e-05
SC	0.576	0.0044	131.00	1.63e-205

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.888
E.vars	-0.888	1.000

Outlier Test Criteria

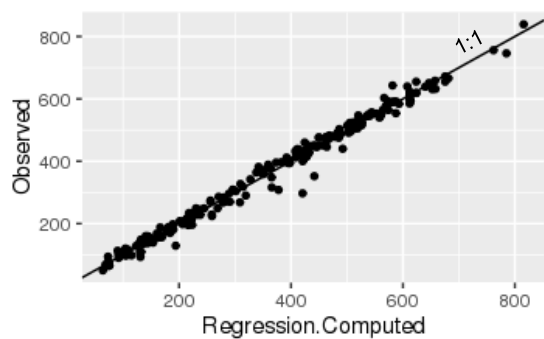
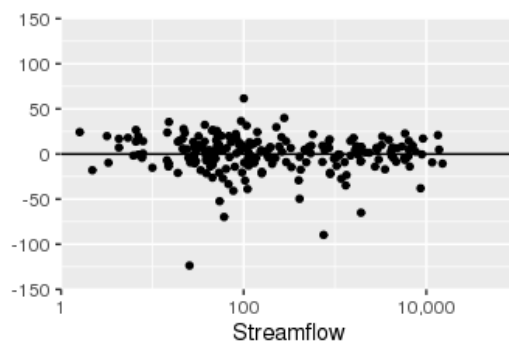
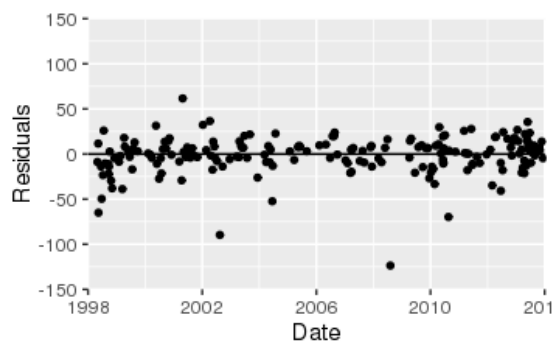
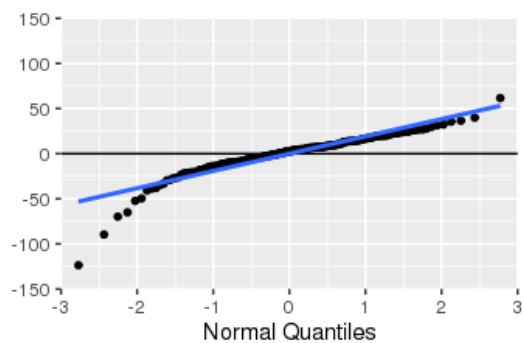
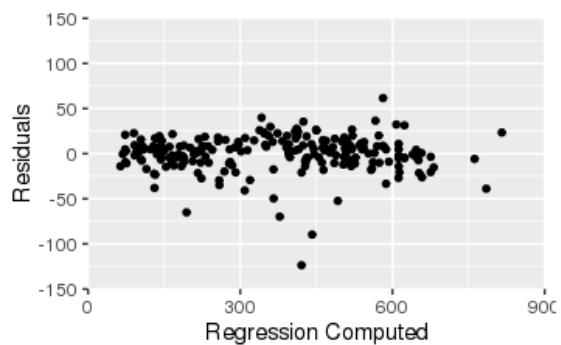
Leverage	Cook's D	DFFITS
0.014	0.105	0.136

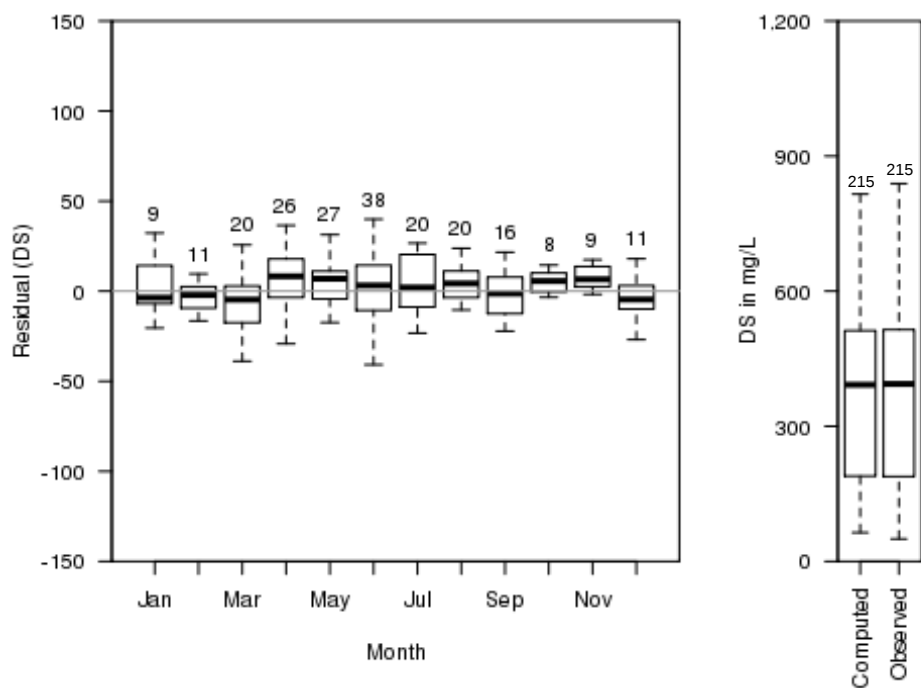
Flagged Observations

	DS	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
5/14/1998 9:26	129	194.0	-65.100		-3.2000		-3.2700	0.00879	4.55e-02	-0.30800
6/24/1998 11:06	316	366.0	-49.700		-2.4400		-2.4700	0.00465	1.39e-02	-0.16900
9/25/1998 10:11	50	63.9	-13.900		-0.6880		-0.6870	0.01740	4.20e-03	-0.09150
10/5/1998 10:21	77	74.3	2.710		0.1340		0.1340	0.01660	1.51e-04	0.01740

11/5/1998	13:45	93	131.0	-38.000	-1.8700	-1.8800	0.01240	2.20e-02	-0.21100
1/12/1999	10:31	643	647.0	-3.660	-0.1810	-0.1810	0.01570	2.61e-04	-0.02280
3/16/1999	13:41	746	785.0	-38.900	-1.9300	-1.9500	0.02920	5.62e-02	-0.33800
8/3/1999	11:51	104	98.1	5.930	0.2930	0.2920	0.01470	6.40e-04	0.03570
2/9/2000	10:51	658	657.0	0.685	0.0339	0.0338	0.01650	9.64e-06	0.00438
5/19/2000	9:46	655	624.0	31.400	1.5500	1.5500	0.01390	1.69e-02	0.18500
12/4/2000	10:11	639	640.0	-0.847	-0.0418	-0.0417	0.01520	1.35e-05	-0.00518
4/26/2001	12:46	643	581.0	61.600	3.0400	3.1000	0.01110	5.20e-02	0.32900
6/6/2001	10:11	68	68.4	-0.422	-0.0209	-0.0208	0.01710	3.77e-06	-0.00274
9/20/2001	10:21	90	92.0	-1.980	-0.0978	-0.0976	0.01520	7.37e-05	-0.01210
1/10/2002	10:46	640	608.0	32.300	1.5900	1.6000	0.01280	1.65e-02	0.18200
2/21/2002	9:51	651	647.0	4.340	0.2140	0.2140	0.01570	3.65e-04	0.02700
4/9/2002	10:06	603	566.0	36.500	1.8000	1.8100	0.01030	1.68e-02	0.18400
8/15/2002	10:01	352	442.0	-89.700	-4.4100	-4.6100	0.00545	5.32e-02	-0.34100
12/18/2002	10:36	756	762.0	-5.830	-0.2900	-0.2890	0.02660	1.15e-03	-0.04780
4/17/2003	10:16	672	675.0	-3.460	-0.1710	-0.1710	0.01810	2.69e-04	-0.02310
12/11/2003	11:31	632	658.0	-26.200	-1.2900	-1.3000	0.01660	1.41e-02	-0.16800
6/16/2004	10:46	440	492.0	-52.300	-2.5700	-2.6100	0.00689	2.30e-02	-0.21700
7/27/2004	9:46	113	90.3	22.700	1.1200	1.1200	0.01530	9.78e-03	0.14000
7/11/2007	12:11	98	106.0	-7.740	-0.3820	-0.3810	0.01410	1.05e-03	-0.04570
8/5/2008	9:31	297	421.0	-124.000	-6.0700	-6.6600	0.00507	9.40e-02	-0.47600
9/9/2009	12:01	114	104.0	9.750	0.4810	0.4800	0.01420	1.67e-03	0.05770
12/17/2009	12:01	585	612.0	-26.900	-1.3300	-1.3300	0.01310	1.17e-02	-0.15300
1/6/2010	11:51	655	675.0	-20.500	-1.0100	-1.0100	0.01810	9.41e-03	-0.13700
2/23/2010	12:56	554	587.0	-33.400	-1.6400	-1.6500	0.01150	1.57e-02	-0.17800
6/9/2010	9:46	98	104.0	-6.170	-0.3040	-0.3040	0.01430	6.69e-04	-0.03650
6/13/2010	19:21	64	73.3	-9.340	-0.4610	-0.4600	0.01660	1.80e-03	-0.05990
6/14/2010	9:41	65	75.6	-10.600	-0.5260	-0.5250	0.01650	2.31e-03	-0.06790
7/6/2010	9:01	94	73.1	20.900	1.0300	1.0300	0.01670	9.02e-03	0.13400
8/19/2010	12:16	308	378.0	-69.800	-3.4300	-3.5200	0.00467	2.76e-02	-0.24100
6/19/2012	9:01	268	309.0	-40.800	-2.0000	-2.0200	0.00511	1.03e-02	-0.14500
3/27/2013	11:36	666	681.0	-15.200	-0.7530	-0.7520	0.01860	5.36e-03	-0.10300
4/15/2013	9:00	631	652.0	-21.400	-1.0600	-1.0600	0.01610	9.19e-03	-0.13600
4/15/2013	9:11	644	651.0	-7.360	-0.3640	-0.3630	0.01610	1.08e-03	-0.04640
6/24/2013	9:40	839	816.0	23.400	1.1700	1.1700	0.03300	2.32e-02	0.21600
7/29/2013	10:40	96	94.6	1.370	0.0675	0.0674	0.01500	3.46e-05	0.00830
8/7/2013	9:46	78	73.2	4.830	0.2390	0.2380	0.01670	4.82e-04	0.03100
8/15/2013	9:10	101	91.6	9.440	0.4660	0.4650	0.01520	1.68e-03	0.05780
6/12/2014	11:40	120	104.0	15.800	0.7780	0.7780	0.01420	4.38e-03	0.09350
9/3/2014	12:10	103	100.0	2.520	0.1240	0.1240	0.01450	1.14e-04	0.01500

Statistical Plots





Models Considered

Model	Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
DS ~ SC		1	20.4	98.8	98.8	4.02	90100	<NA>	± 5.6
DS ~ logSC		1	56.3	90.7	90.6	1430	695000	<NA>	± 15
DS ~ logQ		1	116	60.1	59.9	6790	2940000	<NA>	± 32
DS ~ SC + logQ		2	20.3	98.8	98.8	2.41	89600	2.46	± 5.5
DS ~ SC + logSC		2	20.5	98.8	98.8	5.98	90800	12	± 5.6
DS ~ Q + SC		2	20.5	98.8	98.8	6.01	90700	1.57	± 5.6
DS ~ Q + SC + logQ		3	20.3	98.8	98.8	3.12	89700	2.21	± 5.5
DS ~ SC + logSC + logQ		3	20.3	98.8	98.8	3.45	90000	12.5	± 5.5
DS ~ Q + SC + logSC		3	20.5	98.8	98.8	7.96	91400	3.35	± 5.6
DS ~ Q + SC + logSC + logQ		4	20.3	98.8	98.8	5	90400	3.57	± 5.6

Model-Calibration Data Set

	Date	DS	SC	Computed	Residual	Normal Quantiles	Censored Values
0				DS			
1	1998-05-01	506	871	515	-8.8	-0.648	--
2	1998-05-11	550	912	538	11.6	0.692	--
3	1998-05-14	129	314	194	-65.1	-2.13	--
4	1998-06-16	505	878	519	-13.8	-0.954	--
5	1998-06-24	316	612	366	-49.7	-1.94	--
6	1998-07-10	109	207	132	-23.3	-1.42	--
7	1998-07-20	364	564	338	26	1.65	--
8	1998-08-06	475	820	485	-10.4	-0.816	--

9	1998-09-15	496	858	507	-11	-0.883	--
10	1998-09-22	108	203	130	-22.1	-1.39	--
11	1998-09-25	50	88	63.9	-13.9	-0.991	--
12	1998-10-05	77	106	74.3	2.71	0	--
13	1998-10-22	229	426	258	-29.5	-1.61	--
14	1998-11-05	93	204	131	-38	-1.75	--
15	1998-12-04	428	728	433	-4.64	-0.471	--
16	1999-01-12	643	1100	647	-3.66	-0.357	--
17	1999-02-01	181	306	190	-8.63	-0.634	--
18	1999-02-19	610	1040	612	-2.11	-0.271	--
19	1999-03-16	746	1340	785	-38.9	-1.81	--
20	1999-04-07	274	422	256	17.9	1.07	--
21	1999-04-16	137	201	129	8.28	0.471	--
22	1999-05-24	139	211	135	4.25	0.0933	--
23	1999-06-18	183	300	186	-3.15	-0.308	--
24	1999-06-21	142	221	140	1.68	-0.0583	--
25	1999-07-20	98	177	115	-17	-1.11	--
26	1999-08-03	104	147	98.1	5.93	0.247	--
27	1999-08-19	557	922	544	12.9	0.707	--
28	1999-09-28	153	237	150	3.14	0.035	--
29	2000-02-09	658	1120	657	0.685	-0.105	--
30	2000-03-07	178	287	179	-0.739	-0.187	--
31	2000-03-28	156	256	160	-4.39	-0.432	--
32	2000-05-19	655	1060	624	31.4	1.94	--
33	2000-05-31	267	460	278	-10.9	-0.849	--
34	2000-06-28	196	365	223	-27.4	-1.53	--
35	2000-07-20	426	725	431	-4.7	-0.484	--
36	2000-07-28	195	353	217	-21.5	-1.36	--
37	2000-08-16	450	749	445	5.45	0.223	--
38	2000-09-08	514	846	500	13.6	0.768	--
39	2000-09-25	512	856	506	5.92	0.235	--
40	2000-10-26	159	228	145	14.5	0.883	--
41	2000-11-08	327	515	310	17.4	1.05	--
42	2000-12-04	639	1090	640	-0.847	-0.211	--
43	2001-03-14	198	335	206	-8.33	-0.62	--
44	2001-04-13	290	531	319	-29.2	-1.57	--
45	2001-04-26	643	987	581	61.6	2.77	--
46	2001-05-08	397	663	395	2.23	-0.0466	--
47	2001-06-04	178	292	181	-3.35	-0.32	--
48	2001-06-06	68	95.8	68.4	-0.422	-0.152	--
49	2001-06-23	116	166	109	7.43	0.407	--
50	2001-07-11	483	811	480	2.71	-0.0116	--
51	2001-08-02	451	767	455	-4.08	-0.382	--
52	2001-08-28	474	789	468	6.4	0.259	--
53	2001-09-20	90	137	92	-1.98	-0.259	--
54	2001-10-31	501	853	504	-3.43	-0.332	--
55	2002-01-10	640	1030	608	32.3	2.03	--
56	2002-02-21	651	1100	647	4.34	0.105	--
57	2002-04-09	603	961	566	36.5	2.25	--
58	2002-04-22	164	265	166	-1.79	-0.247	--
59	2002-05-13	348	612	365	-17.4	-1.13	--
60	2002-05-22	270	422	256	13.7	0.784	--
61	2002-06-06	245	388	237	8.28	0.484	--
62	2002-06-13	141	229	145	-4.16	-0.394	--
63	2002-07-09	420	720	428	-7.85	-0.606	--
64	2002-08-15	352	744	442	-89.7	-2.44	--
65	2002-09-19	414	720	428	-13.8	-0.972	--

66	2002-12-18	756	1300	762	-5.83	-0.524	--
67	2003-03-20	184	302	187	-2.87	-0.283	--
68	2003-04-17	672	1150	675	-3.46	-0.344	--
69	2003-04-23	397	642	383	14.1	0.832	--
70	2003-05-14	234	368	225	8.82	0.524	--
71	2003-05-29	296	479	289	6.9	0.344	--
72	2003-06-11	398	656	391	7.01	0.357	--
73	2003-06-24	593	972	573	20.1	1.28	--
74	2003-07-30	523	893	527	-4.24	-0.407	--
75	2003-09-03	188	266	166	21.7	1.33	--
76	2003-12-11	632	1120	658	-26.2	-1.46	--
77	2004-03-09	135	213	136	-0.814	-0.199	--
78	2004-03-30	584	1010	593	-8.93	-0.663	--
79	2004-04-26	590	986	581	8.81	0.511	--
80	2004-05-13	156	264	165	-9.06	-0.677	--
81	2004-05-26	617	1040	612	4.89	0.199	--
82	2004-06-16	440	832	492	-52.3	-2.03	--
83	2004-06-22	156	271	169	-13.2	-0.936	--
84	2004-07-27	113	134	90.3	22.7	1.42	--
85	2005-01-27	217	349	214	2.97	0.0116	--
86	2005-03-23	137	226	144	-6.57	-0.551	--
87	2005-05-10	359	587	351	7.74	0.445	--
88	2005-05-27	198	305	189	9.12	0.551	--
89	2005-06-06	189	291	181	7.99	0.458	--
90	2005-08-31	226	364	223	3.13	0.0233	--
91	2006-02-09	525	872	515	9.63	0.592	--
92	2006-05-02	451	742	440	10.5	0.648	--
93	2006-06-26	174	287	178	-4.33	-0.42	--
94	2006-07-27	432	693	412	19.9	1.2	--
95	2006-08-15	412	658	392	19.9	1.23	--
96	2006-08-23	370	578	346	23.8	1.49	--
97	2006-09-27	445	751	446	-0.641	-0.176	--
98	2007-01-10	509	873	516	-6.95	-0.564	--
99	2007-02-05	564	974	574	-10.1	-0.8	--
100	2007-03-12	400	708	421	-20.9	-1.31	--
101	2007-03-21	420	698	415	4.82	0.176	--
102	2007-03-27	249	444	269	-19.8	-1.2	--
103	2007-04-02	114	167	109	4.59	0.117	--
104	2007-04-18	153	231	146	6.73	0.32	--
105	2007-07-11	98	161	106	-7.74	-0.592	--
106	2007-08-16	412	686	408	3.5	0.0466	--
107	2007-09-06	552	952	561	-9.44	-0.722	--
108	2007-11-26	490	815	483	7.45	0.42	--
109	2007-12-06	544	906	535	9.05	0.537	--
110	2007-12-13	170	296	184	-14	-1.01	--
111	2008-03-06	184	305	189	-4.97	-0.497	--
112	2008-04-14	271	463	280	-9.15	-0.692	--
113	2008-05-29	145	217	138	6.89	0.332	--
114	2008-06-30	234	355	218	16.2	0.972	--
115	2008-08-05	297	708	421	-124	-2.77	--
116	2009-04-06	394	668	398	-4.02	-0.369	--
117	2009-04-13	342	545	327	14.7	0.9	--
118	2009-04-28	149	206	132	17.1	1.03	--
119	2009-06-16	270	482	291	-20.8	-1.28	--
120	2009-07-30	168	255	160	7.68	0.432	--
121	2009-09-09	114	158	104	9.75	0.62	--
122	2009-09-24	139	244	154	-14.6	-1.05	--

123	2009-11-03	208	327	201	6.63	0.308	--
124	2009-11-19	469	780	462	6.6	0.283	--
125	2009-12-01	550	921	543	6.62	0.295	--
126	2009-12-17	585	1040	612	-26.9	-1.49	--
127	2010-01-06	655	1150	675	-20.5	-1.23	--
128	2010-01-19	598	1040	612	-14.1	-1.03	--
129	2010-02-04	543	949	560	-16.5	-1.09	--
130	2010-02-23	554	997	587	-33.4	-1.65	--
131	2010-03-10	433	713	424	9.18	0.564	--
132	2010-04-14	623	1040	612	10.9	0.677	--
133	2010-04-23	389	601	359	29.8	1.87	--
134	2010-05-13	215	349	214	0.786	-0.0933	--
135	2010-06-09	98	158	104	-6.17	-0.537	--
136	2010-06-10	160	221	141	19.5	1.16	--
137	2010-06-14	64	104	73.3	-9.34	-0.707	--
138	2010-06-14	65	108	75.6	-10.6	-0.832	--
139	2010-06-15	128	191	123	4.8	0.164	--
140	2010-06-16	137	204	130	6.54	0.271	--
141	2010-07-06	94	104	73.1	20.9	1.31	--
142	2010-08-19	308	633	378	-69.8	-2.25	--
143	2010-08-25	318	523	314	3.79	0.0699	--
144	2010-11-16	304	501	301	2.53	-0.0233	--
145	2011-03-07	476	759	450	25.7	1.61	--
146	2011-03-16	478	805	477	1.09	-0.0816	--
147	2011-04-06	565	957	564	0.679	-0.117	--
148	2011-04-18	540	946	558	-18	-1.18	--
149	2011-05-02	553	937	553	0.254	-0.14	--
150	2011-06-07	439	691	411	27.9	1.81	--
151	2011-06-21	515	890	526	-11	-0.866	--
152	2011-06-22	491	850	503	-12	-0.9	--
153	2011-08-15	228	378	231	-3.08	-0.295	--
154	2011-09-22	228	390	238	-9.96	-0.784	--
155	2011-12-20	208	339	208	-0.456	-0.164	--
156	2012-02-06	284	462	279	4.78	0.152	--
157	2012-03-01	224	426	259	-34.8	-1.7	--
158	2012-04-07	249	377	230	18.7	1.11	--
159	2012-04-17	450	725	431	19.3	1.13	--
160	2012-06-18	212	362	222	-9.92	-0.768	--
161	2012-06-19	268	513	309	-40.8	-1.87	--
162	2012-07-12	446	783	464	-18	-1.16	--
163	2012-07-19	432	685	408	24.3	1.53	--
164	2012-09-11	426	687	409	16.9	1.01	--
165	2012-10-24	401	661	394	7.13	0.369	--
166	2012-11-07	487	826	489	-1.78	-0.235	--
167	2012-11-14	522	860	508	13.7	0.8	--
168	2012-12-12	523	854	505	18	1.09	--
169	2013-01-16	547	880	520	26.7	1.75	--
170	2013-01-29	483	791	469	14.3	0.849	--
171	2013-02-13	509	860	508	0.535	-0.128	--
172	2013-03-12	525	880	520	5.02	0.211	--
173	2013-03-13	593	1040	614	-20.6	-1.25	--
174	2013-03-27	666	1160	681	-15.2	-1.07	--
175	2013-04-15	631	1110	652	-21.4	-1.33	--
176	2013-04-15	644	1110	651	-7.36	-0.578	--
177	2013-04-24	370	581	348	22.3	1.36	--
178	2013-05-06	451	777	461	-9.67	-0.737	--
179	2013-05-09	271	470	284	-13	-0.918	--

180	2013-05-15	376	596	356	19.7	1.18	--
181	2013-05-21	286	447	271	15.3	0.936	--
182	2013-05-28	460	714	424	35.5	2.13	--
183	2013-06-05	307	492	297	10.5	0.634	--
184	2013-06-05	309	491	296	13	0.722	--
185	2013-06-13	545	915	540	4.68	0.14	--
186	2013-06-24	839	1390	816	23.4	1.46	--
187	2013-07-09	419	721	429	-9.68	-0.753	--
188	2013-07-29	96	141	94.6	1.37	-0.0699	--
189	2013-08-07	78	104	73.2	4.83	0.187	--
190	2013-08-15	101	136	91.6	9.44	0.578	--
191	2013-08-29	394	664	396	-1.6	-0.223	--
192	2013-10-24	526	878	519	7.17	0.382	--
193	2013-10-30	249	402	245	4.19	0.0816	--
194	2013-11-25	524	863	510	13.8	0.816	--
195	2013-12-11	619	1060	624	-4.63	-0.458	--
196	2014-01-14	619	1060	624	-4.63	-0.445	--
197	2014-02-20	607	1040	612	-5.11	-0.511	--
198	2014-03-17	592	997	587	4.65	0.128	--
199	2014-04-09	591	990	584	7.4	0.394	--
200	2014-04-14	578	966	570	8.3	0.497	--
201	2014-05-14	359	584	349	9.74	0.606	--
202	2014-05-15	470	787	466	3.57	0.0583	--
203	2014-05-29	541	882	521	19.9	1.25	--
204	2014-06-03	396	625	373	22.6	1.39	--
205	2014-06-05	438	695	414	24.4	1.57	--
206	2014-06-09	159	228	145	14.4	0.866	--
207	2014-06-12	120	158	104	15.8	0.954	--
208	2014-06-24	382	571	342	40	2.44	--
209	2014-07-10	406	664	395	10.6	0.663	--
210	2014-07-15	476	757	449	26.6	1.7	--
211	2014-07-24	477	782	464	13.4	0.753	--
212	2014-08-04	503	822	486	16.6	0.991	--
213	2014-08-07	478	781	463	15	0.918	--
214	2014-09-03	103	151	100	2.52	-0.035	--
215	2014-10-16	377	609	364	13.1	0.737	--

Definitions

DS: Total dissolved solids in mg/l (70300)

SC: Specific conductance in uS/cm @25C (00095)

Model Archive Summary for Total Suspended Solids at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the total suspended solids (TSS) model developed to compute hourly TSS from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe and typically is placed in the deepest section of the river that has velocity similar to rest of the stream. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: December 26, 2014

Model calibration data period: July, 27 2004 to August 4, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 93 concurrent measurements of total suspended solids, streamflow, and turbidity collected from March 23, 2005 through August 4, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. Eight samples were below laboratory reporting levels; 4 samples were less than 10 mg/L and 4 samples were less than 4 mg/L. Summary statistics and the complete model-calibration dataset are provided below. Samples with Cook's D values greater than the Outlier Test Criteria and studentized residual values greater than 3 or less than negative 3 were considered outliers. A sample collected February 5, 2007 was deemed an outlier and was removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating total suspended solids. A variety of models that predict TSS and models that predict $\log_{10}(\text{TSS})$ were evaluated. The distribution of residuals was examined for normality, and

plots of residuals (the difference between the measured and predicted values) as compared to predicted TSS were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{TSS})$.

Turbidity was selected as the best predictor of TSS based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for total suspended solids at site number 07144100.

Total suspended solids-based model:

$$\log_{10}(\text{TSS}) = 1.01 \times \log_{10}(\text{TURB}) + 0.076,$$

where

TSS = total suspended solids in milligrams per liter (mg/L); and,

TURB = Turbidity, YSI model 6136, in formazin nephelometric units (FNU).

Turbidity makes physical and statistical sense as an explanatory variable for total suspended solids. It makes sense physically because the particles that comprise the suspended solids scatter light, which affects turbidity. Turbidity makes statistical sense as an explanatory variable because it resulted in a model with low standard error, Mallows' C_p and $PRESS$ values, and high R^2 values. The model selected was the simplest model (one explanatory variable) and the best, statistically.

The log-transformed model may be retransformed to the original units so that TSS can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.08. The retransformed model, accounting for BCF is:

$$\text{TSS} = 1.287 \times \text{TURB}^{1.01}.$$

Previous models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(\text{TSS}) = 1.16 \times \log_{10}(\text{TURB}) + 0.000605 \times SC - 0.830$
2.0	2007	--	$\log_{10}(\text{TSS}) = 1.01 \times \log_{10}(\text{TURB}) + 0.076$

Total suspended solids Record

The TSS record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Computed by: Patrick Eslick

Reviewed by: Patrick Rasmussen

Model Statistics, Data, and Plots

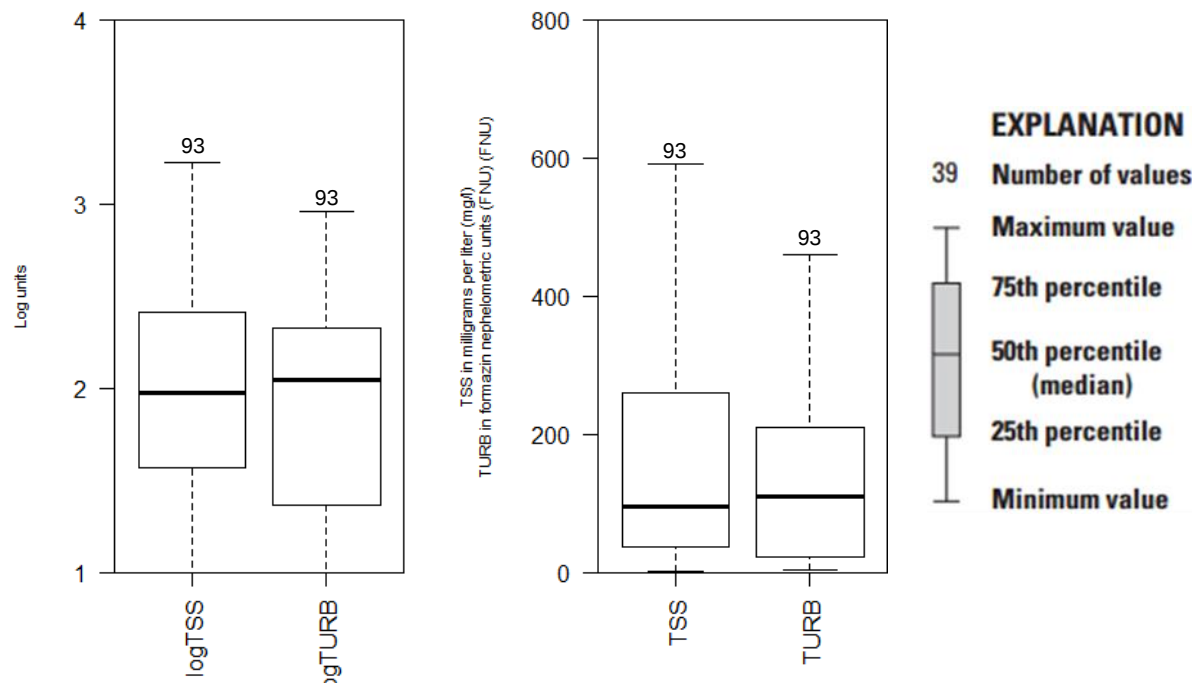
Model

$\log TSS = + 1.01 * \log TURB + 0.076$

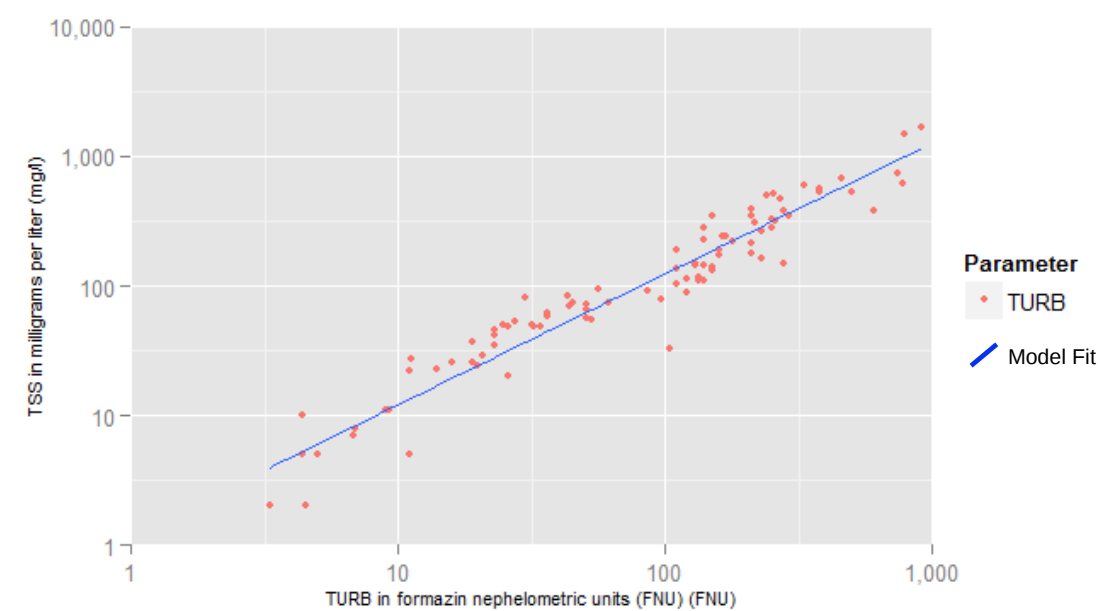
Variable Summary Statistics

	logTSS	logTURB	TSS	TURB
Minimum	0.301	0.519	2	3.3
1st Quartile	1.57	1.36	37	23
Median	1.98	2.04	95	110
Mean	1.93	1.83	196	151
3rd Quartile	2.41	2.32	260	210
Maximum	3.22	2.96	1670	910
Censored [< 10]	4	--	4	--
Censored [< 4]	4	--	4	--

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	93
Standard error (RMSE)	0.182
Upper Model standard percentage error (MSPE)	51.9
Lower Model standard percentage error (MSPE)	34.2
Coefficient of determination (R ²)	0.924
Adjusted Coefficient of Determination (Adj. R ²)	0.923
Bias Correction Factor (BCF)	1.08

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.076	0.0588	1.29	1.99e-01
logTURB	1.010	0.0304	33.20	1.11e-52

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.947
E.vars	-0.947	1.000

Outlier Test Criteria

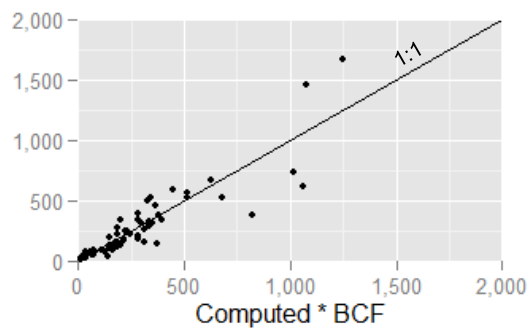
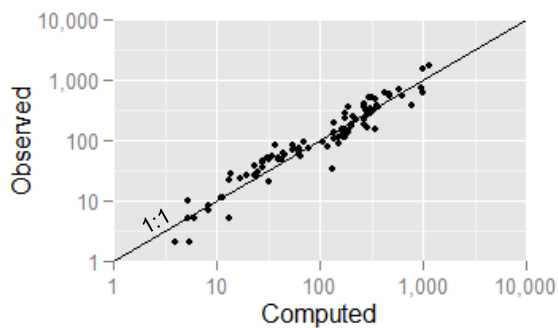
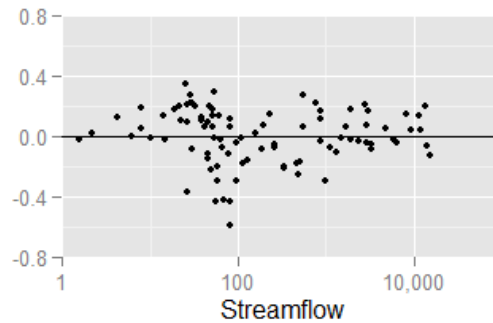
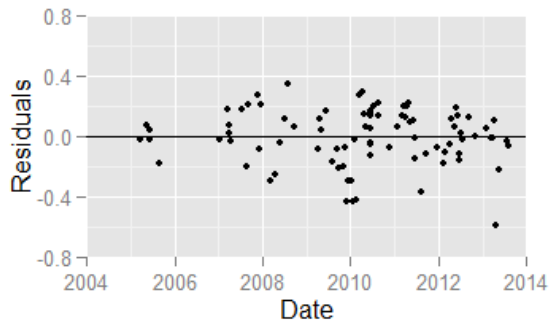
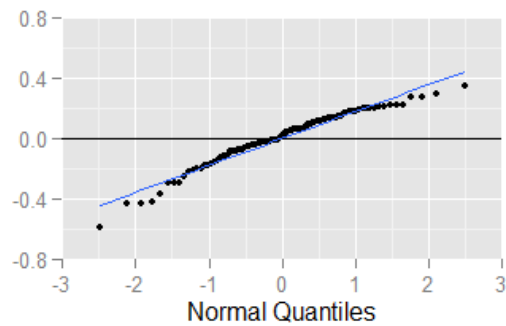
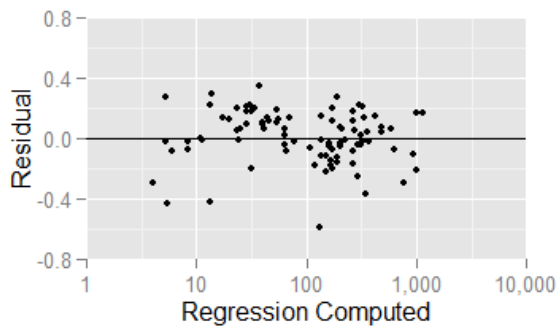
Leverage	Cook's D	DFFITS
0.03225806	0.10548127	0.20739034

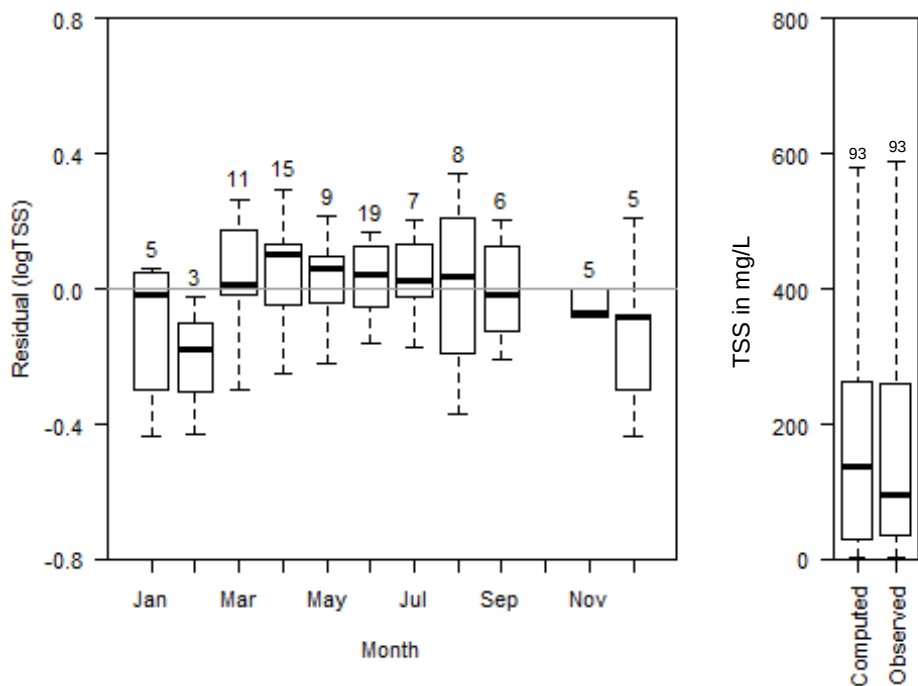
Flagged Observations

	logTSS	Estimate	Residual	Standard Residual	Studentized Residual	Residual Leverage	Cook's D	DFFITS
1/10/2007 11:26	0.9031	0.9225	-0.01944	-0.1092	-0.1086	0.03845	0.0002385	-0.02172
11/26/2007 10:41	1.0000	0.7254	0.27460	1.5520	1.5650	0.05040	0.0639500	0.36050

12/6/2007 11:45	0.6990	0.7814	-0.08241	-0.4649	-0.4629	0.04679	0.0053050	-0.10260
3/6/2008 10:35	2.5800	2.8810	-0.30090	-1.6880	-1.7060	0.03575	0.0528300	-0.32840
8/5/2008 9:31	1.9080	1.5670	0.34190	1.8970	1.9250	0.01431	0.0261200	0.23190
6/16/2009 12:51	3.1640	2.9980	0.16650	0.9372	0.9366	0.04227	0.0193800	0.19670
9/24/2009 11:16	2.7850	2.9940	-0.20880	-1.1750	-1.1770	0.04205	0.0303000	-0.24670
11/19/2009 11:41	0.8451	0.9178	-0.07275	-0.4087	-0.4068	0.03871	0.0033640	-0.08164
12/1/2009 12:41	0.3010	0.7362	-0.43510	-2.4590	-2.5310	0.04969	0.1580000	-0.57870
12/17/2009 12:01	0.3010	0.5997	-0.29870	-1.6960	-1.7140	0.05912	0.0903900	-0.42970
1/6/2010 11:51	0.3010	0.5993	-0.29820	-1.6940	-1.7120	0.05915	0.0901800	-0.42920
1/19/2010 10:01	0.3010	0.7352	-0.43420	-2.4530	-2.5250	0.04975	0.1576000	-0.57770
2/4/2010 10:41	0.6990	0.7217	-0.02272	-0.1284	-0.1277	0.05064	0.0004399	-0.02950
2/23/2010 12:56	0.6990	1.1270	-0.42800	-2.3910	-2.4570	0.02832	0.0833500	-0.41940
4/14/2010 9:06	1.4310	1.1350	0.29650	1.6570	1.6730	0.02798	0.0395000	0.28390
6/9/2010 9:46	3.2230	3.0620	0.16070	0.9062	0.9053	0.04616	0.0198700	0.19910
8/15/2011 10:46	2.1700	2.5420	-0.37160	-2.0690	-2.1070	0.02115	0.0462200	-0.30970
3/1/2012 12:01	2.8690	2.9740	-0.10470	-0.5891	-0.5870	0.04088	0.0073960	-0.12120
4/24/2013 9:31	1.5190	2.1150	-0.59640	-3.3050	-3.5040	0.01173	0.0647900	-0.38160

Statistical Plots





Models Considered

	Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
	logTSS ~ logTURB	1	0.1815	92.39	92.31	1.279	3.166	1	± 43
	logTSS ~ SC	1	0.4146	60.3	59.86	381.9	16.45	1	± 110
	logTSS ~ TURB	1	0.4386	55.57	55.09	437.9	18.73	1	± 120
	logTSS ~ TURB + logTURB	2	0.1818	92.45	92.29	2.496	3.246	2.682	± 43
	logTSS ~ logTURB + SC	2	0.1818	92.45	92.29	2.511	3.181	3.098	± 43
	logTSS ~ Q + logTURB	2	0.182	92.43	92.26	2.765	3.204	1.159	± 43
	logTSS ~ Q + logTURB + SC	3	0.1806	92.63	92.38	2.387	3.163	1.688	± 43
	logTSS ~ Q + logTURB + logSC	3	0.1807	92.63	92.38	2.456	3.179	3.115	± 43
	logTSS ~ Q + logTURB + logQ	3	0.1816	92.55	92.3	3.368	3.228	2.321	± 43
	logTSS ~ TURB + Q + logTURB + SC	4	0.1805	92.72	92.39	3.331	3.242	2.739	± 43
	logTSS ~ Q + logTURB + logQ + SC	4	0.181	92.69	92.35	3.764	3.223	2.522	± 43
	logTSS ~ TURB + Q + logTURB + logSC	4	0.181	92.68	92.35	3.765	3.271	2.698	± 43
	logTSS ~ TURB + Q + logTURB + logQ + SC	5	0.1812	92.75	92.33	5	3.3	2.882	± 43
	logTSS ~ TURB + Q + logTURB + SC + logSC	5	0.1816	92.72	92.3	5.321	3.291	2.896	± 43
	logTSS ~ TURB + Q + logTURB + logQ + logSC	5	0.1817	92.71	92.29	5.468	3.327	2.8	± 43
	logTSS ~ TURB + Q + logTURB + logQ + SC + logSC	6	0.1823	92.75	92.24	7	3.347	2.989	± 43

Model-Calibration Data Set

0	Date	logTSS	logTURB	TSS	TURB	Computed logTSS	Computed TSS	Residual	Normal Quantiles	Censored Values
1	2005-03-23	2.494	2.415	312	260	2.513	351.9	-0.0189	-0.162	--
2	2005-05-10	2.386	2.217	243	165	2.314	222.4	0.0719	0.3	--
3	2005-06-06	2.538	2.462	345	290	2.561	392.9	-0.0231	-0.272	--
4	2005-06-09	2.719	2.58	524	380	2.679	516.1	0.04	0.0808	--
5	2005-08-31	1.898	1.985	79	96.52	2.079	129.5	-0.181	-1.05	--

6	2007-01-10	0.9031	0.8388	8	6.9	0.9225	9.036	-0.0194	-0.189	--
7	2007-03-12	1.623	1.362	42	23	1.45	30.45	0.173	0.923	--
8	2007-03-21	1.681	1.415	48	26	1.504	34.46	0.177	1.01	--
9	2007-03-27	2.511	2.398	324	250	2.496	338.3	0.0147	0	--
10	2007-04-02	2.753	2.58	566	380	2.679	516.1	0.0735	0.329	--
11	2007-04-18	2.176	2.114	150	130	2.209	174.9	-0.0332	-0.329	--
12	2007-07-11	2.593	2.322	392	210	2.419	283.7	0.174	0.965	--
13	2007-08-16	1.301	1.412	20	25.8	1.501	34.19	-0.199	-1.1	--
14	2007-09-06	1.653	1.362	45	23	1.45	30.45	0.203	1.33	--
15	2007-11-26	1	0.6435	10	4.4	0.7254	5.738	0.275	1.91	--
16	2007-12-06	0.699	0.699	5	5	0.7814	6.528	-0.0824	-0.631	< 10
17	2007-12-13	2.714	2.407	518	255	2.505	345.1	0.21	1.39	--
18	2008-03-06	2.58	2.779	380	601.7	2.881	820.6	-0.301	-1.55	--
19	2008-04-14	2.21	2.362	162	230	2.459	311	-0.25	-1.33	--
20	2008-05-29	2.415	2.362	260	230	2.459	311	-0.0443	-0.386	--
21	2008-06-30	2.538	2.324	345	211	2.422	285.1	0.116	0.536	--
22	2008-08-05	1.908	1.477	81	30	1.567	39.82	0.342	2.49	--
23	2008-09-16	2.387	2.23	244	170	2.327	229.2	0.0606	0.217	--
24	2009-04-06	1.732	1.724	54	53	1.816	70.71	-0.0836	-0.664	--
25	2009-04-13	2.354	2.146	226	140	2.242	188.4	0.112	0.505	--
26	2009-04-28	2.583	2.447	383	280	2.545	379.3	0.0377	0.0538	--
27	2009-06-16	3.164	2.895	1460	786	2.998	1075	0.167	0.882	--
28	2009-07-30	2.246	2.322	176	210	2.419	283.7	-0.174	-0.965	--
29	2009-09-09	2.33	2.322	214	210	2.419	283.7	-0.089	-0.698	--
30	2009-09-24	2.785	2.892	610	779.3	2.994	1065	-0.209	-1.21	--
31	2009-11-03	2.041	2.146	110	140	2.242	188.4	-0.2	-1.15	--
32	2009-11-19	0.8451	0.8342	7	6.827	0.9178	8.939	-0.0728	-0.536	--
33	2009-12-01	0.301	0.6542	2	4.51	0.7362	5.883	-0.435	-2.12	< 4
34	2009-12-17	0.301	0.519	2	3.303	0.5997	4.297	-0.299	-1.47	< 4
35	2010-01-06	0.301	0.5185	2	3.3	0.5993	4.292	-0.298	-1.39	< 4
36	2010-01-19	0.301	0.6532	2	4.5	0.7352	5.87	-0.434	-1.91	< 4
37	2010-02-04	0.699	0.6398	5	4.363	0.7217	5.69	-0.0227	-0.244	< 10
38	2010-02-23	0.699	1.041	5	11	1.127	14.47	-0.428	-1.77	< 10
39	2010-03-10	2.538	2.176	345	150	2.272	202	0.266	1.77	--
40	2010-04-14	1.431	1.049	27	11.2	1.135	14.73	0.297	2.12	--
41	2010-04-23	2.276	2.041	189	110	2.136	147.7	0.14	0.769	--
42	2010-05-13	2.826	2.663	670	460	2.763	625.9	0.063	0.272	--
43	2010-06-09	3.223	2.959	1670	910	3.062	1246	0.161	0.843	--
44	2010-06-10	2.243	2.204	175	160	2.3	215.6	-0.0572	-0.474	--
45	2010-06-13	2.771	2.522	590	333	2.621	451.8	0.149	0.805	--
46	2010-06-14	2.666	2.431	463	269.5	2.529	364.9	0.137	0.698	--
47	2010-06-14	2.14	2.176	138	150	2.272	202	-0.132	-0.843	--
48	2010-06-15	2.45	2.398	282	250	2.496	338.3	-0.0456	-0.415	--
49	2010-06-16	2.487	2.339	307	218.2	2.436	294.8	0.051	0.135	--
50	2010-07-06	2.444	2.146	278	140	2.242	188.4	0.202	1.26	--
51	2010-08-19	1.785	1.559	61	36.2	1.649	48.13	0.136	0.664	--
52	2010-08-25	2.701	2.383	502	241.3	2.48	326.4	0.22	1.65	--
53	2010-11-16	2.161	2.146	145	140	2.242	188.4	-0.0804	-0.599	--
54	2011-01-19	1.462	1.315	29	20.63	1.403	27.29	0.0598	0.189	--
55	2011-03-07	1.362	1.146	23	14	1.233	18.45	0.129	0.631	--
56	2011-03-16	1.568	1.279	37	19	1.366	25.11	0.202	1.15	--
57	2011-04-06	1.415	1.203	26	15.97	1.29	21.07	0.125	0.567	--

58	2011-04-18	1.568	1.279	37	19	1.366	25.11	0.202	1.21	--
59	2011-05-02	1.699	1.396	50	24.9	1.485	32.99	0.214	1.47	--
60	2011-05-16	1.544	1.362	35	23	1.45	30.45	0.0939	0.386	--
61	2011-06-07	1.839	1.643	69	43.97	1.734	58.56	0.105	0.445	--
62	2011-06-21	2.127	2.041	134	110	2.136	147.7	-0.00893	-0.0808	--
63	2011-06-22	2.072	2.124	118	133	2.219	178.9	-0.147	-0.882	--
64	2011-08-15	2.17	2.444	148	277.7	2.542	376.1	-0.372	-1.65	--
65	2011-09-22	2.013	2.041	103	110	2.136	147.7	-0.123	-0.805	--
66	2011-12-20	2.72	2.698	525	498.7	2.798	679	-0.0783	-0.567	--
67	2012-02-06	2.045	2.129	111	134.7	2.225	181.2	-0.179	-1.01	--
68	2012-03-01	2.869	2.872	740	744.3	2.974	1017	-0.105	-0.733	--
69	2012-04-07	2.152	2.114	142	130	2.209	174.9	-0.057	-0.445	--
70	2012-04-17	1.763	1.562	58	36.47	1.652	48.48	0.111	0.474	--
71	2012-05-09	1.857	1.703	72	50.52	1.795	67.36	0.0623	0.244	--
72	2012-05-30	1.919	1.638	83	43.45	1.729	57.86	0.19	1.05	--
73	2012-06-12	1.978	1.748	95	55.92	1.84	74.63	0.138	0.733	--
74	2012-06-18	2.114	2.176	130	150	2.272	202	-0.158	-0.923	--
75	2012-06-19	2.057	2.079	114	120	2.174	161.3	-0.117	-0.769	--
76	2012-07-12	1.82	1.704	66	50.6	1.796	67.48	0.0238	0.0269	--
77	2012-07-19	1.863	1.791	73	61.8	1.883	82.56	-0.02	-0.217	--
78	2012-09-11	1.869	1.653	74	45	1.744	59.94	0.125	0.599	--
79	2012-11-07	1.041	0.9574	11	9.065	1.042	11.9	-0.000738	-0.0269	--
80	2013-01-29	1.415	1.276	26	18.9	1.364	24.98	0.0508	0.108	--
81	2013-03-13	1.38	1.301	24	20	1.389	26.45	-0.00871	-0.0538	--
82	2013-03-27	1.041	0.9694	11	9.32	1.054	12.24	-0.0129	-0.108	--
83	2013-04-15	1.699	1.505	50	32	1.595	42.49	0.104	0.415	--
84	2013-04-24	1.519	2.02	33	104.8	2.115	140.7	-0.596	-2.49	--
85	2013-05-21	1.954	2.079	90	120	2.174	161.3	-0.22	-1.26	--
86	2013-07-29	2.27	2.204	186	160	2.3	215.6	-0.0307	-0.3	--
87	2013-08-07	1.959	1.932	91	85.53	2.026	114.6	-0.0667	-0.505	--
88	2014-04-09	1.342	1.041	22	11	1.127	14.47	0.216	1.55	--
89	2014-05-14	1.756	1.705	57	50.65	1.796	67.54	-0.0403	-0.357	--
90	2014-06-03	1.681	1.531	48	34	1.621	45.18	0.0598	0.162	--
91	2014-06-09	2.338	2.255	218	180	2.352	242.8	-0.0134	-0.135	--
92	2014-07-15	1.69	1.509	49	32.27	1.599	42.85	0.0917	0.357	--
93	2014-08-04	1.724	1.439	53	27.47	1.528	36.42	0.196	1.1	--

Definitions

TSS: Total suspended solids in mg/l (00530)

TURB: Turbidity in FNU (63680)

Model Archive Summary for Calcium Concentration at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the calcium concentration (Ca) model developed to compute hourly Ca from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe and typically is placed in the deepest section of the river that has velocity similar to rest of the stream. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 17, 2015

Model calibration data period: May 12, 1998 – August 28, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 219 concurrent measurements of calcium concentration, streamflow, and specific conductance collected from May 1, 1998 through August 7, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. No samples were below laboratory reporting levels. Summary statistics and the complete model-calibration dataset are provided below. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range were considered potential outliers and were investigated. A sample collected November 5, 1998 was deemed an outlier and was removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating calcium concentration. A variety of models that predict Ca and models that predict $\log_{10}(\text{Ca})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted Ca were

examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{Ca})$.

Specific conductance was selected as the best predictor of Ca based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for calcium concentration at site number 07144100.

Calcium concentration-based model:

$$\log_{10}(\text{Ca}) = 1.04 \times \log_{10}(\text{SC}) - 1.11,$$

where

Ca = calcium concentration in milligrams per liter (mg/L); and,

SC = specific conductance in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$).

Specific conductance makes physical and statistical sense as an explanatory variable for calcium concentration. Specific conductance makes physical sense because calcium is an ion, which would affect the conductivity of water. Specific conductance makes statistical sense as an explanatory variable because the model resulted in low standard error, Mallows' C_p and $PRESS$ values, and high R^2 values. The simple-linear regression model with SC as the lone explanatory variable was chosen as the final model.

The log-transformed model may be retransformed to the original units so that Ca can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.01. The retransformed model, accounting for BCF is:

$$\text{Ca} = 0.0784 \times \text{SC}^{1.04}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\text{Ca} = 0.0979 \times \text{SC} - 0.0587$
2.0	2007	--	$\log_{10}(\text{Ca}) = 1.04 \times \log_{10}(\text{SC}) - 1.11$

Calcium Concentration Record

The Ca record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick
Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

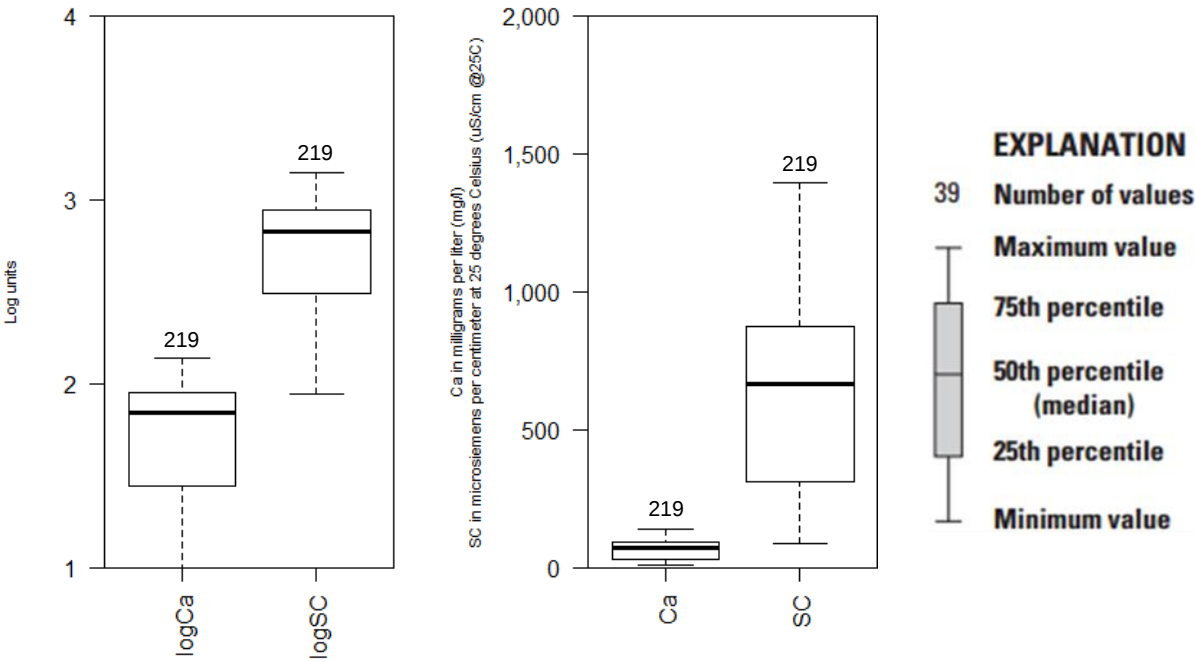
Model

$$\log Ca = + 1.04 * \log SC + -1.11$$

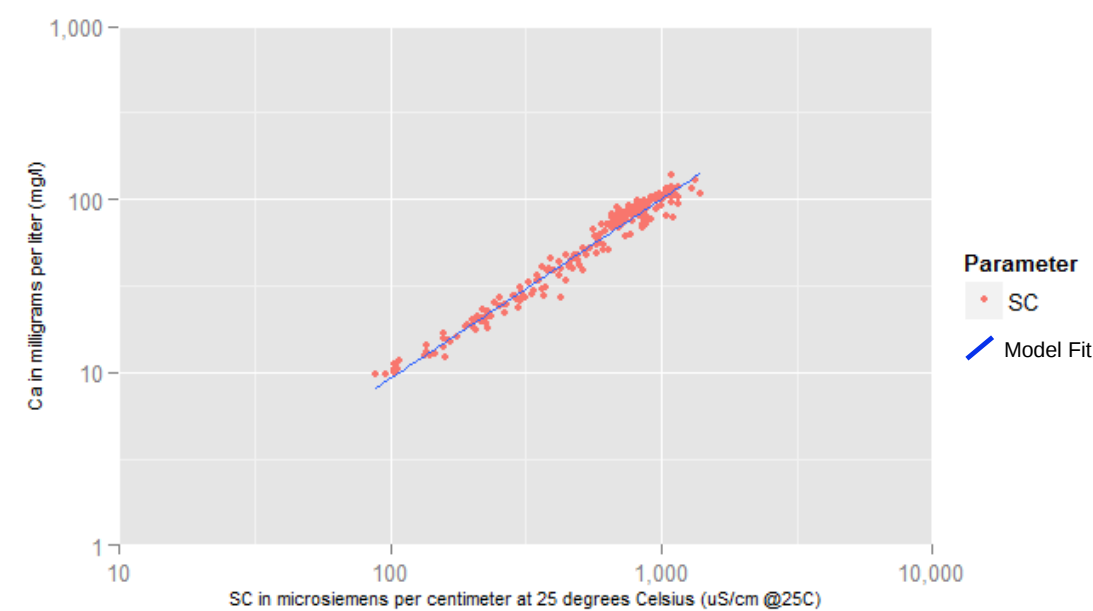
Variable Summary Statistics

	logCa	logSC	Ca	SC
Minimum	0.984	1.94	9.63	88
1st Quartile	1.440	2.49	27.80	306
Median	1.840	2.82	69.50	664
Mean	1.700	2.71	62.00	619
3rd Quartile	1.950	2.94	90.10	872
Maximum	2.140	3.14	138.00	1390

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	219
Standard error (RMSE)	0.0493
Upper Model standard percentage error (MSPE)	12
Lower Model standard percentage error (MSPE)	10.7
Coefficient of determination (R ²)	0.974
Adjusted Coefficient of Determination (Adj. R ²)	0.974
Bias Correction Factor (BCF)	1.01

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-1.11	0.0315	-35.2	1.11e-91
logSC	1.04	0.0115	89.9	1.20e-173

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.994
E.vars	-0.994	1.000

Outlier Test Criteria

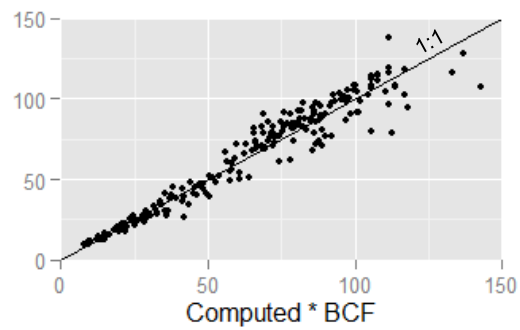
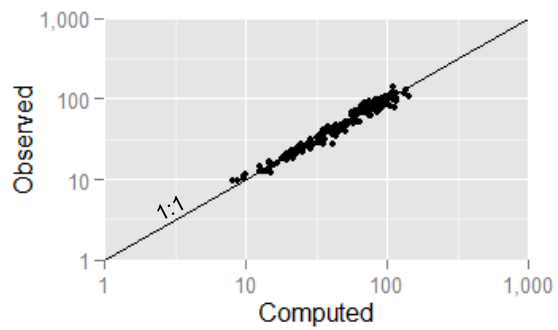
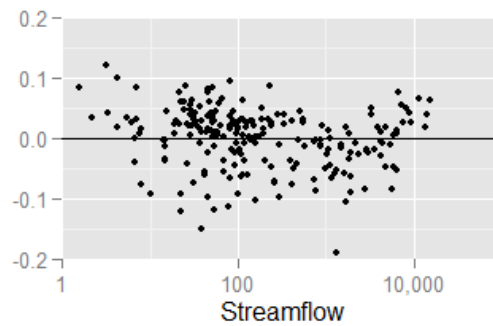
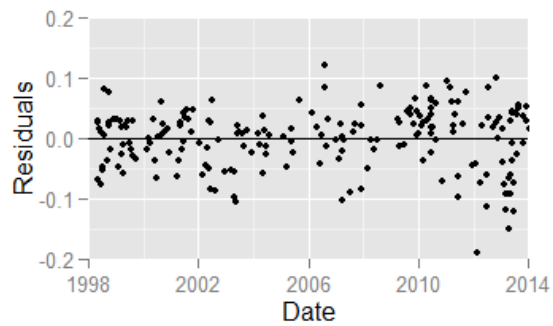
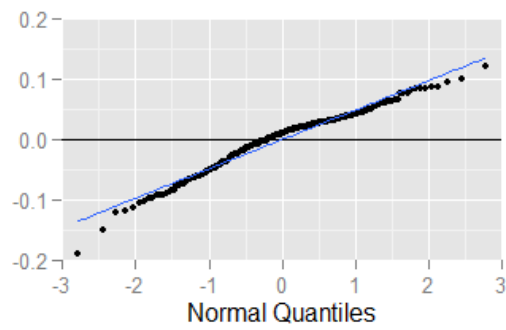
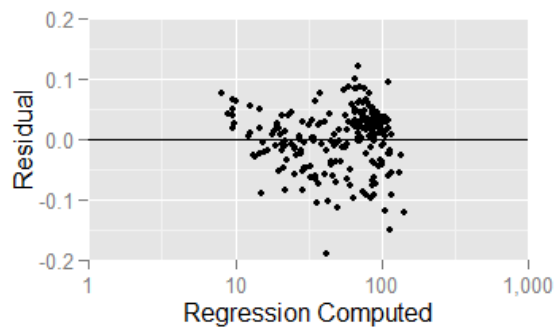
Leverage	Cook's D	DFFITS
0.01369863	0.10541145	0.13514748

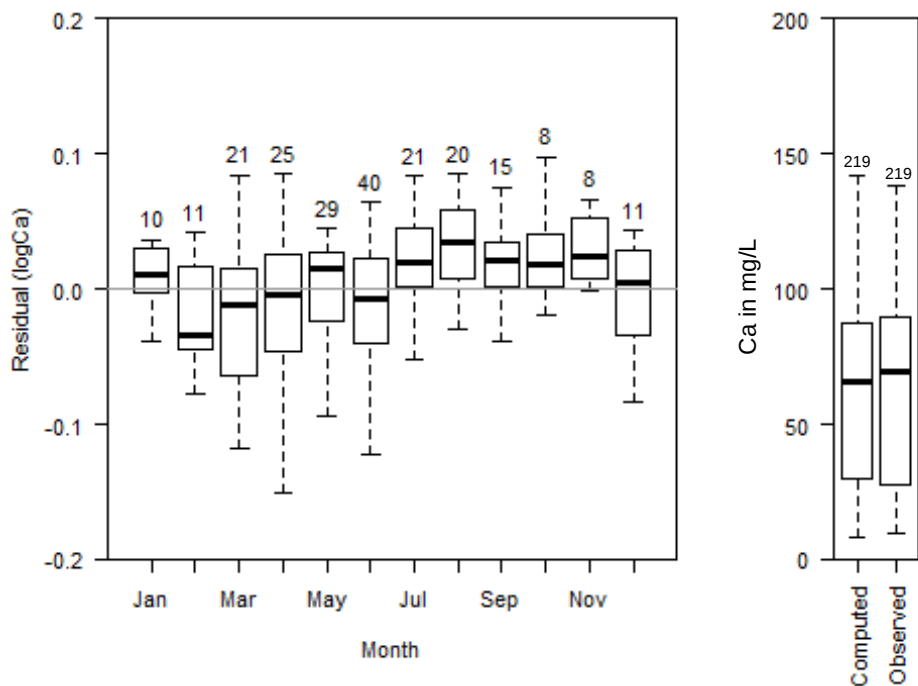
Flagged Observations

	logCa	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
9/25/1998 10:11	0.9836	0.9079	0.075690		1.56300		1.56800	0.036870	4.676e-02	0.30680
10/5/1998 10:21	1.0170	0.9918	0.025270		0.52010		0.51930	0.030430	4.246e-03	0.09199

3/16/1999 13:41	2.1070	2.1340	-0.027270	-0.55660	-0.55580	0.013960	2.193e-03	-0.06613
4/16/1999 11:16	1.2670	1.2790	-0.011750	-0.23980	-0.23930	0.013790	4.021e-04	-0.02830
7/20/1999 10:46	1.2040	1.2220	-0.017980	-0.36750	-0.36680	0.016420	1.127e-03	-0.04739
8/3/1999 11:51	1.1110	1.1400	-0.029370	-0.60150	-0.60070	0.020800	3.843e-03	-0.08754
6/6/2001 10:11	0.9881	0.9463	0.041850	0.86290	0.86230	0.033840	1.304e-02	0.16140
6/23/2001 11:16	1.1880	1.1930	-0.005004	-0.10230	-0.10210	0.017920	9.554e-05	-0.01379
9/20/2001 10:21	1.1170	1.1060	0.010850	0.22240	0.22190	0.022780	5.764e-04	0.03388
6/13/2002 9:31	1.2550	1.3390	-0.083600	-1.70400	-1.71200	0.011380	1.671e-02	-0.18360
8/15/2002 10:01	1.7830	1.8690	-0.086270	-1.75400	-1.76200	0.005946	9.198e-03	-0.13630
4/23/2003 9:51	1.7060	1.8030	-0.097180	-1.97500	-1.98800	0.005057	9.909e-03	-0.14170
5/14/2003 10:01	1.4460	1.5520	-0.106800	-2.17100	-2.19000	0.005747	1.363e-02	-0.16650
10/14/2003 11:01	1.2740	1.2620	0.012440	0.25400	0.25340	0.014550	4.762e-04	0.03080
7/27/2004 9:46	1.1000	1.0970	0.003826	0.07845	0.07827	0.023390	7.370e-05	0.01211
7/27/2006 11:16	1.9570	1.8370	0.119800	2.43500	2.46300	0.005460	1.628e-02	0.18250
3/27/2007 11:46	1.5330	1.6370	-0.103900	-2.11100	-2.12800	0.004802	1.075e-02	-0.14780
4/2/2007 11:51	1.1760	1.1970	-0.020410	-0.41740	-0.41660	0.017710	1.571e-03	-0.05594
7/11/2007 12:11	1.0900	1.1790	-0.089090	-1.82300	-1.83200	0.018630	3.153e-02	-0.25250
12/13/2007 10:16	1.3710	1.4550	-0.083970	-1.70800	-1.71600	0.007739	1.138e-02	-0.15160
9/9/2009 12:01	1.2200	1.1720	0.048460	0.99160	0.99160	0.019030	9.536e-03	0.13810
6/9/2010 9:46	1.1460	1.1710	-0.025100	-0.51370	-0.51280	0.019050	2.562e-03	-0.07146
6/13/2010 15:21	1.0370	0.9888	0.048670	1.00200	1.00200	0.030650	1.587e-02	0.17810
6/13/2010 19:21	1.0490	0.9847	0.064530	1.32800	1.33100	0.030950	2.818e-02	0.23780
6/14/2010 9:41	1.0640	1.0020	0.062770	1.29100	1.29300	0.029720	2.554e-02	0.22630
6/15/2010 9:21	1.2650	1.2570	0.007961	0.16250	0.16220	0.014770	1.981e-04	0.01986
7/6/2010 9:01	1.0000	0.9830	0.016960	0.34930	0.34860	0.031070	1.956e-03	0.06241
1/19/2011 11:41	2.1400	2.0460	0.094290	1.92100	1.93300	0.010480	1.953e-02	0.19890
6/22/2011 10:21	1.8330	1.9300	-0.096570	-1.96400	-1.97700	0.007140	1.387e-02	-0.16770
3/1/2012 12:01	1.4300	1.6190	-0.189000	-3.83900	-3.96700	0.004943	3.661e-02	-0.27960
6/19/2012 9:01	1.5890	1.7020	-0.113400	-2.30400	-2.32700	0.004567	1.217e-02	-0.15760
10/24/2012 9:30	1.9140	1.8160	0.098160	1.99500	2.00800	0.005198	1.039e-02	0.14520
3/12/2013 11:00	1.8530	1.9450	-0.091990	-1.87100	-1.88200	0.007504	1.324e-02	-0.16370
3/13/2013 9:16	1.9030	2.0210	-0.118400	-2.41100	-2.43800	0.009669	2.837e-02	-0.24090
3/27/2013 11:36	1.9760	2.0700	-0.093160	-1.89900	-1.91000	0.011330	2.067e-02	-0.20450
4/15/2013 9:00	1.8990	2.0500	-0.150900	-3.07500	-3.13700	0.010620	5.075e-02	-0.32500
5/6/2013 11:00	1.7950	1.8890	-0.093820	-1.90800	-1.91900	0.006293	1.152e-02	-0.15270
6/13/2013 9:20	1.8880	1.9630	-0.075190	-1.53000	-1.53500	0.007953	9.382e-03	-0.13740
6/24/2013 9:40	2.0290	2.1520	-0.122700	-2.50500	-2.53600	0.014740	4.694e-02	-0.31020
7/29/2013 10:40	1.0930	1.1210	-0.027920	-0.57210	-0.57120	0.021880	3.661e-03	-0.08544
8/7/2013 9:46	1.0210	0.9835	0.037740	0.77700	0.77630	0.031040	9.669e-03	0.13890
8/15/2013 9:10	1.1580	1.1040	0.054350	1.11400	1.11500	0.022930	1.457e-02	0.17080
6/12/2014 11:40	1.1900	1.1720	0.018780	0.38430	0.38350	0.019030	1.432e-03	0.05342

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logCa ~ logSC	1	0.04934	97.38	97.37	39.89	0.5375	1 ± 11	
logCa ~ SC	1	0.09856	89.56	89.51	801.9	2.165	1 ± 23	
logCa ~ logQ	1	0.1597	72.57	72.44	2456	5.646	1 ± 38	
logCa ~ logQ + logSC	2	0.04646	97.69	97.67	11.97	0.4789	3.251 ± 11	
logCa ~ Q + logSC	2	0.04926	97.4	97.38	39.85	0.5361	2.236 ± 11	
logCa ~ logSC + SC	2	0.04943	97.39	97.36	41.6	0.5445	11.99 ± 11	
logCa ~ Q + logQ + logSC	3	0.04543	97.8	97.77	3.041	0.4573	2.477 ± 10	
logCa ~ logQ + logSC + SC	3	0.04627	97.72	97.69	11.06	0.4795	3.395 ± 11	
logCa ~ Q + logSC + SC	3	0.04936	97.41	97.37	41.7	0.5438	3.432 ± 11	
logCa ~ Q + logQ + logSC + SC	4	0.04553	97.8	97.76	5	0.4639	3.645 ± 10	

Model-Calibration Data Set

0	Date	logCa	logSC	Ca	SC	Computed logCa	Computed Ca	Residual	Normal Quantiles	Censored Values
1	1998-05-01	1.87	2.94	74.2	871	1.94	87.73	-0.07	-1.29	--
2	1998-05-06	1.933	2.906	85.8	804.5	1.905	80.79	0.0288	0.58	--
3	1998-05-11	1.987	2.96	97.1	912	1.961	92.02	0.0261	0.462	--
4	1998-05-27	1.942	2.926	87.5	844	1.926	84.91	0.0157	0.115	--
5	1998-06-16	1.953	2.943	89.7	878	1.944	88.46	0.00874	-0.0114	--
6	1998-06-24	1.704	2.787	50.6	612	1.781	60.84	-0.0773	-1.4	--
7	1998-07-10	1.241	2.316	17.4	206.8	1.293	19.75	-0.0522	-1	--
8	1998-07-13	1.435	2.5	27.2	316	1.484	30.65	-0.0492	-0.948	--
9	1998-07-20	1.825	2.751	66.9	564	1.745	55.9	0.0807	1.76	--

10	1998-08-06	1.919	2.914	82.9	820	1.913	82.41	0.00528	-0.0916	--
11	1998-09-15	1.895	2.933	78.6	857.5	1.933	86.32	-0.038	-0.797	--
12	1998-09-22	1.305	2.307	20.2	203	1.284	19.37	0.0209	0.302	--
13	1998-09-25	0.9836	1.944	9.63	88	0.9079	8.14	0.0757	1.71	--
14	1998-10-05	1.017	2.025	10.4	106	0.9918	9.873	0.0253	0.437	--
15	1998-10-22	1.599	2.629	39.7	425.9	1.618	41.77	-0.0194	-0.527	--
16	1998-12-04	1.89	2.862	77.7	728.3	1.86	72.87	0.0306	0.663	--
17	1999-01-12	2.076	3.041	119	1100	2.046	111.8	0.03	0.635	--
18	1999-02-01	1.422	2.486	26.4	306.3	1.47	29.68	-0.0481	-0.93	--
19	1999-02-19	2.049	3.017	112	1040	2.02	105.4	0.0289	0.593	--
20	1999-03-16	2.107	3.127	128	1340	2.134	137.1	-0.0273	-0.677	--
21	1999-03-23	2.064	3.041	116	1100	2.046	111.8	0.0189	0.231	--
22	1999-04-07	1.556	2.625	36	421.7	1.614	41.35	-0.0574	-1.08	--
23	1999-04-16	1.267	2.302	18.5	200.5	1.279	19.13	-0.0118	-0.424	--
24	1999-05-05	1.924	2.905	83.9	804.1	1.904	80.75	0.0193	0.254	--
25	1999-05-24	1.32	2.324	20.9	211	1.302	20.16	0.0183	0.196	--
26	1999-06-18	1.489	2.477	30.8	300.3	1.461	29.07	0.0278	0.527	--
27	1999-06-21	1.314	2.344	20.6	220.7	1.322	21.12	-0.00819	-0.35	--
28	1999-07-20	1.204	2.247	16	176.8	1.222	16.78	-0.018	-0.513	--
29	1999-08-03	1.111	2.168	12.9	147.3	1.14	13.89	-0.0294	-0.706	--
30	1999-08-19	1.994	2.965	98.6	921.9	1.966	93.05	0.0279	0.54	--
31	1999-09-28	1.32	2.375	20.9	237.2	1.355	22.77	-0.0345	-0.736	--
32	2000-02-09	2.033	3.049	108	1118	2.053	113.7	-0.0197	-0.553	--
33	2000-03-07	1.439	2.458	27.5	287.4	1.441	27.78	-0.00169	-0.207	--
34	2000-03-28	1.378	2.407	23.9	255.5	1.388	24.59	-0.0097	-0.387	--
35	2000-05-19	2.061	3.025	115	1060	2.029	107.6	0.0318	0.706	--
36	2000-05-31	1.616	2.662	41.3	459.6	1.653	45.21	-0.0366	-0.751	--
37	2000-06-28	1.483	2.562	30.4	364.9	1.549	35.58	-0.0657	-1.24	--
38	2000-07-20	1.86	2.86	72.5	724.9	1.858	72.52	0.00256	-0.138	--
39	2000-07-28	1.535	2.548	34.3	353	1.534	34.38	0.00166	-0.172	--
40	2000-08-16	1.932	2.874	85.6	749	1.872	75.02	0.06	1.4	--
41	2000-09-08	1.933	2.927	85.8	846	1.927	85.12	0.00616	-0.0801	--
42	2000-09-25	1.955	2.932	90.1	855.9	1.933	86.15	0.0222	0.35	--
43	2000-10-26	1.348	2.358	22.3	228	1.337	21.85	0.0116	0.0458	--
44	2000-11-08	1.719	2.711	52.4	514.6	1.703	50.83	0.0159	0.126	--
45	2000-12-04	2.017	3.037	104	1088	2.041	110.5	-0.0237	-0.593	--
46	2001-03-14	1.447	2.525	28	335.3	1.51	32.6	-0.0633	-1.19	--
47	2001-04-13	1.68	2.725	47.9	531.3	1.718	52.54	-0.0375	-0.766	--
48	2001-04-26	2.021	2.994	105	986.6	1.997	99.84	0.0246	0.412	--
49	2001-05-08	1.838	2.821	68.9	662.5	1.817	66.06	0.021	0.314	--
50	2001-06-04	1.428	2.465	26.8	291.9	1.448	28.24	-0.0199	-0.566	--
51	2001-06-06	0.9881	1.981	9.73	95.82	0.9463	8.891	0.0418	1	--
52	2001-06-23	1.188	2.219	15.4	165.5	1.193	15.68	-0.005	-0.302	--
53	2001-07-11	1.943	2.909	87.6	811.1	1.908	81.48	0.0342	0.782	--
54	2001-08-02	1.929	2.885	84.9	767.3	1.883	76.92	0.0456	1.12	--
55	2001-08-28	1.928	2.897	84.7	789	1.896	79.18	0.032	0.721	--
56	2001-09-20	1.117	2.136	13.1	136.7	1.106	12.86	0.0108	0.0343	--
57	2001-10-31	1.977	2.931	94.8	853	1.931	85.85	0.0458	1.15	--
58	2002-01-10	2.009	3.014	102	1032	2.017	104.6	-0.00839	-0.362	--
59	2002-02-21	1.985	3.041	96.7	1100	2.046	111.8	-0.0602	-1.12	--
60	2002-04-09	1.939	2.983	86.8	960.7	1.985	97.12	-0.0461	-0.896	--
61	2002-04-22	1.389	2.423	24.5	264.9	1.404	25.53	-0.0151	-0.5	--

62	2002-05-13	1.732	2.786	53.9	611.6	1.781	60.8	-0.0496	-0.966	--
63	2002-05-22	1.642	2.625	43.9	422	1.614	41.38	0.0284	0.566	--
64	2002-06-06	1.602	2.589	40	388.1	1.576	37.93	0.0257	0.449	--
65	2002-06-13	1.255	2.36	18	229.1	1.339	21.96	-0.0836	-1.47	--
66	2002-07-09	1.916	2.857	82.4	720	1.855	72.01	0.0612	1.43	--
67	2002-08-15	1.783	2.872	60.7	744	1.869	74.5	-0.0863	-1.54	--
68	2002-09-19	1.851	2.857	70.9	720	1.855	72.01	-0.00405	-0.278	--
69	2002-12-18	2.064	3.114	116	1300	2.121	132.9	-0.0564	-1.04	--
70	2003-03-20	1.41	2.479	25.7	301.5	1.463	29.2	-0.0527	-1.02	--
71	2003-04-17	2.009	3.061	102	1150	2.066	117	-0.057	-1.06	--
72	2003-04-23	1.706	2.808	50.8	642	1.803	63.94	-0.0972	-1.82	--
73	2003-05-14	1.446	2.566	27.9	368	1.552	35.9	-0.107	-1.95	--
74	2003-05-29	1.678	2.68	47.6	479	1.671	47.19	0.00644	-0.0572	--
75	2003-06-11	1.833	2.817	68	656	1.813	65.38	0.0197	0.266	--
76	2003-06-24	2	2.988	100	972	1.99	98.3	0.0101	0.0114	--
77	2003-07-30	1.959	2.951	91	892.6	1.951	89.99	0.00756	-0.0458	--
78	2003-09-03	1.393	2.425	24.7	265.9	1.406	25.62	-0.0133	-0.462	--
79	2003-10-14	1.274	2.286	18.8	193	1.262	18.38	0.0124	0.0572	--
80	2003-12-11	2.029	3.049	107	1120	2.054	113.9	-0.0243	-0.621	--
81	2004-03-09	1.314	2.328	20.6	212.8	1.306	20.35	0.00809	-0.0229	--
82	2004-03-30	1.993	3.003	98.5	1007	2.006	101.9	-0.0122	-0.437	--
83	2004-04-26	2.033	2.994	108	986.3	1.996	99.81	0.037	0.846	--
84	2004-05-13	1.342	2.421	22	263.6	1.402	25.4	-0.0597	-1.1	--
85	2004-05-26	2.033	3.017	108	1040	2.02	105.4	0.0131	0.0687	--
86	2004-06-16	1.907	2.92	80.7	832	1.92	83.66	-0.0129	-0.449	--
87	2004-06-22	1.387	2.433	24.4	270.8	1.414	26.11	-0.0268	-0.663	--
88	2004-07-27	1.1	2.126	12.6	133.8	1.097	12.57	0.00383	-0.126	--
89	2005-01-27	1.53	2.542	33.9	348.7	1.528	33.95	0.00211	-0.149	--
90	2005-03-23	1.286	2.355	19.3	226.3	1.333	21.68	-0.0479	-0.913	--
91	2005-05-10	1.779	2.769	60.1	587	1.763	58.27	0.0162	0.138	--
92	2005-05-27	1.461	2.484	28.9	305	1.468	29.55	-0.00691	-0.314	--
93	2005-06-06	1.423	2.464	26.5	291.3	1.447	28.18	-0.0239	-0.607	--
94	2005-08-31	1.611	2.561	40.8	364	1.547	35.5	0.0632	1.5	--
95	2006-02-09	1.983	2.941	96.1	872	1.941	87.84	0.0418	0.985	--
96	2006-05-02	1.885	2.87	76.8	741.9	1.868	74.28	0.0172	0.172	--
97	2006-06-08	1.96	3	91.2	1000	2.003	101.2	-0.0427	-0.862	--
98	2006-06-26	1.444	2.457	27.8	286.7	1.44	27.71	0.00414	-0.115	--
99	2006-07-27	1.957	2.841	90.6	692.7	1.837	69.18	0.12	2.78	--
100	2006-08-15	1.898	2.818	79	658	1.814	65.59	0.0835	1.82	--
101	2006-08-23	1.741	2.762	55.1	578.2	1.756	57.36	-0.0147	-0.487	--
102	2006-09-27	1.904	2.876	80.2	750.9	1.874	75.22	0.0306	0.649	--
103	2007-01-10	1.939	2.941	86.9	873	1.941	87.94	-0.00246	-0.231	--
104	2007-02-05	1.957	2.989	90.5	974	1.991	98.51	-0.0341	-0.721	--
105	2007-03-12	1.87	2.85	74.1	708	1.847	70.77	0.0227	0.375	--
106	2007-03-21	1.842	2.844	69.5	698	1.841	69.73	0.00127	-0.184	--
107	2007-03-27	1.533	2.647	34.1	443.7	1.637	43.59	-0.104	-1.88	--
108	2007-04-02	1.176	2.223	15	167	1.197	15.82	-0.0204	-0.58	--
109	2007-04-18	1.34	2.364	21.9	231	1.343	22.15	-0.00219	-0.219	--
110	2007-07-11	1.09	2.206	12.3	160.6	1.179	15.19	-0.0891	-1.58	--
111	2007-08-16	1.842	2.837	69.5	686.4	1.833	68.53	0.00882	0	--
112	2007-09-06	2.004	2.979	101	952	1.981	96.21	0.0238	0.399	--
113	2007-11-26	1.965	2.911	92.2	815	1.911	81.89	0.0542	1.26	--

114	2007-12-06	1.98	2.957	95.4	906	1.958	91.39	0.0214	0.338	--
115	2007-12-13	1.371	2.472	23.5	296.5	1.455	28.69	-0.084	-1.5	--
116	2008-03-06	1.418	2.485	26.2	305.2	1.468	29.56	-0.0497	-0.985	--
117	2008-04-14	1.652	2.666	44.9	463.5	1.656	45.6	-0.00406	-0.29	--
118	2008-05-29	1.294	2.336	19.7	216.8	1.314	20.74	-0.0197	-0.54	--
119	2008-06-30	1.533	2.55	34.1	355.2	1.536	34.6	-0.00367	-0.254	--
120	2008-08-05	1.932	2.85	85.6	707.5	1.847	70.72	0.0857	2.13	--
121	2009-04-06	1.852	2.825	71.1	668.2	1.821	66.65	0.0308	0.677	--
122	2009-04-13	1.716	2.737	52	545.4	1.73	53.99	-0.0136	-0.475	--
123	2009-04-28	1.316	2.314	20.7	206	1.291	19.67	0.025	0.424	--
124	2009-06-16	1.663	2.683	46	481.9	1.674	47.49	-0.0111	-0.412	--
125	2009-07-30	1.433	2.407	27.1	255.4	1.388	24.58	0.0451	1.1	--
126	2009-09-09	1.22	2.199	16.6	158	1.172	14.94	0.0485	1.17	--
127	2009-09-24	1.407	2.387	25.5	243.7	1.367	23.41	0.0399	0.948	--
128	2009-11-03	1.521	2.514	33.2	326.7	1.499	31.73	0.0224	0.362	--
129	2009-11-19	1.957	2.892	90.6	780	1.891	78.24	0.0664	1.58	--
130	2009-12-01	2.009	2.964	102	920.6	1.965	92.92	0.0432	1.04	--
131	2009-12-17	2.025	3.017	106	1040	2.02	105.4	0.00513	-0.103	--
132	2010-01-06	2.072	3.061	118	1150	2.066	117	0.00627	-0.0687	--
133	2010-01-19	2.057	3.017	114	1040	2.02	105.4	0.0366	0.829	--
134	2010-02-04	2	2.977	100	948.6	1.979	95.85	0.0211	0.326	--
135	2010-02-23	1.964	2.999	92	997	2.001	100.9	-0.0375	-0.782	--
136	2010-03-10	1.877	2.853	75.3	713	1.85	71.29	0.0265	0.487	--
137	2010-04-14	2.049	3.017	112	1040	2.02	105.4	0.0289	0.607	--
138	2010-04-23	1.859	2.779	72.2	600.8	1.773	59.69	0.0854	2.03	--
139	2010-05-13	1.56	2.543	36.3	349	1.529	33.98	0.0314	0.692	--
140	2010-06-09	1.146	2.198	14	157.9	1.171	14.93	-0.0251	-0.649	--
141	2010-06-10	1.362	2.344	23	221	1.323	21.15	0.039	0.913	--
142	2010-06-13	1.037	2.022	10.9	105.3	0.9888	9.805	0.0487	1.19	--
143	2010-06-14	1.049	2.018	11.2	104.3	0.9847	9.714	0.0645	1.54	--
144	2010-06-14	1.064	2.035	11.6	108.4	1.002	10.1	0.0628	1.47	--
145	2010-06-15	1.265	2.281	18.4	190.9	1.257	18.18	0.00796	-0.0343	--
146	2010-06-16	1.303	2.309	20.1	203.5	1.286	19.42	0.0176	0.184	--
147	2010-07-06	1	2.017	10	104	0.983	9.677	0.017	0.161	--
148	2010-08-19	1.854	2.801	71.5	633.1	1.797	63.01	0.0576	1.32	--
149	2010-08-25	1.708	2.718	51	522.7	1.71	51.66	-0.00284	-0.242	--
150	2010-11-16	1.618	2.699	41.5	500.5	1.691	49.39	-0.0729	-1.32	--
151	2011-01-19	2.14	3.041	138	1100	2.046	111.8	0.0943	2.26	--
152	2011-03-07	1.963	2.88	91.8	759	1.878	76.06	0.0844	1.95	--
153	2011-03-16	1.964	2.906	92.1	805.2	1.905	80.87	0.0592	1.34	--
154	2011-04-06	1.993	2.981	98.5	957	1.983	96.73	0.0106	0.0229	--
155	2011-04-18	1.998	2.976	99.5	946	1.978	95.58	0.0202	0.278	--
156	2011-05-02	2.013	2.972	103	936.9	1.973	94.63	0.0395	0.93	--
157	2011-06-07	1.895	2.839	78.6	691	1.836	69.01	0.0592	1.37	--
158	2011-06-21	1.886	2.95	77	890.5	1.95	89.77	-0.0639	-1.21	--
159	2011-06-22	1.833	2.93	68.1	850.5	1.93	85.59	-0.0966	-1.76	--
160	2011-08-15	1.588	2.578	38.7	378.3	1.565	36.94	0.0229	0.387	--
161	2011-09-22	1.653	2.591	45	390.2	1.579	38.15	0.0744	1.66	--
162	2011-12-20	1.471	2.53	29.6	339	1.515	32.97	-0.0441	-0.879	--
163	2012-02-06	1.613	2.665	41	461.9	1.655	45.44	-0.042	-0.846	--
164	2012-03-01	1.43	2.63	26.9	426.4	1.619	41.82	-0.189	-2.78	--
165	2012-04-07	1.489	2.576	30.8	376.9	1.563	36.8	-0.0746	-1.34	--

166	2012-04-17	1.879	2.86	75.6	725	1.858	72.53	0.0207	0.29	--
167	2012-06-18	1.484	2.559	30.5	362.4	1.545	35.33	-0.0611	-1.17	--
168	2012-06-19	1.589	2.71	38.8	513.3	1.702	50.69	-0.113	-2.03	--
169	2012-07-12	1.925	2.894	84.2	782.7	1.892	78.53	0.033	0.736	--
170	2012-07-19	1.916	2.836	82.5	685	1.832	68.38	0.0842	1.88	--
171	2012-09-11	1.852	2.837	71.2	687.5	1.834	68.64	0.0186	0.207	--
172	2012-10-24	1.914	2.82	82.1	661	1.816	65.9	0.0982	2.44	--
173	2012-11-07	1.943	2.917	87.7	825.8	1.916	83.02	0.0265	0.5	--
174	2012-11-14	1.933	2.934	85.8	859.7	1.935	86.55	-0.00106	-0.196	--
175	2012-12-12	1.966	2.931	92.4	854	1.932	85.96	0.0341	0.766	--
176	2013-01-16	1.906	2.945	80.6	880.5	1.945	88.72	-0.039	-0.829	--
177	2013-01-29	1.912	2.898	81.6	791	1.897	79.39	0.0146	0.0916	--
178	2013-02-13	1.857	2.934	72	860	1.935	86.58	-0.0774	-1.43	--
179	2013-03-12	1.853	2.944	71.3	880	1.945	88.67	-0.092	-1.62	--
180	2013-03-13	1.903	3.018	80	1043	2.021	105.7	-0.118	-2.13	--
181	2013-03-27	1.976	3.064	94.7	1160	2.07	118.1	-0.0932	-1.66	--
182	2013-04-15	1.899	3.045	79.2	1110	2.05	112.8	-0.151	-2.44	--
183	2013-04-24	1.692	2.764	49.2	580.8	1.758	57.63	-0.066	-1.26	--
184	2013-05-06	1.795	2.89	62.4	777	1.889	77.93	-0.0938	-1.71	--
185	2013-05-09	1.602	2.672	40	470.2	1.663	46.29	-0.0607	-1.15	--
186	2013-05-15	1.797	2.775	62.6	595.7	1.769	59.16	0.0273	0.513	--
187	2013-05-21	1.682	2.65	48.1	447.1	1.64	43.93	0.0421	1.02	--
188	2013-05-28	1.895	2.854	78.6	714.2	1.851	71.41	0.0444	1.06	--
189	2013-06-05	1.644	2.692	44.1	491.9	1.683	48.51	-0.0387	-0.813	--
190	2013-06-05	1.673	2.691	47.1	491	1.682	48.41	-0.00924	-0.375	--
191	2013-06-13	1.888	2.962	77.2	915.3	1.963	92.37	-0.0752	-1.37	--
192	2013-06-24	2.029	3.144	107	1393	2.152	142.8	-0.123	-2.26	--
193	2013-07-09	1.896	2.858	78.7	721.4	1.856	72.16	0.0404	0.966	--
194	2013-07-29	1.093	2.15	12.4	141.3	1.121	13.31	-0.0279	-0.692	--
195	2013-08-07	1.021	2.017	10.5	104.1	0.9835	9.686	0.0377	0.879	--
196	2013-08-15	1.158	2.134	14.4	136	1.104	12.79	0.0543	1.29	--
197	2013-08-29	1.867	2.822	73.7	664	1.818	66.21	0.0492	1.21	--
198	2013-10-24	1.98	2.943	95.6	878	1.944	88.46	0.0364	0.813	--
199	2013-10-30	1.584	2.604	38.4	402.1	1.592	39.36	-0.008	-0.338	--
200	2013-11-25	1.988	2.936	97.3	863	1.936	86.9	0.0518	1.24	--
201	2013-12-11	2.057	3.025	114	1060	2.029	107.6	0.028	0.553	--
202	2014-01-14	2.045	3.025	111	1060	2.029	107.6	0.0164	0.149	--
203	2014-02-20	2.033	3.017	108	1040	2.02	105.4	0.0131	0.0801	--
204	2014-03-17	2.017	2.999	104	997	2.001	100.9	0.0157	0.103	--
205	2014-04-09	2.033	2.996	108	990.5	1.998	100.2	0.0351	0.797	--
206	2014-04-14	2.021	2.985	105	966.3	1.987	97.71	0.034	0.751	--
207	2014-05-14	1.752	2.766	56.5	583.5	1.76	57.91	-0.00797	-0.326	--
208	2014-05-15	1.87	2.896	74.2	787	1.895	78.97	-0.0244	-0.635	--
209	2014-05-29	1.948	2.945	88.7	882	1.946	88.88	0.00183	-0.161	--
210	2014-06-03	1.818	2.796	65.7	625.4	1.791	62.22	0.0263	0.475	--
211	2014-06-05	1.835	2.842	68.4	695.3	1.839	69.45	-0.00393	-0.266	--
212	2014-06-09	1.326	2.358	21.2	228.1	1.337	21.86	-0.0106	-0.399	--
213	2014-06-12	1.19	2.199	15.5	158	1.172	14.94	0.0188	0.219	--
214	2014-06-24	1.788	2.757	61.4	571	1.75	56.62	0.0379	0.896	--
215	2014-07-10	1.863	2.822	72.9	663.7	1.818	66.18	0.0447	1.08	--
216	2014-07-15	1.915	2.879	82.2	757.4	1.877	75.89	0.0374	0.862	--
217	2014-07-24	1.911	2.893	81.5	782.2	1.892	78.47	0.0192	0.242	--

218	2014-08-04	1.989	2.915	97.4	821.7	1.914	82.58	0.0744	1.62	--
219	2014-08-07	1.921	2.893	83.3	781	1.891	78.35	0.0293	0.621	--

Definitions

Ca: Calcium in mg/l (00915)

SC: Specific conductance in uS/cm @25C (00095)

Model Archive Summary for Sodium Concentration at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the sodium concentration (Na) model developed to compute hourly Na from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100 Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 1, 1998 to August 7, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 217 concurrent measurements of sodium concentration, streamflow, and specific conductance collected from May 1, 1998 through August 7, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. No samples were below laboratory reporting levels. Summary statistics and the complete model-calibration dataset are provided below. Samples with Cook's D values greater than the outlier test criteria and studentized residual values greater than 3 or less than negative 3 were considered outliers. Samples collected November 5, 1998; and August 7, 2013 were deemed outliers and removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating sodium concentration. A variety of models that predict Na and models that predict $\log_{10}(\text{Na})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted Na were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the

range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{Na})$.

Specific conductance was selected as the best predictor of Na based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for sodium concentration at site number 07144100.

Sodium concentration-based model:

$$\log_{10}(\text{Na}) = 1.33 \times \log_{10}(\text{SC}) - 2.08,$$

where

Na = sodium concentration in milligrams per liter (mg/L); and,

SC = specific conductance in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$).

Specific conductance makes physical and statistical sense as an explanatory variable for sodium concentration. It makes physical sense because sodium is an ion, which affects the conductivity of water. This correlates well with SC because SC is a measure of the conductivity of water. Specific conductance makes statistical sense as an explanatory variable because it resulted in a model with low standard error, Mallows' C_p and $PRESS$ values, and high R^2 values. The model selected was the simplest model (one explanatory variable) even though some of the other models were marginally better statistically.

The log-transformed model may be retransformed to the original units so that Na can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.01. The retransformed model, accounting for BCF is:

$$\text{Na} = 0.0084 \times \text{SC}^{1.33}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\text{Na} = 0.101 \times \text{SC} + 3.79 \log_{10}(\text{Q}) - 23.4$
2.0	2007	--	$\log_{10}(\text{Na}) = 1.33 \times \log_{10}(\text{SC}) - 2.08$

Sodium Concentration Record

The Na record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick

Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

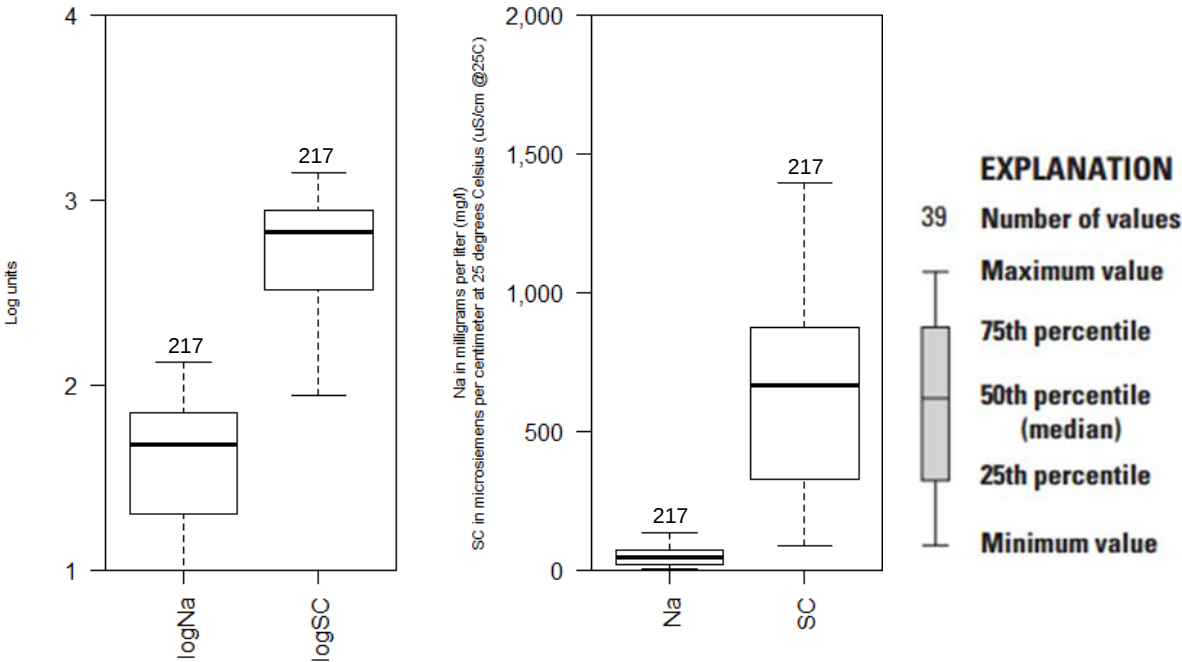
Model

$\log Na = + 1.33 * \log SC + -2.08$

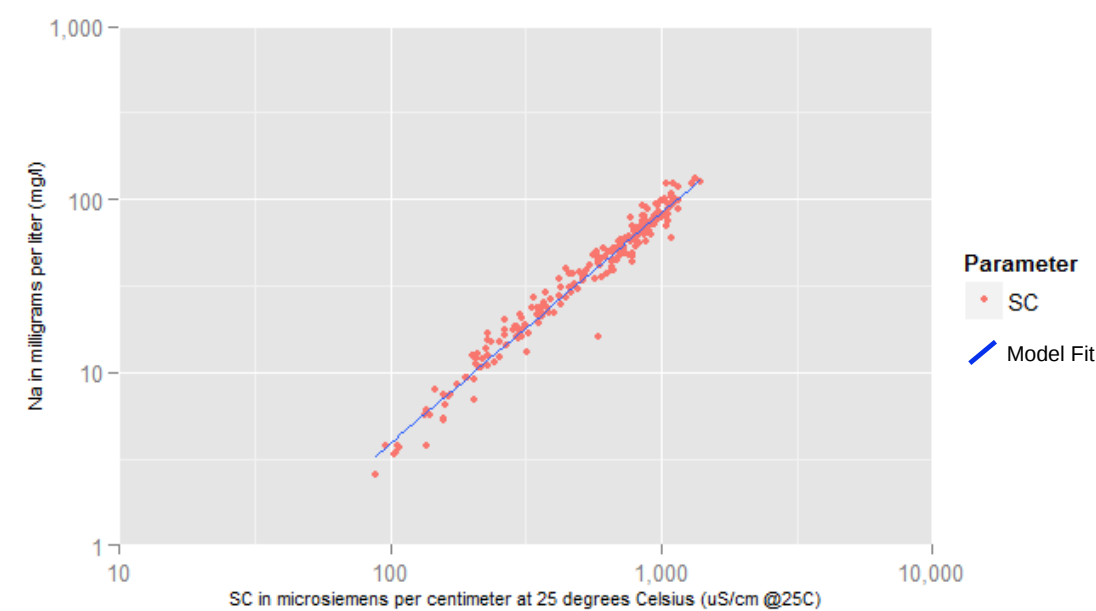
Variable Summary Statistics

	logNa	logSC	Na	SC
Minimum	0.405	1.95	2.54	88.2
1st Quartile	1.300	2.51	20.10	319.0
Median	1.680	2.82	47.70	664.0
Mean	1.550	2.72	47.70	623.0
3rd Quartile	1.850	2.94	70.60	872.0
Maximum	2.120	3.14	132.00	1390.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	217
Standard error (RMSE)	0.0681
Upper Model standard percentage error (MSPE)	17
Lower Model standard percentage error (MSPE)	14.5
Coefficient of determination (R ²)	0.968
Adjusted Coefficient of Determination (Adj. R ²)	0.968
Bias Correction Factor (BCF)	1.01

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-2.08	0.0449	-46.3	9.73e-114
logSC	1.33	0.0164	81.2	2.47e-163

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.995
E.vars	-0.995	1.000

Outlier Test Criteria

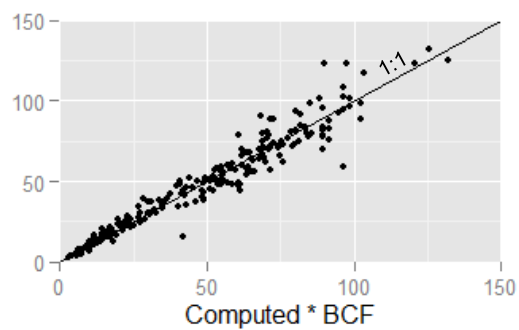
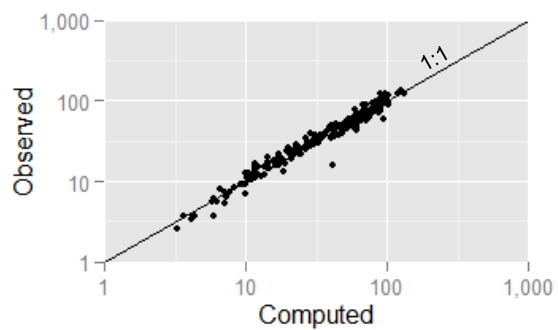
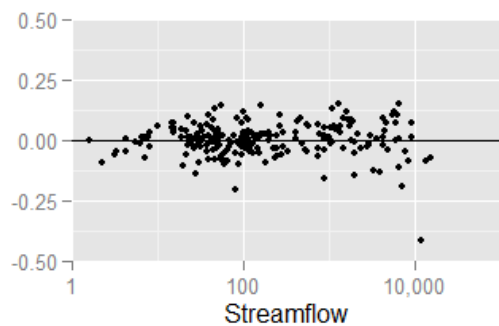
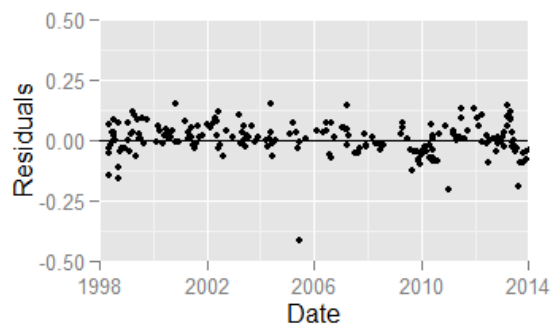
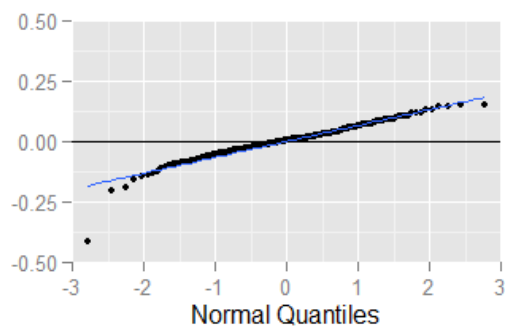
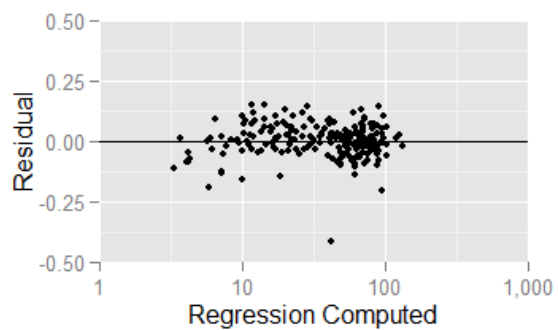
Leverage	Cook's D	DFFITS
0.01382488	0.10541193	0.13576885

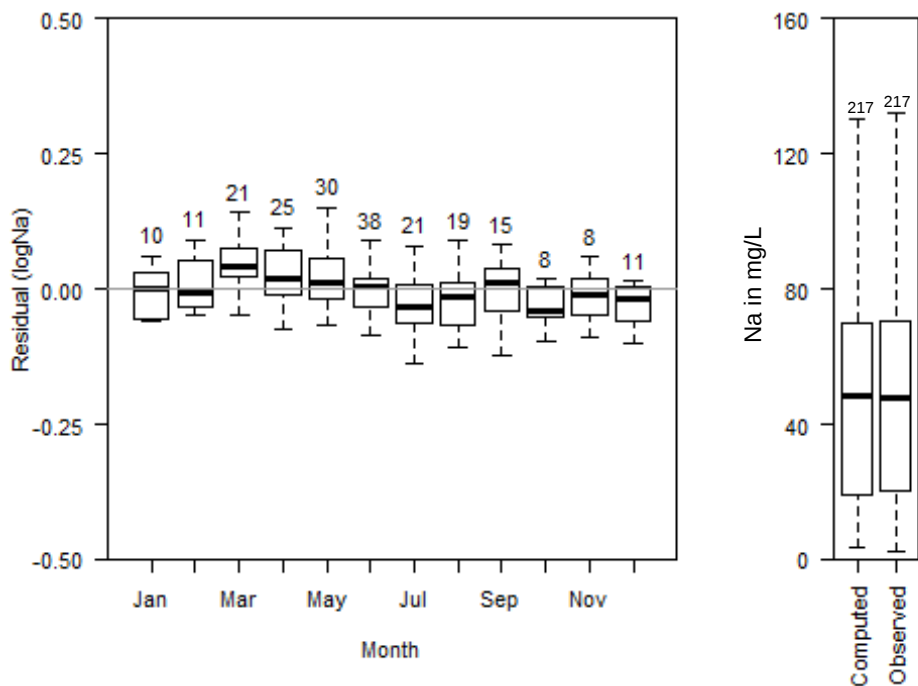
Flagged Observations

	logNa	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
5/14/1998 9:26	1.1170	1.2620	-0.144600	-2.13100	-2.14900	0.007334	1.678e-02	-0.184700
7/10/1998 10:51	1.0450	1.0110	0.034590	0.51150	0.51060	0.014140	1.876e-03	0.061140
9/22/1998 10:16	0.8382	1.0000	-0.162200	-2.39900	-2.42600	0.014500	4.235e-02	-0.294300

9/25/1998 10:11	0.4048	0.5171	-0.112300	-1.68200	-1.68900	0.039510	5.817e-02	-0.342600
10/5/1998 10:21	0.5752	0.6249	-0.049740	-0.74250	-0.74170	0.032610	9.291e-03	-0.136200
3/16/1999 13:41	2.1210	2.0930	0.027080	0.40050	0.39970	0.014230	1.157e-03	0.048020
4/16/1999 11:16	1.0970	0.9931	0.103900	1.53600	1.54100	0.014770	1.769e-02	0.188700
5/24/1999 13:06	1.1040	1.0230	0.081260	1.20100	1.20300	0.013720	1.004e-02	0.141900
7/20/1999 10:46	0.9279	0.9200	0.007904	0.11710	0.11680	0.017610	1.228e-04	0.015640
8/3/1999 11:51	0.9036	0.8143	0.089310	1.32600	1.32800	0.022330	2.008e-02	0.200700
10/26/2000 11:36	1.2200	1.0670	0.152700	2.25500	2.27700	0.012240	3.152e-02	0.253500
6/6/2001 10:11	0.5752	0.5652	0.009997	0.14950	0.14920	0.036340	4.215e-04	0.028970
6/23/2001 11:16	0.8591	0.8819	-0.022800	-0.33790	-0.33720	0.019220	1.119e-03	-0.047210
9/20/2001 10:21	0.7846	0.7712	0.013430	0.19960	0.19910	0.024460	4.994e-04	0.031530
6/13/2002 9:31	1.1880	1.0700	0.117300	1.73300	1.74200	0.012150	1.848e-02	0.193200
10/14/2003 11:01	0.9638	0.9709	-0.007144	-0.10570	-0.10550	0.015590	8.849e-05	-0.013270
5/13/2004 12:41	1.3030	1.1520	0.151600	2.23700	2.25900	0.009815	2.481e-02	0.224900
7/27/2004 9:46	0.7559	0.7585	-0.002609	-0.03879	-0.03870	0.025110	1.938e-05	-0.006212
6/9/2005 10:56	1.2040	1.6190	-0.415100	-6.10900	-6.70400	0.004761	8.927e-02	-0.463700
3/27/2007 11:46	1.5940	1.4530	0.141200	2.07800	2.09500	0.004920	1.068e-02	0.147300
4/2/2007 11:51	0.8663	0.8871	-0.020770	-0.30780	-0.30720	0.019000	9.175e-04	-0.042750
7/11/2007 12:11	0.8075	0.8645	-0.056990	-0.84520	-0.84470	0.019990	7.287e-03	-0.120600
4/28/2009 10:06	1.0790	1.0090	0.070560	1.04300	1.04400	0.014210	7.847e-03	0.125300
9/9/2009 12:01	0.7316	0.8551	-0.123500	-1.83200	-1.84200	0.020420	3.497e-02	-0.265900
12/17/2009 12:01	1.8460	1.9460	-0.100100	-1.47700	-1.48100	0.009723	1.071e-02	-0.146800
6/9/2010 9:46	0.8733	0.8545	0.018770	0.27850	0.27790	0.020440	8.092e-04	0.040140
6/13/2010 15:21	0.5328	0.6198	-0.087090	-1.30000	-1.30200	0.032920	2.877e-02	-0.240300
6/14/2010 9:41	0.5611	0.6365	-0.075380	-1.12500	-1.12500	0.031920	2.085e-02	-0.204400
6/15/2010 9:21	0.9694	0.9647	0.004737	0.07010	0.06994	0.015830	3.952e-05	0.008870
6/16/2010 9:11	0.9624	1.0020	-0.039340	-0.58170	-0.58080	0.014460	2.482e-03	-0.070350
7/6/2010 9:01	0.5263	0.6125	-0.086150	-1.28600	-1.28800	0.033370	2.856e-02	-0.239400
1/19/2011 11:41	1.7730	1.9790	-0.206100	-3.04200	-3.10200	0.010600	4.958e-02	-0.321200
6/22/2011 10:21	1.9590	1.8300	0.128500	1.89300	1.90400	0.007157	1.291e-02	0.161700
12/20/2011 11:16	1.4270	1.2970	0.129300	1.90400	1.91600	0.006708	1.225e-02	0.157500
3/13/2013 9:16	2.0900	1.9480	0.141800	2.09200	2.10800	0.009766	2.157e-02	0.209400
4/15/2013 9:00	2.0900	1.9840	0.105500	1.55700	1.56300	0.010750	1.318e-02	0.162900
5/6/2013 11:00	1.8940	1.7780	0.116000	1.70800	1.71600	0.006291	9.240e-03	0.136600
6/24/2013 9:40	2.0970	2.1160	-0.019190	-0.28390	-0.28330	0.015050	6.156e-04	-0.035010
7/29/2013 10:40	0.7559	0.7904	-0.034500	-0.51250	-0.51170	0.023500	3.161e-03	-0.079370
8/15/2013 9:10	0.5775	0.7681	-0.190600	-2.83300	-2.88100	0.024620	1.013e-01	-0.457700
6/12/2014 11:40	0.7218	0.8550	-0.133100	-1.97500	-1.98900	0.020420	4.067e-02	-0.287100
7/24/2014 9:10	1.6420	1.7820	-0.139100	-2.04900	-2.06500	0.006349	1.341e-02	-0.165000

Statistical Plots





Models Considered

	Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
	logNa ~ logSC	1	0.06811	96.84	96.83	14.67	1.017	1 ± 16	
	logNa ~ SC	1	0.1361	87.4	87.34	696.4	4.092	1 ± 32	
	logNa ~ logQ	1	0.2298	64.07	63.9	2379	11.63	1 ± 55	
	logNa ~ Q + logSC	2	0.06637	97.02	96.99	4.183	1.026	1.93 ± 15	
	logNa ~ logSC + SC	2	0.06733	96.93	96.9	10.42	0.9977	12.3 ± 16	
	logNa ~ logQ + logSC	2	0.06827	96.84	96.81	16.67	1.05	2.95 ± 16	
	logNa ~ Q + logQ + logSC	3	0.06617	97.05	97.01	3.873	1.028	2.312 ± 15	
	logNa ~ Q + logSC + SC	3	0.06639	97.03	96.99	5.263	1.089	2.469 ± 15	
	logNa ~ logQ + logSC + SC	3	0.06746	96.93	96.89	12.26	1.037	3.045 ± 16	
	logNa ~ Q + logQ + logSC + SC	4	0.06619	97.06	97.01	5	1.095	2.866 ± 15	

Model-Calibration Data Set

0	Date	logNa	logSC	Na	SC	Computed logNa	Computed Na	Residual	Normal Quantiles	Censored Values
1	1998-05-01	1.907	2.94	80.7	871.2	1.844	70.65	0.0628	1.04	--
2	1998-05-06	1.766	2.906	58.3	804.5	1.798	63.52	-0.0322	-0.6	--
3	1998-05-11	1.82	2.96	66	912	1.871	75.1	-0.051	-0.979	--
4	1998-05-14	1.117	2.504	13.1	318.9	1.262	18.49	-0.145	-2.03	--
5	1998-05-27	1.803	2.926	63.5	844	1.826	67.72	-0.0229	-0.454	--
6	1998-06-16	1.841	2.943	69.4	877.9	1.848	71.37	-0.00711	-0.209	--
7	1998-06-24	1.662	2.779	45.9	601.2	1.629	43.07	0.0326	0.572	--
8	1998-07-10	1.045	2.315	11.1	206.7	1.011	10.37	0.0346	0.627	--
9	1998-07-13	1.274	2.5	18.8	316	1.257	18.26	0.0176	0.329	--

10	1998-07-20	1.673	2.751	47.1	564.1	1.592	39.57	0.0807	1.26	--
11	1998-08-06	1.804	2.914	63.7	819.7	1.809	65.13	-0.0046	-0.127	--
12	1998-09-15	1.904	2.933	80.2	857.4	1.835	69.16	0.0694	1.06	--
13	1998-09-22	0.8382	2.308	6.89	203.1	1	10.13	-0.162	-2.13	--
14	1998-09-25	0.4048	1.945	2.54	88.18	0.5171	3.328	-0.112	-1.76	--
15	1998-10-05	0.5752	2.026	3.76	106.2	0.6249	4.265	-0.0497	-0.942	--
16	1998-10-22	1.396	2.629	24.9	425.9	1.429	27.19	-0.0332	-0.642	--
17	1998-12-04	1.706	2.862	50.8	728.3	1.74	55.63	-0.0344	-0.685	--
18	1999-01-12	1.975	3.041	94.4	1100	1.979	96.42	-0.00418	-0.116	--
19	1999-02-01	1.31	2.486	20.4	306.3	1.238	17.52	0.0712	1.14	--
20	1999-02-19	1.897	3.017	78.9	1040	1.947	89.47	-0.0496	-0.924	--
21	1999-03-16	2.121	3.127	132	1340	2.093	125.5	0.0271	0.466	--
22	1999-03-23	2.009	3.041	102	1100	1.979	96.42	0.0294	0.532	--
23	1999-04-07	1.538	2.625	34.5	421.7	1.424	26.84	0.114	1.76	--
24	1999-04-16	1.097	2.302	12.5	200.5	0.9931	9.956	0.104	1.66	--
25	1999-05-05	1.731	2.905	53.8	804.1	1.798	63.48	-0.0668	-1.16	--
26	1999-05-24	1.104	2.324	12.7	211	1.023	10.66	0.0813	1.28	--
27	1999-06-18	1.23	2.477	17	300.3	1.227	17.06	0.00352	0.0115	--
28	1999-06-21	1.072	2.344	11.8	220.7	1.049	11.31	0.0233	0.416	--
29	1999-07-20	0.9279	2.247	8.47	176.8	0.92	8.414	0.0079	0.0693	--
30	1999-08-03	0.9036	2.168	8.01	147.3	0.8143	6.597	0.0893	1.43	--
31	1999-08-19	1.862	2.965	72.8	921.9	1.877	76.18	-0.0147	-0.317	--
32	1999-09-28	1.173	2.375	14.9	237.2	1.09	12.46	0.0827	1.31	--
33	2000-02-09	1.982	3.049	96	1118	1.989	98.59	-0.00654	-0.186	--
34	2000-03-07	1.26	2.458	18.2	287.4	1.202	16.09	0.0585	0.96	--
35	2000-03-28	1.173	2.407	14.9	255.5	1.133	13.76	0.0397	0.699	--
36	2000-05-19	1.941	3.025	87.3	1060	1.958	91.77	-0.0167	-0.353	--
37	2000-05-31	1.489	2.662	30.8	459.6	1.474	30.1	0.015	0.293	--
38	2000-06-28	1.384	2.562	24.2	364.9	1.34	22.13	0.0439	0.775	--
39	2000-07-20	1.752	2.86	56.5	724.9	1.738	55.29	0.0145	0.233	--
40	2000-07-28	1.348	2.548	22.3	353	1.321	21.17	0.0276	0.492	--
41	2000-08-16	1.771	2.874	59	749	1.756	57.75	0.0144	0.221	--
42	2000-09-08	1.841	2.927	69.4	846	1.827	67.93	0.0143	0.209	--
43	2000-09-25	1.872	2.932	74.4	855.9	1.834	68.99	0.0378	0.67	--
44	2000-10-26	1.22	2.358	16.6	228	1.067	11.82	0.153	2.77	--
45	2000-11-08	1.529	2.711	33.8	514.6	1.539	35	-0.0101	-0.245	--
46	2000-12-04	1.967	3.037	92.6	1088	1.973	95.04	-0.00627	-0.162	--
47	2001-03-14	1.369	2.525	23.4	335.3	1.291	19.77	0.0783	1.23	--
48	2001-04-13	1.591	2.725	39	531.3	1.558	36.53	0.0335	0.586	--
49	2001-04-26	1.92	2.994	83.1	986.6	1.916	83.4	0.00348	0	--
50	2001-05-08	1.695	2.821	49.5	662.5	1.685	49.03	0.00916	0.0925	--
51	2001-06-04	1.265	2.465	18.4	291.9	1.211	16.43	0.0542	0.839	--
52	2001-06-06	0.5752	1.981	3.76	95.82	0.5652	3.717	0.01	0.139	--
53	2001-06-23	0.8591	2.219	7.23	165.5	0.8819	7.708	-0.0228	-0.441	--
54	2001-07-11	1.769	2.909	58.7	811.1	1.803	64.22	-0.034	-0.656	--
55	2001-08-02	1.756	2.885	57	767.3	1.77	59.64	-0.0146	-0.305	--
56	2001-08-28	1.843	2.897	69.6	789	1.787	61.9	0.0559	0.872	--
57	2001-09-20	0.7846	2.136	6.09	136.7	0.7712	5.973	0.0134	0.186	--
58	2001-10-31	1.851	2.931	70.9	853	1.832	68.68	0.0188	0.378	--
59	2002-01-10	2.004	3.014	101	1032	1.942	88.59	0.062	0.997	--
60	2002-02-21	2.033	3.041	108	1100	1.979	96.42	0.0543	0.856	--
61	2002-04-09	1.971	2.983	93.5	960.7	1.901	80.49	0.0701	1.1	--

62	2002-04-22	1.246	2.423	17.6	264.9	1.154	14.43	0.0912	1.46	--
63	2002-05-13	1.714	2.786	51.8	611.6	1.639	44.07	0.0753	1.21	--
64	2002-05-22	1.442	2.625	27.7	422	1.424	26.87	0.0183	0.341	--
65	2002-06-06	1.342	2.589	22	388.1	1.376	24.02	-0.0331	-0.627	--
66	2002-06-13	1.188	2.36	15.4	229.1	1.07	11.89	0.117	1.88	--
67	2002-07-09	1.711	2.857	51.4	720	1.734	54.78	-0.0227	-0.416	--
68	2002-08-15	1.688	2.872	48.8	744	1.753	57.23	-0.0642	-1.14	--
69	2002-09-19	1.77	2.857	58.9	720	1.734	54.78	0.0365	0.656	--
70	2002-12-18	2.09	3.114	123	1300	2.076	120.5	0.014	0.197	--
71	2003-03-20	1.33	2.479	21.4	301.5	1.229	17.15	0.101	1.61	--
72	2003-04-17	1.993	3.061	98.4	1150	2.005	102.3	-0.0119	-0.269	--
73	2003-04-23	1.702	2.808	50.3	642	1.667	47.01	0.0344	0.613	--
74	2003-05-14	1.403	2.566	25.3	368	1.345	22.38	0.0583	0.889	--
75	2003-05-29	1.498	2.68	31.5	479	1.498	31.81	0.000741	-0.0693	--
76	2003-06-11	1.649	2.817	44.6	656	1.68	48.39	-0.0304	-0.559	--
77	2003-06-24	1.926	2.988	84.4	972	1.907	81.75	0.0189	0.391	--
78	2003-07-30	1.868	2.951	73.8	892.6	1.858	72.97	0.00994	0.127	--
79	2003-09-03	1.215	2.425	16.4	265.9	1.156	14.5	0.0584	0.924	--
80	2003-10-14	0.9638	2.286	9.2	193	0.9709	9.461	-0.00714	-0.221	--
81	2003-12-11	2.004	3.049	101	1120	1.99	98.77	0.0147	0.269	--
82	2004-03-09	1.029	2.328	10.7	212.8	1.028	10.78	0.00179	-0.0462	--
83	2004-03-30	1.899	3.003	79.3	1007	1.928	85.67	-0.0285	-0.519	--
84	2004-04-26	1.923	2.994	83.7	986.3	1.916	83.36	0.00678	0.0577	--
85	2004-05-13	1.303	2.421	20.1	263.6	1.152	14.34	0.152	2.44	--
86	2004-05-26	1.98	3.017	95.6	1040	1.947	89.47	0.0338	0.6	--
87	2004-06-16	1.747	2.92	55.9	832	1.817	66.44	-0.07	-1.19	--
88	2004-06-22	1.152	2.433	14.2	270.8	1.167	14.86	-0.0147	-0.329	--
89	2004-07-27	0.7559	2.126	5.7	133.8	0.7585	5.801	-0.00261	-0.0925	--
90	2005-01-27	1.336	2.542	21.7	348.7	1.314	20.82	0.0229	0.403	--
91	2005-03-23	1.137	2.355	13.7	226.3	1.063	11.7	0.0736	1.19	--
92	2005-05-10	1.646	2.769	44.3	587	1.615	41.72	0.0311	0.559	--
93	2005-05-27	1.204	2.484	16	305	1.236	17.42	-0.0319	-0.586	--
94	2005-06-06	1.204	2.464	16	291.3	1.209	16.39	-0.00533	-0.139	--
95	2005-06-09	1.204	2.772	16	591	1.619	42.1	-0.415	-2.77	--
96	2005-08-31	1.34	2.561	21.9	364	1.339	22.06	0.00194	-0.0231	--
97	2006-02-09	1.883	2.941	76.3	872	1.845	70.73	0.0379	0.685	--
98	2006-05-02	1.78	2.87	60.2	741.9	1.751	57.02	0.0286	0.505	--
99	2006-06-08	1.993	3	98.5	1000	1.924	84.91	0.0695	1.08	--
100	2006-06-26	1.241	2.457	17.4	286.7	1.2	16.04	0.0404	0.714	--
101	2006-07-27	1.647	2.841	44.4	692.7	1.711	52.03	-0.0639	-1.12	--
102	2006-08-15	1.61	2.818	40.7	658	1.681	48.58	-0.0719	-1.21	--
103	2006-08-23	1.679	2.762	47.7	578.2	1.607	40.88	0.072	1.16	--
104	2006-09-27	1.767	2.876	58.5	750.9	1.758	57.94	0.00919	0.104	--
105	2007-01-10	1.895	2.941	78.6	873	1.845	70.84	0.0502	0.807	--
106	2007-02-05	1.962	2.989	91.6	974	1.909	81.98	0.0532	0.823	--
107	2007-03-12	1.766	2.85	58.3	708	1.724	53.57	0.0418	0.744	--
108	2007-03-21	1.758	2.844	57.3	698	1.716	52.56	0.0425	0.76	--
109	2007-03-27	1.594	2.647	39.3	443.7	1.453	28.72	0.141	2.13	--
110	2007-04-02	0.8663	2.223	7.35	167	0.8871	7.8	-0.0208	-0.403	--
111	2007-04-18	1.093	2.364	12.4	231	1.075	12.02	0.0184	0.353	--
112	2007-07-11	0.8075	2.206	6.42	160.6	0.8645	7.405	-0.057	-1.04	--
113	2007-08-16	1.655	2.837	45.2	686.4	1.706	51.4	-0.0508	-0.96	--

114	2007-09-06	1.861	2.979	72.6	952	1.895	79.52	-0.0345	-0.729	--
115	2007-11-26	1.831	2.911	67.7	815	1.805	64.63	0.0252	0.454	--
116	2007-12-06	1.849	2.957	70.6	906	1.867	74.43	-0.0179	-0.378	--
117	2007-12-13	1.193	2.472	15.6	296.5	1.22	16.77	-0.0265	-0.505	--
118	2008-03-06	1.246	2.485	17.6	305.2	1.236	17.43	0.0092	0.116	--
119	2008-04-14	1.462	2.666	29	463.5	1.478	30.44	-0.0161	-0.341	--
120	2008-05-29	1.025	2.336	10.6	216.8	1.038	11.05	-0.013	-0.293	--
121	2008-06-30	1.286	2.55	19.3	355.2	1.324	21.34	-0.0387	-0.76	--
122	2008-08-05	1.701	2.85	50.2	707.5	1.723	53.52	-0.0228	-0.428	--
123	2009-04-06	1.718	2.825	52.2	668.2	1.69	49.59	0.0273	0.479	--
124	2009-04-13	1.621	2.737	41.8	545.4	1.573	37.82	0.0484	0.791	--
125	2009-04-28	1.079	2.314	12	206	1.009	10.32	0.0706	1.12	--
126	2009-06-16	1.507	2.683	32.1	481.9	1.501	32.07	0.00545	0.0346	--
127	2009-07-30	1.09	2.407	12.3	255.4	1.133	13.75	-0.0433	-0.807	--
128	2009-09-09	0.7316	2.199	5.39	158	0.8551	7.246	-0.123	-1.81	--
129	2009-09-24	1.061	2.387	11.5	243.7	1.106	12.91	-0.0452	-0.823	--
130	2009-11-03	1.228	2.514	16.9	326.7	1.276	19.09	-0.0479	-0.872	--
131	2009-11-19	1.692	2.892	49.2	780	1.78	60.96	-0.088	-1.43	--
132	2009-12-01	1.795	2.964	62.4	920.6	1.876	76.04	-0.0808	-1.31	--
133	2009-12-17	1.846	3.017	70.2	1040	1.946	89.43	-0.1	-1.61	--
134	2010-01-06	1.947	3.061	88.5	1150	2.005	102.3	-0.058	-1.06	--
135	2010-01-19	1.892	3.017	77.9	1040	1.947	89.47	-0.0551	-1.02	--
136	2010-02-04	1.856	2.977	71.7	948.6	1.893	79.14	-0.0379	-0.744	--
137	2010-02-23	1.892	2.999	78	997	1.922	84.57	-0.0301	-0.545	--
138	2010-03-10	1.679	2.853	47.7	713	1.728	54.07	-0.0494	-0.907	--
139	2010-04-14	1.922	3.017	83.6	1040	1.947	89.47	-0.0245	-0.479	--
140	2010-04-23	1.554	2.779	35.8	600.8	1.629	43.03	-0.0749	-1.23	--
141	2010-05-13	1.377	2.543	23.8	349	1.314	20.85	0.0625	1.02	--
142	2010-06-09	0.8733	2.198	7.47	157.9	0.8545	7.237	0.0188	0.366	--
143	2010-06-13	0.5328	2.022	3.41	105.3	0.6198	4.216	-0.0871	-1.4	--
144	2010-06-14	0.5611	2.035	3.64	108.4	0.6365	4.38	-0.0754	-1.26	--
145	2010-06-15	0.9694	2.281	9.32	190.9	0.9647	9.326	0.00474	0.0231	--
146	2010-06-16	0.9624	2.309	9.17	203.5	1.002	10.16	-0.0393	-0.775	--
147	2010-07-06	0.5263	2.017	3.36	104	0.6125	4.145	-0.0861	-1.37	--
148	2010-08-19	1.571	2.801	37.2	633.1	1.659	46.14	-0.0885	-1.46	--
149	2010-08-25	1.573	2.718	37.4	522.7	1.548	35.73	0.0248	0.441	--
150	2010-11-16	1.583	2.699	38.3	500.5	1.523	33.73	0.0602	0.979	--
151	2011-01-19	1.773	3.041	59.3	1100	1.979	96.42	-0.206	-2.44	--
152	2011-03-07	1.788	2.88	61.4	759	1.764	58.78	0.024	0.428	--
153	2011-03-16	1.833	2.906	68.1	805.2	1.798	63.6	0.0347	0.642	--
154	2011-04-06	1.914	2.981	82.1	957	1.898	80.08	0.0159	0.305	--
155	2011-04-18	1.906	2.976	80.6	946	1.892	78.85	0.0146	0.257	--
156	2011-05-02	1.887	2.972	77.1	936.9	1.886	77.84	0.000879	-0.0577	--
157	2011-06-07	1.72	2.839	52.5	691	1.71	51.86	0.0104	0.151	--
158	2011-06-21	1.946	2.95	88.3	890.5	1.857	72.74	0.0892	1.4	--
159	2011-06-22	1.959	2.93	90.9	850.5	1.83	68.41	0.128	1.95	--
160	2011-08-15	1.367	2.578	23.3	378.3	1.361	23.22	0.00658	0.0462	--
161	2011-09-22	1.42	2.591	26.3	390.2	1.379	24.2	0.0412	0.729	--
162	2011-12-20	1.427	2.53	26.7	339	1.297	20.06	0.129	2.03	--
163	2012-02-06	1.568	2.665	37	461.9	1.476	30.3	0.0918	1.5	--
164	2012-03-01	1.489	2.63	30.8	426.4	1.43	27.24	0.0584	0.942	--
165	2012-04-07	1.459	2.576	28.8	376.9	1.359	23.1	0.101	1.57	--

166	2012-04-17	1.731	2.86	53.8	725	1.738	55.29	-0.00685	-0.197	--
167	2012-06-18	1.324	2.559	21.1	362.4	1.336	21.92	-0.0116	-0.257	--
168	2012-06-19	1.554	2.71	35.8	513.3	1.538	34.88	0.0163	0.317	--
169	2012-07-12	1.686	2.894	48.5	782.7	1.782	61.24	-0.0963	-1.53	--
170	2012-07-19	1.703	2.836	50.5	685	1.705	51.26	-0.00146	-0.0809	--
171	2012-09-11	1.709	2.837	51.2	687.5	1.707	51.51	0.00244	-0.0115	--
172	2012-10-24	1.638	2.82	43.5	661	1.684	48.88	-0.0456	-0.856	--
173	2012-11-07	1.8	2.917	63.1	825.8	1.813	65.78	-0.013	-0.281	--
174	2012-11-14	1.849	2.934	70.7	859.7	1.836	69.4	0.0131	0.174	--
175	2012-12-12	1.824	2.931	66.7	854	1.833	68.79	-0.00838	-0.233	--
176	2013-01-16	1.859	2.945	72.3	880.5	1.85	71.65	0.00893	0.0809	--
177	2013-01-29	1.818	2.898	65.8	791	1.788	62.11	0.0301	0.545	--
178	2013-02-13	1.811	2.934	64.7	860	1.837	69.44	-0.0257	-0.492	--
179	2013-03-12	1.949	2.944	89	880	1.85	71.6	0.0995	1.53	--
180	2013-03-13	2.09	3.018	123	1043	1.948	89.78	0.142	2.26	--
181	2013-03-27	2.068	3.064	117	1160	2.01	103.5	0.0583	0.907	--
182	2013-04-15	2.09	3.045	123	1110	1.984	97.59	0.106	1.7	--
183	2013-04-24	1.698	2.764	49.9	580.8	1.609	41.13	0.0889	1.37	--
184	2013-05-06	1.894	2.89	78.3	777	1.778	60.64	0.116	1.81	--
185	2013-05-09	1.573	2.672	37.4	470.2	1.487	31.03	0.0861	1.34	--
186	2013-05-15	1.618	2.775	41.5	595.7	1.624	42.54	-0.00574	-0.151	--
187	2013-05-21	1.428	2.65	26.8	447.1	1.458	29.01	-0.0294	-0.532	--
188	2013-05-28	1.758	2.854	57.3	714.2	1.729	54.19	0.0292	0.519	--
189	2013-06-05	1.48	2.692	30.2	491.9	1.513	32.96	-0.033	-0.613	--
190	2013-06-13	1.874	2.962	74.9	915.3	1.873	75.46	0.00181	-0.0346	--
191	2013-06-24	2.097	3.144	125	1393	2.116	132.2	-0.0192	-0.391	--
192	2013-07-09	1.686	2.858	48.5	721.4	1.735	54.93	-0.049	-0.889	--
193	2013-07-29	0.7559	2.15	5.7	141.3	0.7904	6.243	-0.0345	-0.714	--
194	2013-08-15	0.5775	2.134	3.78	136	0.7681	5.931	-0.191	-2.26	--
195	2013-08-29	1.59	2.822	38.9	664	1.687	49.17	-0.0968	-1.57	--
196	2013-10-24	1.753	2.943	56.6	878	1.849	71.38	-0.0957	-1.5	--
197	2013-10-30	1.344	2.604	22.1	402.1	1.396	25.19	-0.0518	-0.997	--
198	2013-11-25	1.793	2.936	62.1	863	1.839	69.76	-0.0455	-0.839	--
199	2013-12-11	1.877	3.025	75.4	1060	1.958	91.77	-0.0803	-1.28	--
200	2014-01-14	1.915	3.025	82.3	1060	1.958	91.77	-0.0423	-0.791	--
201	2014-02-20	1.912	3.017	81.7	1040	1.947	89.47	-0.0344	-0.699	--
202	2014-03-17	1.898	2.999	79.1	997	1.922	84.57	-0.024	-0.466	--
203	2014-04-09	1.901	2.996	79.6	990.5	1.918	83.83	-0.0175	-0.366	--
204	2014-04-14	1.873	2.985	74.7	966.3	1.904	81.12	-0.0308	-0.572	--
205	2014-05-14	1.626	2.766	42.3	583.5	1.612	41.39	0.0145	0.245	--
206	2014-05-15	1.779	2.896	60.1	787	1.785	61.69	-0.00629	-0.174	--
207	2014-05-29	1.848	2.945	70.5	882	1.851	71.81	-0.00299	-0.104	--
208	2014-06-03	1.665	2.796	46.2	625.4	1.652	45.4	0.0126	0.162	--
209	2014-06-05	1.728	2.842	53.5	695.3	1.713	52.29	0.0149	0.281	--
210	2014-06-09	1.033	2.358	10.8	228.1	1.068	11.82	-0.0342	-0.67	--
211	2014-06-12	0.7218	2.199	5.27	158	0.855	7.244	-0.133	-1.88	--
212	2014-06-24	1.539	2.757	34.6	571	1.599	40.21	-0.0602	-1.08	--
213	2014-07-10	1.584	2.822	38.4	663.7	1.686	49.14	-0.102	-1.66	--
214	2014-07-15	1.68	2.879	47.9	757.4	1.763	58.61	-0.0826	-1.34	--
215	2014-07-24	1.642	2.893	43.9	782.2	1.782	61.18	-0.139	-1.95	--
216	2014-08-04	1.749	2.915	56.1	821.7	1.81	65.34	-0.0612	-1.1	--
217	2014-08-07	1.671	2.893	46.9	781	1.781	61.06	-0.11	-1.7	--

Definitions

Na: Sodium in mg/l (00930)

SC: Specific conductance in uS/cm @25C (00095)

Model Archive Summary for Alkalinity at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the alkalinity (ALK) model developed to compute hourly ALK from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 1, 1998 to August 4, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 187 concurrent measurements of alkalinity, streamflow, and SC collected from May 1, 1998 through August 4, 2014. Samples were collected throughout the range of continuously observed hydrologic and specific conductance conditions. There were no samples below laboratory reporting levels. Summary statistics and complete model-calibration dataset are provided below. Samples with Cook's D values greater than the outlier test criteria and studentized residual values greater than 3 or less than negative 3 were considered outliers. A sample collected July 10, 1998 was deemed an outlier and was removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating alkalinity. A variety of models that predict ALK and models that predict $\log_{10}(\text{ALK})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted ALK were

examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{ALK})$.

Specific conductance and streamflow were selected as the best predictors of ALK based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error (MSPE), prediction error sum of squares (PRESS), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for alkalinity at site number 07144100.

Alkalinity-based model:

$$\log_{10}(\text{ALK}) = 0.731 \times \log_{10}(\text{SC}) - 0.094 \times \log_{10}(Q) + 0.36,$$

where

ALK = alkalinity in milligrams per liter as calcium carbonate (mg/L as CaCO_3),

SC = specific conductance, in microsiemens per centimeter ($\mu\text{S}/\text{cm}$) at 25 degrees Celsius; and

Q = streamflow, in cubic feet per second (ft^3/s).

The use of specific conductance and streamflow as explanatory variables makes sense both physically and statistically. Physically because alkalinity is composed of major ions that affect the conductivity of water and results in a clear correlation between alkalinity and specific conductance. Alkalinity correlates well with streamflow because high streamflow values tend to dilute concentrations of dissolved constituents associated with alkalinity. Specific conductance and streamflow make statistical sense as explanatory variables because they resulted in a model with low model percentage error, Mallows' C_p , and PRESS values, and high adjusted R^2 values.

The log-transformed model may be retransformed to the original units so that ALK can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.01. The retransformed model, accounting for BCF is:

$$\text{ALK} = \frac{2.314 \times \text{SC}^{0.731}}{Q^{0.094}}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(\text{ALK}) = 0.671 \times \log_{10}(\text{SC}) - 0.1211 \times \log_{10}(Q) + 0.574$
1.1	2007	--	$\log_{10}(\text{ALK}) = 0.731 \times \log_{10}(\text{SC}) - 0.094 \times \log_{10}(Q) + 0.36$

Alkalinity Concentration Record

The ALK record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick
Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

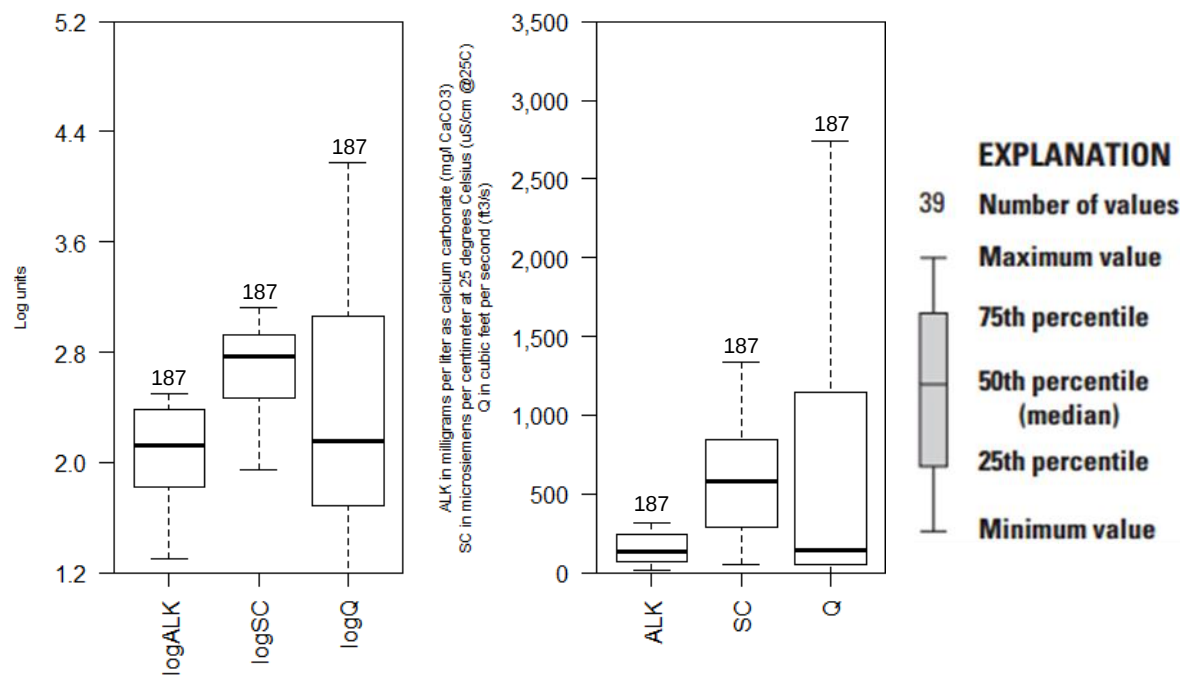
Model

$\log\text{ALK} = + 0.731 * \log\text{SC} + -0.094 * \log\text{Q} + 0.36$

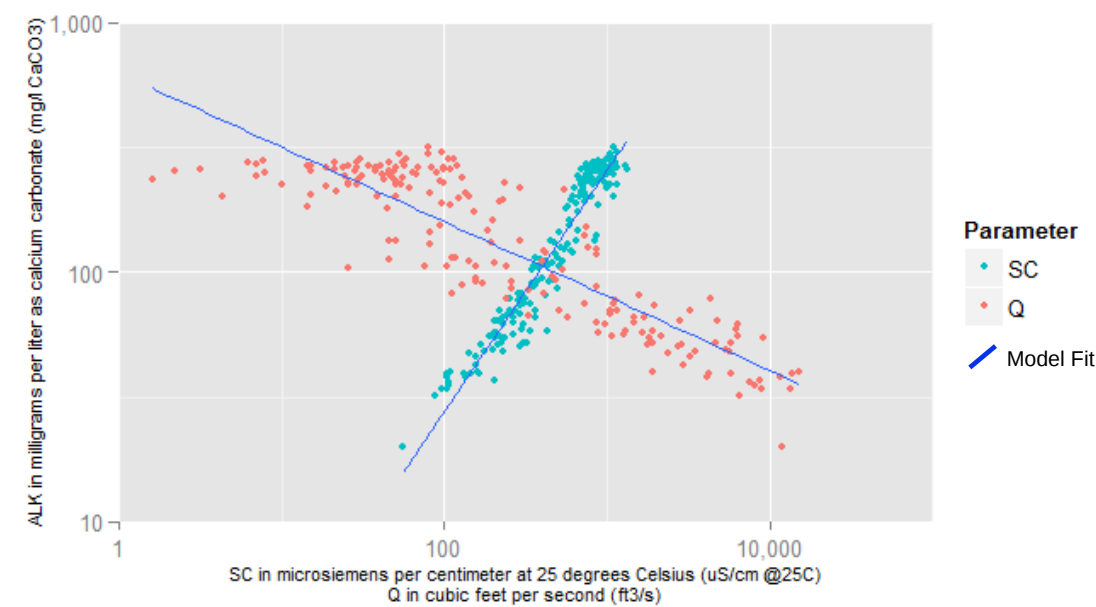
Variable Summary Statistics

	logALK	logSC	logQ	ALK	SC	Q
Minimum	1.30	1.75	0.204	20	56	1.6
1st Quartile	1.82	2.46	1.680	66	291	48.0
Median	2.13	2.77	2.150	134	584	142.0
Mean	2.10	2.68	2.350	155	585	1400.0
3rd Quartile	2.39	2.93	3.070	244	850	1170.0
Maximum	2.50	3.13	4.180	318	1340	15100.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	187
Standard error (RMSE)	0.0691
Upper Model standard percentage error (MSPE)	17.2
Lower Model standard percentage error (MSPE)	14.7
Coefficient of determination (R ²)	0.949
Adjusted Coefficient of Determination (Adj. R ²)	0.948
Bias Correction Factor (BCF)	1.01
Variance Inflation Factors (VIF)	
logSC	logQ
3.269302	3.269302

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.360	0.1020	3.53	5.19e-04
logSC	0.731	0.0303	24.10	7.36e-59
logQ	-0.094	0.0101	-9.27	5.17e-17

Correlation Matrix

	Intercept	logSC	logQ
Intercept	1.000	-0.990	-0.896
logSC	-0.990	1.000	0.833
logQ	-0.896	0.833	1.000

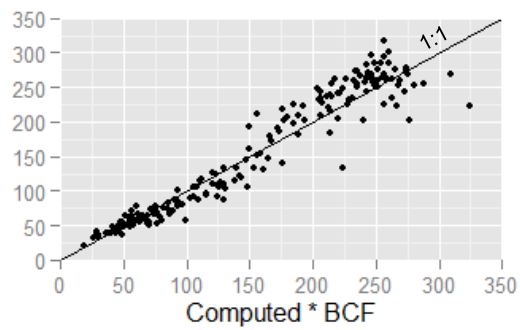
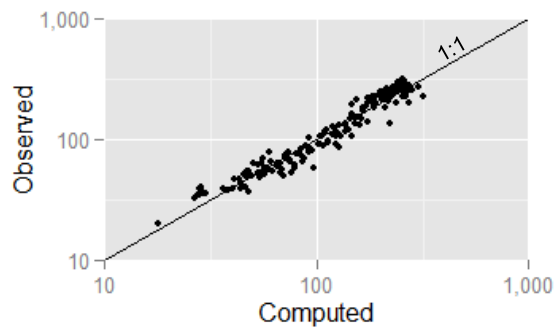
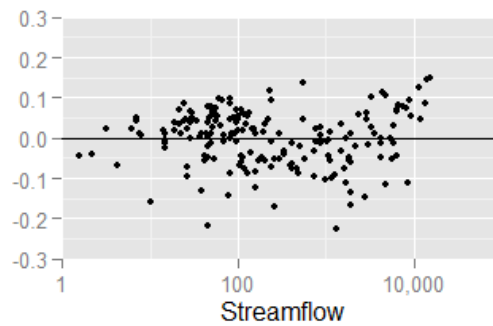
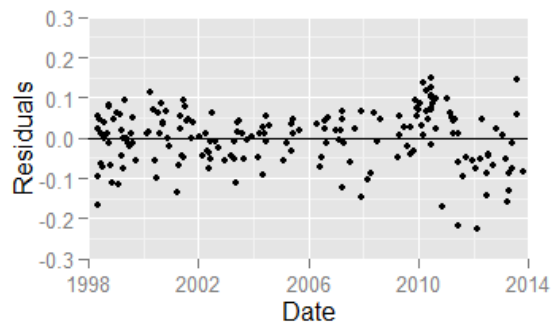
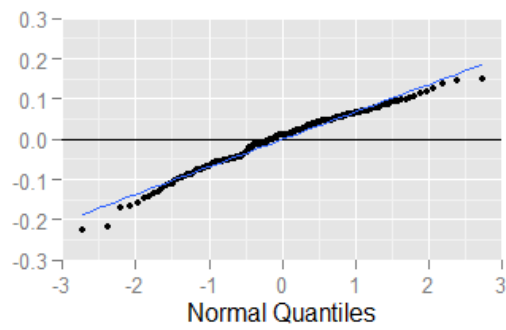
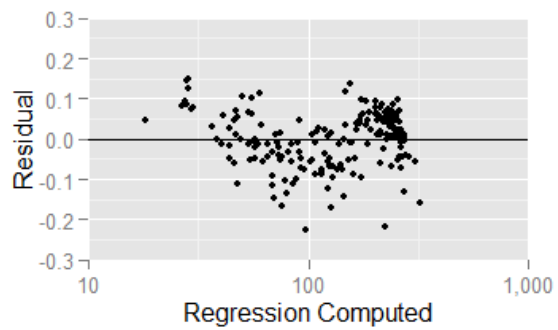
Outlier Test Criteria

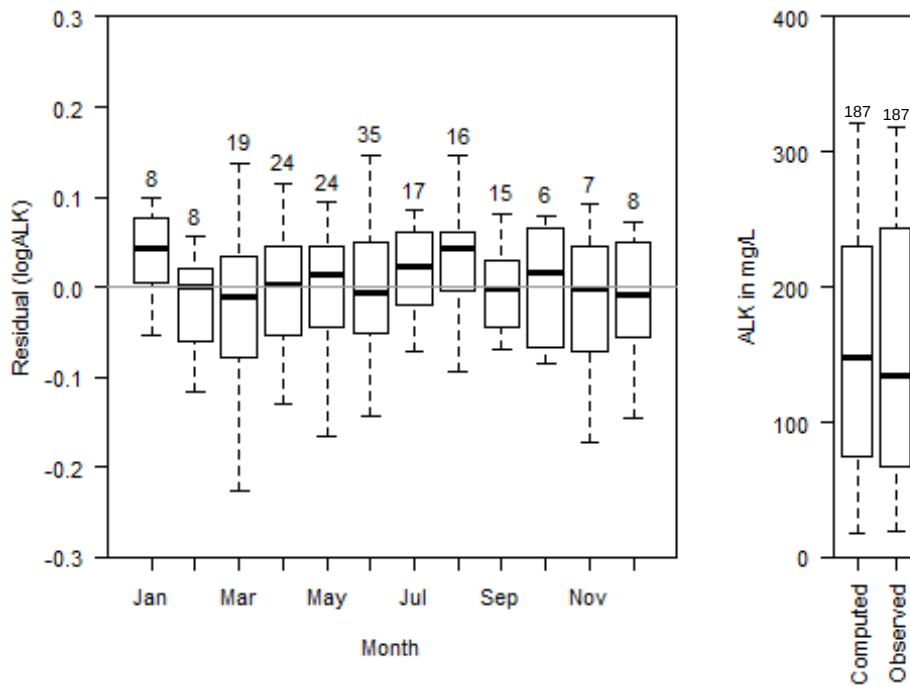
Leverage	Cook's D	DFFITS
0.03208556	0.19457405	0.20683508

Flagged Observations

	logALK	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
5/1/1998 13:06	2.146	2.240	-0.09417		-1.3910		-1.3940	0.038520	0.025830	-0.27910
5/14/1998 9:26	1.716	1.882	-0.16560		-2.4130		-2.4460	0.012550	0.024670	-0.27570
9/25/1998 10:11	1.505	1.423	0.08167		1.2070		1.2080	0.039880	0.020170	0.24630
10/5/1998 10:21	1.556	1.477	0.07975		1.1730		1.1740	0.030690	0.014520	0.20890
11/5/1998 13:41	1.568	1.679	-0.11040		-1.6170		-1.6240	0.023060	0.020570	-0.24950
2/1/1999 11:06	1.716	1.833	-0.11660		-1.7080		-1.7170	0.022800	0.022680	-0.26220
3/28/2000 12:46	1.892	1.778	0.11410		1.6670		1.6750	0.017820	0.016810	0.22560
3/14/2001 10:41	1.763	1.898	-0.13460		-1.9620		-1.9780	0.013220	0.017190	-0.22890
6/6/2001 10:11	1.531	1.437	0.09426		1.3890		1.3930	0.034460	0.022950	0.26310
6/9/2005 10:56	1.301	1.255	0.04587		0.6866		0.6856	0.064010	0.010750	0.17930
7/27/2006 11:16	2.412	2.389	0.02233		0.3321		0.3313	0.051910	0.002013	0.07753
8/15/2006 9:16	2.382	2.341	0.04129		0.6088		0.6078	0.035380	0.004532	0.11640
12/13/2007 10:16	1.699	1.844	-0.14510		-2.1170		-2.1380	0.014970	0.022710	-0.26350
3/10/2010 9:11	2.326	2.188	0.13780		2.0180		2.0350	0.021760	0.030200	0.30350
6/13/2010 19:21	1.580	1.454	0.12590		1.8530		1.8650	0.031210	0.036870	0.33480
6/14/2010 9:41	1.602	1.455	0.14700		2.1620		2.1840	0.030930	0.049750	0.39030
7/6/2010 9:01	1.531	1.447	0.08480		1.2480		1.2500	0.031590	0.016930	0.22570
6/22/2011 10:21	2.127	2.346	-0.21860		-3.1790		-3.2620	0.009123	0.031030	-0.31300
8/15/2011 10:46	2.017	2.111	-0.09446		-1.3930		-1.3970	0.036310	0.024380	-0.27120
3/1/2012 12:01	1.763	1.990	-0.22610		-3.2980		-3.3910	0.014480	0.053270	-0.41100
7/12/2012 10:16	2.401	2.443	-0.04166		-0.6205		-0.6194	0.054820	0.007443	-0.14920
7/19/2012 10:16	2.369	2.414	-0.04450		-0.6694		-0.6684	0.073220	0.011800	-0.18790
9/11/2012 10:16	2.305	2.375	-0.06917		-1.0250		-1.0250	0.044500	0.016300	-0.22120
3/27/2013 11:36	2.346	2.506	-0.15980		-2.3340		-2.3630	0.017350	0.032060	-0.31390
4/15/2013 9:11	2.305	2.436	-0.13070		-1.9060		-1.9200	0.013690	0.016810	-0.22620
8/7/2013 9:46	1.591	1.446	0.14530		2.1380		2.1590	0.031640	0.049760	0.39020

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logALK ~ logSC	1	0.0834	92.47	92.43	137.1	1.314	1 ± 19	
logALK ~ SC	1	0.1098	86.94	86.87	372.3	2.293	1 ± 26	
logALK ~ logQ	1	0.1405	78.63	78.52	725.2	3.733	1 ± 33	
logALK ~ logSC + logQ	2	0.06905	94.86	94.81	37.3	0.9064	3.269 ± 16	
logALK ~ logQ + SC	2	0.07444	94.03	93.97	72.67	1.058	2.439 ± 17	
logALK ~ logSC + SC	2	0.08204	92.75	92.67	127.1	1.279	10.86 ± 19	
logALK ~ Q + logSC + logQ	3	0.06408	95.6	95.53	7.94	0.7815	2.563 ± 15	
logALK ~ logSC + logQ + SC	3	0.06503	95.47	95.4	13.56	0.8113	14.91 ± 15	
logALK ~ Q + logQ + SC	3	0.07363	94.19	94.1	67.85	1.047	2.245 ± 17	
logALK ~ Q + logSC + logQ + SC	4	0.0634	95.72	95.62	5	0.7722	3.887 ± 15	

Model-Calibration Data Set

0	Date	logALK	logSC	logQ	ALK	SC	Q	Computed logALK	Computed ALK	Residual	Normal Quantiles	Censored Values
1	1998-05-01	2.146	2.94	2.862	140	871.2	728.1	2.24	176	-0.0942	-1.35	--
2	1998-05-06	2.305	2.906	2.155	202	804.5	143	2.281	193.5	0.024	0.257	--
3	1998-05-11	2.38	2.96	2.111	240	912	129	2.325	214.1	0.0548	0.82	--
4	1998-05-14	1.716	2.504	3.285	52	318.9	1928	1.882	77.06	-0.166	-2.07	--
5	1998-05-27	2.358	2.926	1.998	228	844	99.57	2.311	207.3	0.0465	0.596	--
6	1998-06-16	2.369	2.943	1.633	234	877.9	43	2.358	230.9	0.0111	0.0536	--
7	1998-06-24	2.083	2.779	2.615	121	601.2	412.1	2.146	141.6	-0.063	-0.959	--
8	1998-07-13	1.892	2.5	2.385	78	316	242.6	1.963	93	-0.0711	-1.05	--
9	1998-07-20	2.255	2.751	1.653	180	564.1	45	2.216	166.4	0.0393	0.443	--
10	1998-08-06	2.35	2.914	1.462	224	819.7	29	2.352	227.9	-0.00221	-0.175	--
11	1998-09-15	2.405	2.933	1.176	254	857.4	15	2.394	250.5	0.0112	0.067	--
12	1998-09-22	1.756	2.308	2.947	57	203.1	884.6	1.77	59.62	-0.0143	-0.384	--
13	1998-09-25	1.505	1.945	3.818	32	88.18	6575	1.423	26.84	0.0817	1.35	--

14	1998-10-05	1.556	2.026	3.882	36	106.2	7617	1.477	30.33	0.0797	1.32	--
15	1998-10-22	2.025	2.629	2.015	106	425.9	103.6	2.093	125.3	-0.0674	-1	--
16	1998-11-05	1.568	2.31	3.938	37	204.1	8663	1.679	48.28	-0.11	-1.5	--
17	1998-12-04	2.279	2.862	2.346	190	728.3	222	2.232	172.6	0.0469	0.628	--
18	1999-01-12	2.453	3.041	2.055	284	1100	113.5	2.39	248.5	0.0632	0.959	--
19	1999-02-01	1.716	2.486	3.67	52	306.3	4680	1.833	68.84	-0.117	-1.58	--
20	1999-02-19	2.427	3.017	2.079	267	1040	120	2.37	237.3	0.0565	0.839	--
21	1999-03-16	2.408	3.127	2.041	256	1340	110	2.454	287.9	-0.0458	-0.612	--
22	1999-03-23	2.413	3.041	1.991	259	1100	98	2.396	252	0.0172	0.161	--
23	1999-04-07	1.903	2.625	3.202	80	421.7	1594	1.978	96.22	-0.0749	-1.1	--
24	1999-04-16	1.69	2.302	3.733	49	200.5	5405	1.692	49.83	-0.00205	-0.161	--
25	1999-05-05	2.354	2.905	2.377	226	804.1	238.5	2.26	184.3	0.0937	1.54	--
26	1999-05-24	1.756	2.324	3.219	57	211	1656	1.757	57.8	-0.000795	-0.121	--
27	1999-06-18	1.914	2.477	2.613	82	300.3	409.8	1.926	85.29	-0.0118	-0.327	--
28	1999-06-21	1.74	2.344	3.334	55	220.7	2158	1.76	58.26	-0.0197	-0.413	--
29	1999-07-20	1.681	2.247	3.547	48	176.8	3528	1.67	47.3	0.0116	0.0804	--
30	1999-08-03	1.591	2.168	3.63	39	147.3	4265	1.604	40.67	-0.0129	-0.37	--
31	1999-08-19	2.394	2.965	1.949	248	921.9	89	2.344	223.5	0.0505	0.729	--
32	1999-09-28	1.732	2.375	3.264	54	237.2	1835	1.79	62.36	-0.0573	-0.897	--
33	2000-02-09	2.418	3.049	1.92	262	1118	83.15	2.408	259	0.0102	-0.0268	--
34	2000-03-07	1.886	2.458	3.053	77	287.4	1129	1.87	75.1	0.0161	0.134	--
35	2000-03-28	1.892	2.407	3.639	78	255.5	4352	1.778	60.71	0.114	1.88	--
36	2000-05-19	2.45	3.025	2.031	282	1060	107.3	2.381	243.2	0.0696	1.12	--
37	2000-05-31	2.033	2.662	2.312	108	459.6	205.1	2.089	124.2	-0.0556	-0.858	--
38	2000-06-28	1.845	2.562	3.067	70	364.9	1168	1.945	89.13	-0.0997	-1.42	--
39	2000-07-20	2.314	2.86	2.132	206	724.9	135.4	2.251	180.2	0.0633	0.98	--
40	2000-07-28	2.025	2.548	2.198	106	353	157.7	2.016	105	0.00934	-0.0402	--
41	2000-08-16	2.418	2.874	1.38	262	749	24	2.332	217.2	0.0867	1.46	--
42	2000-09-08	2.417	2.927	1.279	261	846	19	2.38	242.7	0.0369	0.413	--
43	2000-09-25	2.412	2.932	1.331	258	855.9	21.43	2.379	242	0.0331	0.355	--
44	2000-10-26	1.792	2.358	3.808	62	228	6430	1.726	53.85	0.0665	1.02	--
45	2000-11-08	2.161	2.711	1.914	145	514.6	82	2.162	147.1	-0.000917	-0.134	--
46	2000-12-04	2.401	3.037	1.663	252	1088	46	2.424	268.4	-0.0222	-0.443	--
47	2001-03-14	1.763	2.525	3.279	58	335.3	1903	1.898	80.03	-0.135	-1.74	--
48	2001-04-13	2.041	2.725	2.602	110	531.3	400	2.108	129.7	-0.0664	-0.98	--
49	2001-04-26	2.415	2.994	2.001	260	986.6	100.3	2.361	232.2	0.0543	0.765	--
50	2001-05-08	2.238	2.821	2.186	173	662.5	153.3	2.217	166.8	0.0211	0.202	--
51	2001-06-04	1.833	2.465	3.021	68	291.9	1049	1.878	76.49	-0.0459	-0.628	--
52	2001-06-06	1.531	1.981	3.952	34	95.82	8956	1.437	27.7	0.0943	1.58	--
53	2001-06-23	1.591	2.219	3.628	39	165.5	4250	1.641	44.3	-0.0501	-0.712	--
54	2001-07-11	2.405	2.909	1.69	254	811.1	49	2.328	215.3	0.0771	1.26	--
55	2001-08-02	2.382	2.885	1.394	241	767.3	24.76	2.338	220.4	0.0441	0.533	--
56	2001-08-28	2.384	2.897	1.491	242	789	31	2.338	220.2	0.0462	0.58	--
57	2001-09-20	1.58	2.136	3.62	38	136.7	4166	1.581	38.6	-0.00153	-0.148	--
58	2001-10-31	2.405	2.931	1.453	254	853	28.35	2.366	235.1	0.0388	0.428	--
59	2002-01-10	2.418	3.014	1.574	262	1032	37.52	2.415	263.3	0.00315	-0.107	--
60	2002-02-21	2.387	3.041	1.623	244	1100	42	2.431	272.9	-0.0433	-0.564	--
61	2002-04-09	2.365	2.983	1.971	232	960.7	93.59	2.355	229.2	0.0105	0	--
62	2002-04-22	1.799	2.423	3.171	63	264.9	1481	1.833	68.97	-0.0341	-0.502	--
63	2002-05-13	2.076	2.786	2.621	119	611.6	417.9	2.151	143.2	-0.0751	-1.15	--
64	2002-05-22	2.041	2.625	2.152	110	422	141.9	2.077	120.8	-0.0356	-0.518	--
65	2002-06-06	2.021	2.589	2.387	105	388.1	243.9	2.028	108	-0.00705	-0.216	--
66	2002-06-13	1.681	2.36	3.758	48	229.1	5729	1.732	54.62	-0.0509	-0.729	--
67	2002-07-09	2.371	2.857	1.477	235	720	30	2.31	206.6	0.0611	0.917	--
68	2002-08-15	2.182	2.872	2.875	152	744	750	2.189	156.4	-0.00713	-0.23	--
69	2002-09-19	2.312	2.857	1.176	205	720	15	2.338	220.5	-0.0265	-0.457	--
70	2002-12-18	2.428	3.114	1.613	268	1300	41	2.485	309	-0.0566	-0.877	--
71	2003-03-20	1.771	2.479	3.799	59	301.5	6294	1.815	66.18	-0.0446	-0.596	--
72	2003-04-17	2.415	3.061	1.843	260	1150	69.73	2.424	268.8	-0.00916	-0.271	--
73	2003-04-23	2.127	2.808	2.464	134	642	290.9	2.181	153.5	-0.0537	-0.783	--
74	2003-05-14	1.82	2.566	3.233	66	368	1710	1.932	86.53	-0.112	-1.54	--
75	2003-05-29	2.121	2.68	2.286	132	479	193	2.105	128.8	0.0159	0.121	--
76	2003-06-11	2.272	2.817	1.987	187	656	97	2.232	172.9	0.0394	0.457	--
77	2003-06-24	2.422	2.988	1.756	264	972	57	2.379	242.2	0.0426	0.502	--

78	2003-07-30	2.444	2.951	0.8865	278	892.6	7.7	2.434	274.7	0.0104	-0.0134	--
79	2003-09-03	1.82	2.425	2.757	66	265.9	571.5	1.873	75.63	-0.0539	-0.801	--
80	2003-10-14	1.74	2.286	3.033	55	193	1079	1.746	56.38	-0.0055	-0.189	--
81	2003-12-11	2.438	3.049	1.658	274	1120	45.48	2.433	274.4	0.00457	-0.0939	--
82	2004-03-09	1.708	2.328	3.254	51	212.8	1794	1.756	57.73	-0.0486	-0.661	--
83	2004-03-30	2.334	3.003	2.465	216	1007	292	2.323	213.2	0.011	0.0402	--
84	2004-04-26	2.417	2.994	1.708	261	986.3	51	2.388	247.4	0.0285	0.313	--
85	2004-05-13	1.748	2.421	3.104	56	263.6	1270	1.838	69.73	-0.09	-1.32	--
86	2004-05-26	2.418	3.017	1.699	262	1040	50	2.406	257.7	0.0125	0.0939	--
87	2004-06-16	2.375	2.905	1.74	237	804	55	2.32	211.6	0.0545	0.801	--
88	2004-06-22	1.845	2.433	3.017	70	270.8	1040	1.855	72.45	-0.0097	-0.285	--
89	2004-07-27	1.591	2.126	3.767	39	133.8	5845	1.561	36.79	0.0305	0.327	--
90	2005-01-27	1.954	2.542	2.234	90	348.7	171.3	2.009	103.3	-0.0544	-0.82	--
91	2005-03-23	1.716	2.355	3.766	52	226.3	5836	1.728	54.04	-0.0115	-0.313	--
92	2005-05-10	2.204	2.769	2.299	160	587	199	2.168	149	0.0362	0.399	--
93	2005-05-27	1.875	2.484	2.862	75	305	727.9	1.907	81.73	-0.0321	-0.487	--
94	2005-06-06	1.863	2.464	3.288	73	291.3	1943	1.853	72.08	0.0108	0.0134	--
95	2005-06-09	1.301	1.748	4.076	20	56	11900	1.255	18.21	0.0459	0.549	--
96	2005-08-31	2.057	2.561	2.047	114	364	111.5	2.04	111	0.017	0.148	--
97	2006-05-02	2.297	2.87	2.086	198	741.9	121.8	2.262	185.1	0.0344	0.384	--
98	2006-06-08	2.348	3	1.415	223	1000	26	2.42	266.2	-0.0717	-1.07	--
99	2006-06-26	1.914	2.457	2.049	82	286.7	111.9	1.964	93.14	-0.0501	-0.695	--
100	2006-07-27	2.412	2.841	0.5021	258	692.7	3.177	2.389	248	0.0223	0.23	--
101	2006-08-15	2.382	2.818	0.8451	241	658	7	2.341	221.8	0.0413	0.487	--
102	2006-08-23	2.258	2.762	1.163	181	578.2	14.56	2.27	188.4	-0.0121	-0.341	--
103	2006-09-27	2.431	2.876	0.8451	270	750.9	7	2.383	244.3	0.0487	0.712	--
104	2007-01-10	2.422	2.941	1.159	264	873	14.42	2.401	254.8	0.0206	0.189	--
105	2007-02-05	2.428	2.989	1.176	268	974	15	2.434	275	-0.00598	-0.202	--
106	2007-03-12	2.342	2.85	1.279	220	708	19	2.323	213	0.0192	0.175	--
107	2007-03-21	2.346	2.844	1.708	222	698	51	2.278	192.2	0.0679	1.07	--
108	2007-03-27	1.964	2.647	2.198	92	443.7	157.9	2.089	124.1	-0.125	-1.63	--
109	2007-04-02	1.708	2.223	3.46	51	167	2882	1.66	46.25	0.0477	0.678	--
110	2007-04-18	1.799	2.364	2.935	63	231	861	1.812	65.67	-0.0128	-0.355	--
111	2007-07-11	1.602	2.206	3.284	40	160.6	1924	1.664	46.69	-0.0619	-0.938	--
112	2007-09-06	2.428	2.979	1.415	268	952	26	2.404	256.8	0.0237	0.243	--
113	2007-11-26	2.418	2.911	1.462	262	815	29	2.351	226.9	0.0677	1.05	--
114	2007-12-13	1.699	2.472	3.438	50	296.5	2740	1.844	70.68	-0.145	-1.88	--
115	2008-03-06	1.792	2.484	2.99	62	305	977.7	1.895	79.51	-0.103	-1.46	--
116	2008-04-14	1.968	2.666	2.685	93	463.1	484	2.056	115.2	-0.0879	-1.29	--
117	2008-05-29	1.806	2.336	3.454	64	216.8	2846	1.743	56.02	0.0631	0.938	--
118	2008-06-30	1.94	2.55	2.942	87	355.2	874.4	1.948	89.8	-0.00851	-0.257	--
119	2008-08-05	2.358	2.85	1.407	228	707.5	25.5	2.311	207.1	0.0469	0.645	--
120	2009-04-06	2.164	2.825	2.272	146	668.2	187	2.212	164.7	-0.0472	-0.645	--
121	2009-04-13	2.093	2.737	2.933	124	545.4	856.8	2.085	123.1	0.00843	-0.0536	--
122	2009-04-28	1.732	2.314	3.963	54	206	9190	1.679	48.35	0.0533	0.747	--
123	2009-06-16	2.072	2.683	2.939	118	481.9	868.3	2.045	112.3	0.0267	0.299	--
124	2009-07-30	1.845	2.407	2.712	70	255.4	515.4	1.865	74.16	-0.0198	-0.428	--
125	2009-09-09	1.663	2.199	3.509	46	158	3227	1.638	43.95	0.0251	0.285	--
126	2009-09-24	1.826	2.387	2.522	67	243.7	333	1.868	74.65	-0.0417	-0.549	--
127	2009-11-03	1.929	2.514	2.516	85	326.7	328	1.962	92.63	-0.0321	-0.472	--
128	2009-11-19	2.396	2.892	1.813	249	780	65	2.304	203.7	0.0924	1.5	--
129	2009-12-01	2.436	2.964	1.74	273	920.6	55	2.363	233.6	0.073	1.2	--
130	2009-12-17	2.453	3.017	1.771	284	1040	59	2.399	253.6	0.0544	0.783	--
131	2010-01-06	2.48	3.061	1.982	302	1150	96	2.411	260.8	0.0689	1.1	--
132	2010-01-19	2.471	3.017	1.903	296	1040	80	2.387	246.5	0.0847	1.38	--
133	2010-02-04	2.398	2.977	1.806	250	948.6	64	2.367	235.4	0.0314	0.341	--
134	2010-02-23	2.387	2.999	1.833	244	997	68.13	2.38	242.7	0.00763	-0.067	--
135	2010-03-10	2.326	2.853	2.739	212	713.5	548	2.188	156.2	0.138	2.2	--
136	2010-04-14	2.47	3.017	1.724	295	1040	53	2.403	256.2	0.0664	1	--
137	2010-04-23	2.286	2.779	2.357	193	600.8	227.7	2.17	149.6	0.116	1.97	--
138	2010-05-13	2.009	2.543	2.733	102	349	541.2	1.962	92.74	0.0466	0.612	--
139	2010-06-09	1.623	2.198	3.471	42	157.9	2959	1.641	44.28	-0.0177	-0.399	--
140	2010-06-10	1.845	2.346	3.518	70	222	3294	1.745	56.23	0.1	1.74	--
141	2010-06-13	1.544	2.022	3.915	35	105.3	8227	1.471	29.91	0.0734	1.23	--

142	2010-06-14	1.58	2.018	4.063	38	104.3	11570	1.454	28.78	0.126	2.07	--
143	2010-06-14	1.602	2.035	4.178	40	108.4	15060	1.455	28.86	0.147	2.73	--
144	2010-06-15	1.74	2.281	3.809	55	190.9	6438	1.67	47.29	0.0708	1.17	--
145	2010-06-16	1.806	2.309	3.682	64	203.5	4808	1.702	50.93	0.104	1.81	--
146	2010-07-06	1.531	2.017	4.127	34	104	13400	1.447	28.31	0.0848	1.42	--
147	2010-08-19	2.338	2.801	1.785	218	633.1	61	2.24	175.9	0.0983	1.63	--
148	2010-08-25	2.1	2.718	2.887	126	522.7	770	2.076	120.5	0.0246	0.271	--
149	2010-11-16	1.934	2.699	2.418	86	500.5	262	2.106	129.2	-0.172	-2.2	--
150	2011-01-19	2.502	3.041	1.907	318	1100	80.75	2.404	256.6	0.0984	1.69	--
151	2011-03-07	2.365	2.88	1.708	232	759	51	2.305	204.3	0.0605	0.897	--
152	2011-03-16	2.375	2.906	1.681	237	805.2	48	2.326	214.5	0.0485	0.695	--
153	2011-04-06	2.401	2.981	1.58	252	957	38	2.391	248.8	0.0108	0.0268	--
154	2011-04-18	2.428	2.97	1.531	268	933	34	2.387	246.8	0.0411	0.472	--
155	2011-05-02	2.441	2.972	1.462	276	936.9	29	2.395	251.3	0.046	0.564	--
156	2011-06-07	2.322	2.839	1.342	210	691	21.97	2.31	206.5	0.0126	0.107	--
157	2011-06-21	2.265	2.95	2.041	184	890.5	109.9	2.324	213.6	-0.0596	-0.917	--
158	2011-06-22	2.127	2.93	1.659	134	850.5	45.65	2.346	224.3	-0.219	-2.38	--
159	2011-08-15	2.017	2.578	1.415	104	378.3	26	2.111	130.8	-0.0945	-1.38	--
160	2011-09-22	2.049	2.591	1.66	112	390.2	45.68	2.098	126.9	-0.0491	-0.678	--
161	2011-12-20	1.869	2.53	3.037	74	339	1090	1.924	85.01	-0.055	-0.839	--
162	2012-02-06	1.982	2.665	2.667	96	461.9	464	2.057	115.5	-0.075	-1.12	--
163	2012-03-01	1.763	2.63	3.117	58	426.4	1310	1.99	98.8	-0.226	-2.73	--
164	2012-04-07	1.964	2.576	2.414	92	376.9	259.4	2.016	105.1	-0.0526	-0.747	--
165	2012-04-17	2.318	2.86	1.917	208	725	82.69	2.271	188.8	0.0473	0.661	--
166	2012-06-18	1.944	2.559	2.114	88	362.4	130	2.032	109	-0.0877	-1.26	--
167	2012-06-19	2.021	2.71	1.886	105	513.3	76.95	2.164	147.7	-0.143	-1.81	--
168	2012-07-12	2.401	2.894	0.3424	252	782.7	2.2	2.443	280.7	-0.0417	-0.533	--
169	2012-07-19	2.369	2.836	0.2041	234	685	1.6	2.414	262.4	-0.0445	-0.58	--
170	2012-09-11	2.305	2.837	0.6335	202	687.5	4.3	2.375	239.8	-0.0692	-1.02	--
171	2012-11-07	2.439	2.917	0.7924	275	825.8	6.2	2.418	264.9	0.0215	0.216	--
172	2013-01-29	2.4	2.898	0.8976	251	791	7.9	2.394	250.9	0.00545	-0.0804	--
173	2013-03-13	2.35	3.018	1.73	224	1043	53.73	2.404	256.4	-0.0534	-0.765	--
174	2013-03-27	2.346	3.064	1	222	1160	10	2.506	324.6	-0.16	-1.97	--
175	2013-04-15	2.305	3.045	1.591	202	1108	39	2.436	276.3	-0.131	-1.69	--
176	2013-04-24	2.114	2.764	1.913	130	580.8	81.85	2.201	160.7	-0.0868	-1.23	--
177	2013-05-21	2.127	2.65	1.699	134	447.1	49.97	2.138	139	-0.0108	-0.299	--
178	2013-06-05	2.057	2.692	2.064	114	491.9	116	2.134	137.8	-0.0769	-1.17	--
179	2013-07-29	1.672	2.149	3.378	47	141	2388	1.614	41.6	0.0582	0.858	--
180	2013-08-07	1.591	2.017	4.14	39	104.1	13790	1.446	28.25	0.145	2.38	--
181	2013-10-30	1.973	2.604	2.19	94	402.1	154.8	2.058	115.7	-0.085	-1.2	--
182	2014-04-09	2.453	2.996	1.484	284	990.5	30.51	2.41	260.4	0.0429	0.518	--
183	2014-05-14	2.188	2.766	1.98	154	583.5	95.58	2.196	158.9	-0.0084	-0.243	--
184	2014-06-03	2.303	2.796	1.706	201	625.4	50.82	2.244	177.4	0.0595	0.877	--
185	2014-06-09	1.82	2.358	3.168	66	228.1	1474	1.786	61.85	0.0334	0.37	--
186	2014-07-15	2.387	2.879	1.663	244	757.4	46	2.309	206	0.0789	1.29	--
187	2014-08-04	2.436	2.915	1.328	273	821.5	21.26	2.366	235	0.0703	1.15	--

Definitions

ALK: Alkalinity in mg/l CaCO3 (39087)

SC: Specific conductance in uS/cm @25C (00095)

Q: Stream flow, mean. daily in ft3/s (00060)

Model Archive Summary for Bicarbonate at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the bicarbonate concentration (HCO_3) model developed to compute hourly HCO_3 from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 1, 1998 to August 4, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 186 concurrent measurements of bicarbonate concentration, streamflow, and SC collected from May 1, 1998 through August 4, 2014. Samples were collected throughout the range of continuously observed hydrologic and specific conductance conditions. There were no samples below laboratory reporting levels. Summary statistics and complete model-calibration dataset are provided below. Samples with Cook's D values greater than the outlier test criteria and studentized residual values greater than 3 or less than negative 3 were considered outliers. Samples collected July 10, 1998 and September 20, 2001 were deemed outliers and were removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating bicarbonate concentration. A variety of models that predict HCO_3 and models that predict $\log_{10}(\text{HCO}_3)$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted

HCO₃ were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated log₁₀(HCO₃).

Specific conductance and streamflow were selected as the best predictors of HCO₃ based on residual plots, relatively high adjusted coefficient of determination (adjusted *R*²) and relatively low model standard percentage error (*MSPE*), prediction error sum of squares (*PRESS*), and Mallows' *C_p*. Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for bicarbonate concentration at site number 07144100.

Bicarbonate concentration-based model:

$$\log_{10}(HCO_3) = 0.727 \times \log_{10}(SC) - 0.0959 \times \log_{10}(Q) + 0.460 ,$$

where

HCO₃ = bicarbonate concentration, in milligrams per liter (mg/L); and

SC = specific conductance, in microsiemens per centimeter (μS/cm) at 25 degrees Celsius; and

Q = streamflow, in cubic feet per second (ft³/s).

The use of specific conductance and streamflow as explanatory variables for bicarbonate makes physical and statistical sense. *SC* makes physical sense because bicarbonate is composed of major ions, which affect the conductivity of water. Bicarbonate concentration correlates with streamflow because high streamflows tend to dilute bicarbonate concentrations. Specific conductance and streamflow make statistical sense as explanatory variables because they resulted in a model with low standard error, Mallows' *C_p* and *PRESS* values, and high *R*² values. The simple-linear regression model with *SC* as the lone explanatory variable was considered but, ultimately, discarded because the *SC-Q* model reduced the model standard error 17 percent.

The log-transformed model may be retransformed to the original units so that HCO₃ can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.01. The retransformed model, accounting for BCF is:

$$HCO_3 = \frac{2.913 \times SC^{0.727}}{Q^{0.0959}}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(HCO_3) = 0.000462 \times SC - 0.174 \log_{10}(Q) + 2.32$
2.0	2007	--	$\log_{10}(HCO_3) = 0.727 \times \log_{10}(SC) - 0.0959 \times \log_{10}(Q) + 0.460$

Bicarbonate Concentration Record

The HCO₃ record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick
Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

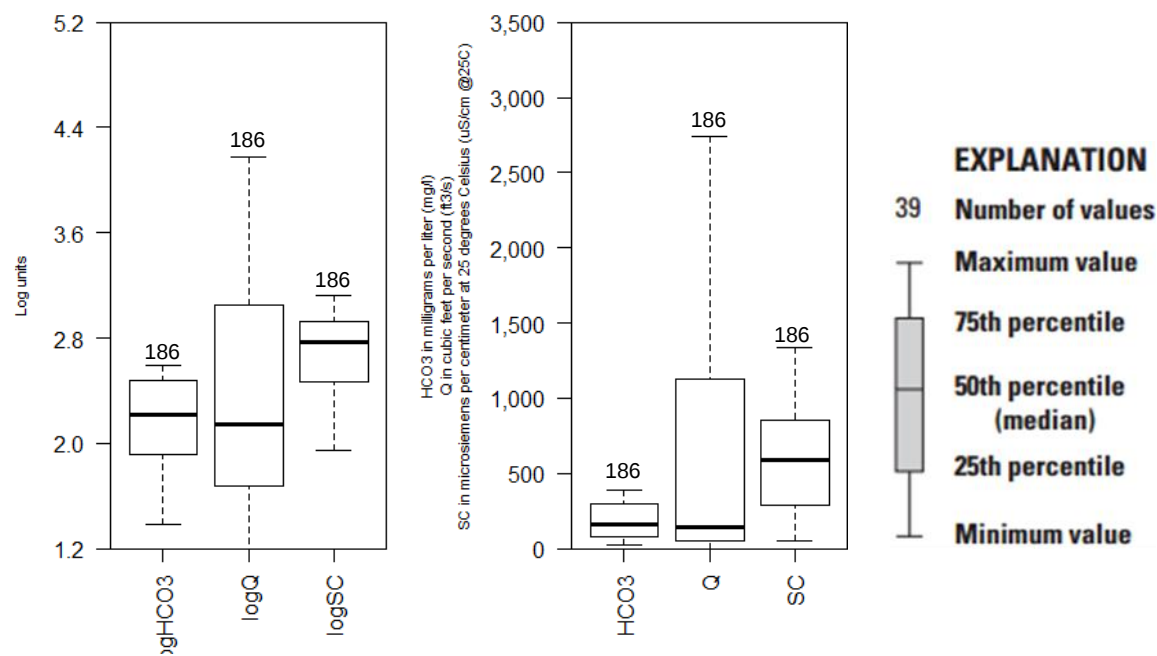
Model

$$\log\text{HCO3} = + -0.0959 * \log\text{Q} + 0.727 * \log\text{SC} + 0.46$$

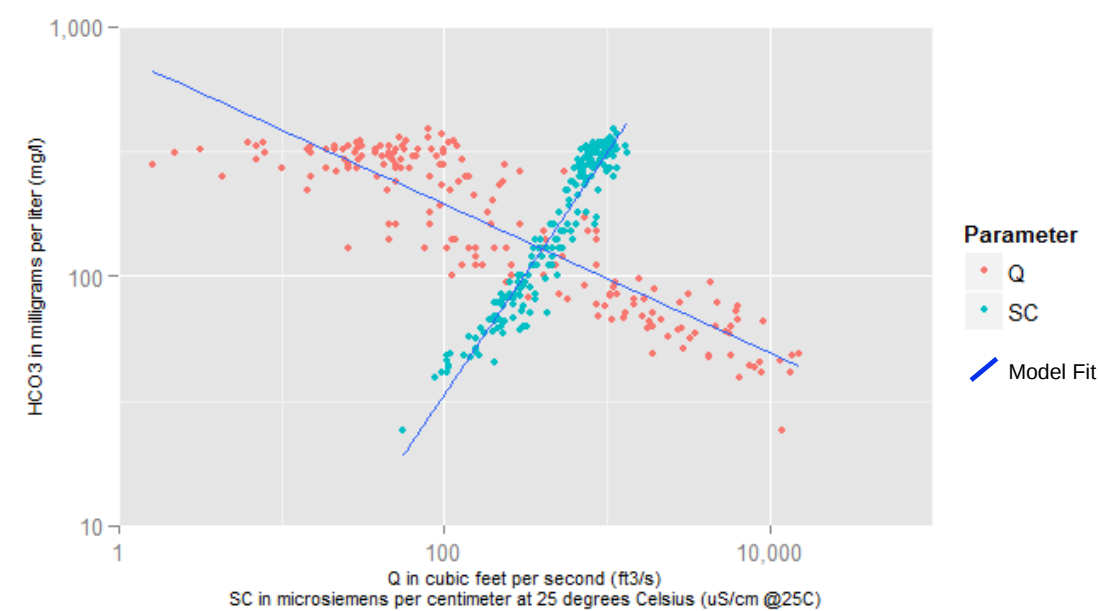
Variable Summary Statistics

	logHCO3	logQ	logSC	HCO3	Q	SC
Minimum	1.38	0.204	1.75	24	1.6	56
1st Quartile	1.91	1.680	2.47	82	48.0	292
Median	2.22	2.140	2.77	165	139.0	585
Mean	2.19	2.340	2.68	190	1380.0	587
3rd Quartile	2.48	3.050	2.93	300	1130.0	850
Maximum	2.59	4.180	3.13	390	15100.0	1340

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	186
Standard error (RMSE)	0.07
Upper Model standard percentage error (MSPE)	17.5
Lower Model standard percentage error (MSPE)	14.9
Coefficient of determination (R ²)	0.947
Adjusted Coefficient of Determination (Adj. R ²)	0.946
Bias Correction Factor (BCF)	1.01
Variance Inflation Factors (VIF)	
logQ	logSC
3.242007	3.242007

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.4600	0.1040	4.43	1.59e-05
logQ	-0.0959	0.0103	-9.31	3.92e-17
logSC	0.7270	0.0309	23.60	2.63e-57

Correlation Matrix

	Intercept	logQ	logSC
Intercept	1.000	-0.895	-0.990
logQ	-0.895	1.000	0.832
logSC	-0.990	0.832	1.000

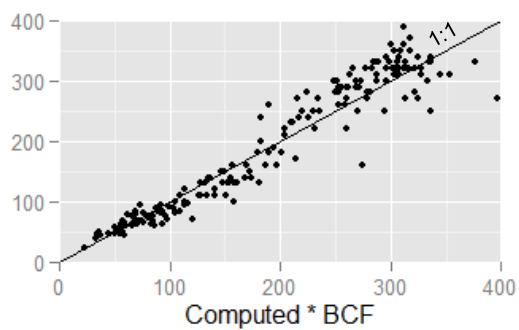
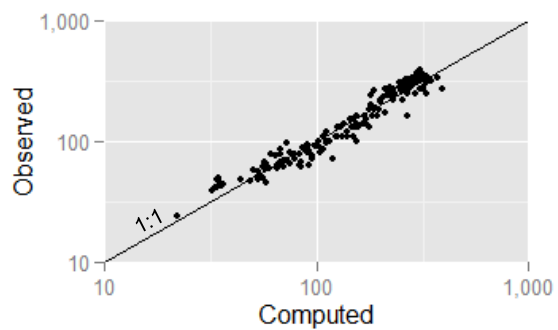
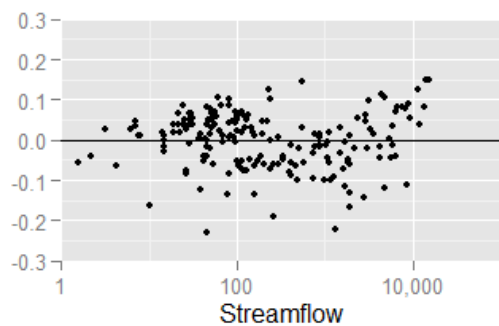
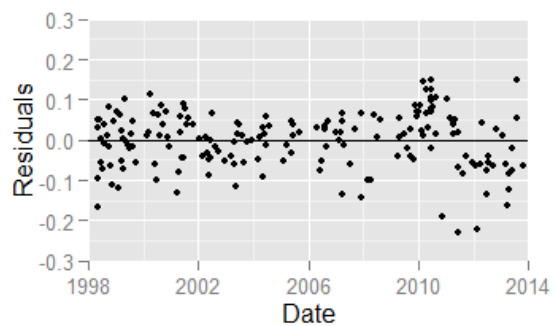
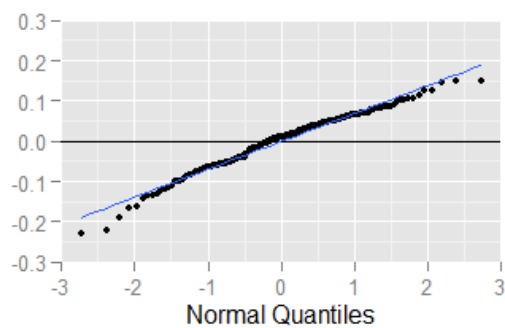
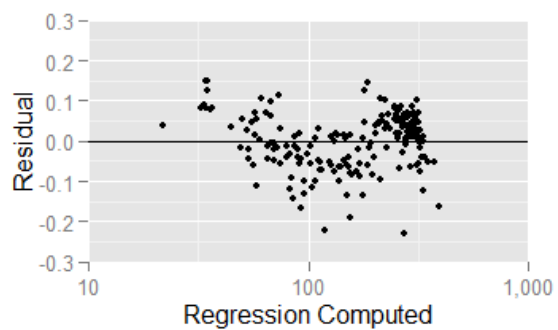
Outlier Test Criteria

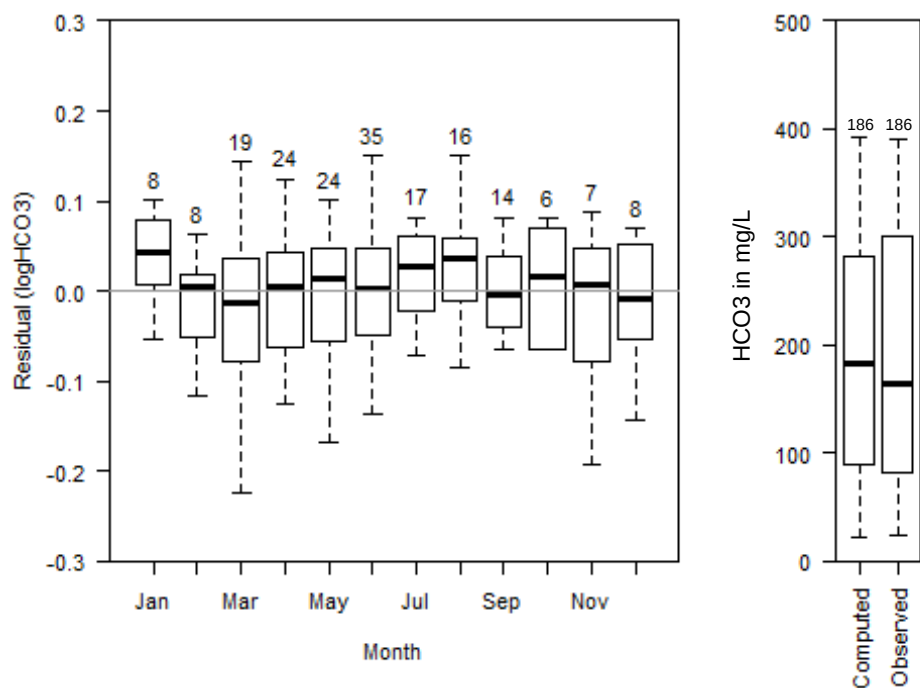
Leverage	Cook's D	DFFITS
0.03225806	0.19457287	0.20739034

Flagged Observations

	logHC03	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
5/1/1998 13:06	2.230	2.324	-0.09392		-1.3680		-1.3720	0.038650	0.025090	-0.27500
5/14/1998 9:26	1.799	1.966	-0.16710		-2.4020		-2.4340	0.012670	0.024680	-0.27570
9/25/1998 10:11	1.591	1.509	0.08174		1.1920		1.1940	0.040790	0.020150	0.24610
10/5/1998 10:21	1.643	1.562	0.08147		1.1820		1.1840	0.031410	0.015110	0.21320
11/5/1998 13:41	1.653	1.763	-0.10970		-1.5850		-1.5920	0.023340	0.020010	-0.24600
2/1/1999 11:06	1.799	1.917	-0.11740		-1.6970		-1.7050	0.022940	0.022530	-0.26130
3/28/2000 12:46	1.978	1.863	0.11520		1.6600		1.6680	0.018010	0.016850	0.22600
3/14/2001 10:41	1.851	1.983	-0.13150		-1.8920		-1.9050	0.013330	0.016110	-0.22140
6/6/2001 10:11	1.613	1.523	0.09011		1.3100		1.3130	0.035270	0.020920	0.25100
6/9/2005 10:56	1.380	1.341	0.03899		0.5761		0.5751	0.065400	0.007743	0.15210
7/27/2006 11:16	2.505	2.478	0.02698		0.3957		0.3948	0.051940	0.002860	0.09241
8/15/2006 9:16	2.462	2.429	0.03335		0.4850		0.4840	0.035400	0.002878	0.09272
12/13/2007 10:16	1.785	1.929	-0.14340		-2.0640		-2.0830	0.015110	0.021790	-0.25800
3/10/2010 9:11	2.415	2.272	0.14310		2.0670		2.0860	0.021710	0.031600	0.31070
6/13/2010 19:21	1.663	1.539	0.12380		1.7970		1.8080	0.031920	0.035510	0.32840
6/14/2010 9:41	1.690	1.540	0.15030		2.1820		2.2040	0.031600	0.051770	0.39820
7/6/2010 9:01	1.613	1.532	0.08110		1.1780		1.1790	0.032300	0.015430	0.21540
11/16/2010 12:26	2.000	2.192	-0.19190		-2.7480		-2.7990	0.005705	0.014450	-0.21200
6/22/2011 10:21	2.204	2.432	-0.22790		-3.2710		-3.3610	0.009128	0.032850	-0.32260
8/15/2011 10:46	2.114	2.200	-0.08566		-1.2460		-1.2480	0.036460	0.019600	-0.24280
3/1/2012 12:01	1.851	2.074	-0.22300		-3.2080		-3.2940	0.014540	0.050640	-0.40010
7/12/2012 10:16	2.491	2.532	-0.04069		-0.5979		-0.5968	0.054840	0.006913	-0.14380
7/19/2012 10:16	2.447	2.503	-0.05603		-0.8314		-0.8307	0.073280	0.018220	-0.23360
9/11/2012 10:16	2.398	2.463	-0.06523		-0.9532		-0.9529	0.044520	0.014110	-0.20570
3/27/2013 11:36	2.431	2.593	-0.16190		-2.3330		-2.3620	0.017370	0.032070	-0.31410
4/15/2013 9:11	2.398	2.522	-0.12420		-1.7870		-1.7980	0.013750	0.014840	-0.21230
8/7/2013 9:46	1.681	1.531	0.15050		2.1850		2.2080	0.032340	0.053180	0.40360

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logHCO3 ~ logSC	1	0.08477	92.17	92.13	138.1	1.35	1 ± 20	
logHCO3 ~ SC	1	0.1106	86.69	86.61	362.5	2.31	1 ± 26	
logHCO3 ~ logQ	1	0.1402	78.59	78.47	693.8	3.7	1 ± 33	
logHCO3 ~ logQ + logSC	2	0.07001	94.69	94.63	37.18	0.9266	3.242 ± 16	
logHCO3 ~ logQ + SC	2	0.07481	93.94	93.87	67.99	1.063	2.423 ± 17	
logHCO3 ~ logSC + SC	2	0.08339	92.47	92.38	128.2	1.314	10.81 ± 19	
logHCO3 ~ Q + logQ + logSC	3	0.06493	95.46	95.38	7.81	0.7983	2.55 ± 15	
logHCO3 ~ logQ + logSC + SC	3	0.06591	95.32	95.24	13.44	0.8292	3.32 ± 15	
logHCO3 ~ Q + logQ + SC	3	0.07408	94.09	93.99	63.82	1.054	2.232 ± 17	
logHCO3 ~ Q + logQ + logSC + SC	4	0.06426	95.57	95.48	5	0.7896	3.909 ± 15	

Model-Calibration Data Set

0	Date	logHCO3	logQ	logSC	HCO3	Q	SC	Computed logHCO3	Computed HCO3	Residual	Normal Quantiles	Censored Values
1	1998-05-01	2.23	2.862	2.94	170	728.1	871.2	2.324	213.7	-0.0939	-1.35	--
2	1998-05-06	2.398	2.155	2.906	250	143	804.5	2.367	235.7	0.031	0.322	--
3	1998-05-11	2.462	2.111	2.96	290	129	912	2.411	260.8	0.0515	0.743	--
4	1998-05-14	1.799	3.285	2.504	63	1928	318.9	1.966	93.72	-0.167	-2.07	--
5	1998-05-27	2.447	1.998	2.926	280	99.57	844	2.397	252.7	0.05	0.725	--
6	1998-06-16	2.447	1.633	2.943	280	43	877.9	2.445	281.8	0.00262	-0.128	--
7	1998-06-24	2.176	2.615	2.779	150	412.1	601.2	2.231	172.3	-0.0548	-0.761	--
8	1998-07-13	1.978	2.385	2.5	95	242.6	316	2.05	113.5	-0.0721	-1.09	--
9	1998-07-20	2.342	1.653	2.751	220	45	564.1	2.303	203.4	0.0394	0.483	--
10	1998-08-06	2.431	1.462	2.914	270	29	819.7	2.439	278.4	-0.00791	-0.252	--
11	1998-09-15	2.491	1.176	2.933	310	15	857.4	2.481	306.4	0.0104	-0.00673	--
12	1998-09-22	1.839	2.947	2.308	69	884.6	203.1	1.856	72.73	-0.0175	-0.35	--
13	1998-09-25	1.591	3.818	1.945	39	6575	88.18	1.509	32.71	0.0817	1.35	--

14	1998-10-05	1.643	3.882	2.026	44	7617	106.2	1.562	36.93	0.0815	1.31	--
15	1998-10-22	2.114	2.015	2.629	130	103.6	425.9	2.179	153.1	-0.0655	-1.02	--
16	1998-11-05	1.653	3.938	2.31	45	8663	204.1	1.763	58.65	-0.11	-1.49	--
17	1998-12-04	2.362	2.346	2.862	230	222	728.3	2.317	210.2	0.0445	0.56	--
18	1999-01-12	2.544	2.055	3.041	350	113.5	1100	2.475	302.5	0.0687	1.09	--
19	1999-02-01	1.799	3.67	2.486	63	4680	306.3	1.917	83.59	-0.117	-1.58	--
20	1999-02-19	2.519	2.079	3.017	330	120	1040	2.455	288.9	0.0632	0.914	--
21	1999-03-16	2.491	1.991	3.127	310	98	1340	2.544	354.2	-0.0525	-0.725	--
22	1999-03-23	2.505	1.991	3.041	320	98	1100	2.481	306.8	0.0237	0.224	--
23	1999-04-07	1.991	3.202	2.625	98	1594	421.7	2.063	116.9	-0.0713	-1.07	--
24	1999-04-16	1.778	3.733	2.302	60	5405	200.5	1.777	60.58	0.00118	-0.142	--
25	1999-05-05	2.447	2.377	2.905	280	238.5	804.1	2.345	224.3	0.102	1.68	--
26	1999-05-24	1.839	3.219	2.324	69	1656	211	1.842	70.42	-0.00343	-0.196	--
27	1999-06-18	2	2.613	2.477	100	409.8	300.3	2.012	104	-0.0118	-0.294	--
28	1999-06-21	1.826	3.334	2.344	67	2158	220.7	1.845	70.93	-0.0194	-0.408	--
29	1999-07-20	1.771	3.547	2.247	59	3528	176.8	1.755	57.58	0.016	0.115	--
30	1999-08-03	1.672	3.63	2.168	47	4265	147.3	1.689	49.52	-0.0173	-0.336	--
31	1999-08-19	2.477	1.949	2.965	300	89	921.9	2.43	272.3	0.0474	0.624	--
32	1999-09-28	1.82	3.264	2.375	66	1835	237.2	1.875	75.93	-0.0555	-0.797	--
33	2000-02-09	2.505	1.92	3.049	320	83.15	1118	2.494	315.5	0.0116	0.0337	--
34	2000-03-07	1.973	3.053	2.458	94	1129	287.4	1.956	91.46	0.0173	0.155	--
35	2000-03-28	1.978	3.639	2.407	95	4352	255.5	1.863	73.78	0.115	1.88	--
36	2000-05-19	2.531	2.031	3.025	340	107.3	1060	2.466	296.1	0.0655	0.955	--
37	2000-05-31	2.114	2.312	2.662	130	205.1	459.6	2.175	151.5	-0.0612	-0.893	--
38	2000-06-28	1.929	3.067	2.562	85	1168	364.9	2.03	108.4	-0.1	-1.45	--
39	2000-07-20	2.398	2.132	2.86	250	135.4	724.9	2.336	219.6	0.0616	0.893	--
40	2000-07-28	2.114	2.198	2.548	130	157.7	353	2.103	128.3	0.0112	0.00673	--
41	2000-08-16	2.505	1.38	2.874	320	24	749	2.419	265.5	0.0865	1.45	--
42	2000-09-08	2.505	1.279	2.927	320	19	846	2.467	296.6	0.0383	0.423	--
43	2000-09-25	2.505	1.331	2.932	320	21.43	855.9	2.466	295.7	0.0396	0.498	--
44	2000-10-26	1.881	3.808	2.358	76	6430	228	1.81	65.41	0.0705	1.14	--
45	2000-11-08	2.255	1.914	2.711	180	82	514.6	2.249	179.6	0.0063	-0.101	--
46	2000-12-04	2.491	1.663	3.037	310	46	1088	2.51	327.3	-0.0182	-0.379	--
47	2001-03-14	1.851	3.279	2.525	71	1903	335.3	1.983	97.32	-0.132	-1.68	--
48	2001-04-13	2.114	2.602	2.725	130	400	531.3	2.193	157.9	-0.0792	-1.2	--
49	2001-04-26	2.505	2.001	2.994	320	100.3	986.6	2.446	282.8	0.059	0.835	--
50	2001-05-08	2.322	2.186	2.821	210	153.3	662.5	2.303	203.3	0.0195	0.196	--
51	2001-06-04	1.919	3.021	2.465	83	1049	291.9	1.964	93.16	-0.0448	-0.591	--
52	2001-06-06	1.613	3.952	1.981	41	8956	95.82	1.523	33.73	0.0901	1.54	--
53	2001-06-23	1.681	3.628	2.219	48	4250	165.5	1.726	53.92	-0.0451	-0.608	--
54	2001-07-11	2.491	1.69	2.909	310	49	811.1	2.414	262.7	0.0773	1.22	--
55	2001-08-02	2.462	1.394	2.885	290	24.76	767.3	2.425	269.4	0.0374	0.408	--
56	2001-08-28	2.477	1.491	2.897	300	31	789	2.424	269.1	0.0527	0.761	--
57	2001-10-31	2.491	1.453	2.931	310	28.35	853	2.453	287.2	0.0386	0.438	--
58	2002-01-10	2.505	1.574	3.014	320	37.52	1032	2.501	321.2	0.00376	-0.115	--
59	2002-02-21	2.477	1.623	3.041	300	42	1100	2.517	332.8	-0.0396	-0.498	--
60	2002-04-09	2.447	1.971	2.983	280	93.59	960.7	2.441	279.3	0.00652	-0.0741	--
61	2002-04-22	1.886	3.171	2.423	77	1481	264.9	1.919	83.98	-0.0323	-0.467	--
62	2002-05-13	2.146	2.621	2.786	140	417.9	611.6	2.236	174.2	-0.0896	-1.28	--
63	2002-05-22	2.114	2.152	2.625	130	141.9	422	2.164	147.5	-0.0496	-0.674	--
64	2002-06-06	2.114	2.387	2.589	130	243.9	388.1	2.114	131.8	-0.00053	-0.155	--
65	2002-06-13	1.771	3.758	2.36	59	5729	229.1	1.817	66.37	-0.0457	-0.624	--
66	2002-07-09	2.462	1.477	2.857	290	30	720	2.397	252.5	0.0655	0.977	--
67	2002-08-15	2.255	2.875	2.872	180	750	744	2.273	190	-0.018	-0.365	--
68	2002-09-19	2.398	1.176	2.857	250	15	720	2.426	269.9	-0.0278	-0.452	--
69	2002-12-18	2.519	1.613	3.114	330	41	1300	2.571	376.6	-0.052	-0.708	--
70	2003-03-20	1.857	3.799	2.479	72	6294	301.5	1.899	80.32	-0.0421	-0.575	--
71	2003-04-17	2.505	1.843	3.061	320	69.73	1150	2.51	327.4	-0.00454	-0.224	--
72	2003-04-23	2.204	2.464	2.808	160	290.9	642	2.266	186.9	-0.062	-0.934	--
73	2003-05-14	1.903	3.233	2.566	80	1710	368	2.017	105.2	-0.114	-1.54	--
74	2003-05-29	2.204	2.286	2.68	160	193	479	2.191	157.1	0.0134	0.0741	--
75	2003-06-11	2.362	1.987	2.817	230	97	656	2.319	210.9	0.0431	0.544	--
76	2003-06-24	2.505	1.756	2.988	320	57	972	2.465	295.4	0.0402	0.513	--
77	2003-07-30	2.531	0.8865	2.951	340	7.7	892.6	2.521	336.3	0.0101	-0.0202	--

78	2003-09-03	1.903	2.757	2.425	80	571.5	265.9	1.96	92.25	-0.0565	-0.835	--
79	2003-10-14	1.826	3.033	2.286	67	1079	193	1.832	68.76	-0.00589	-0.238	--
80	2003-12-11	2.519	1.658	3.049	330	45.48	1120	2.519	334.6	-0.000621	-0.169	--
81	2004-03-09	1.792	3.254	2.328	62	1794	212.8	1.842	70.32	-0.0493	-0.657	--
82	2004-03-30	2.415	2.465	3.003	260	292	1007	2.408	259.1	0.00693	-0.0606	--
83	2004-04-26	2.505	1.708	2.994	320	51	986.3	2.474	301.7	0.0309	0.308	--
84	2004-05-13	1.833	3.104	2.421	68	1270	263.6	1.924	84.93	-0.0911	-1.31	--
85	2004-05-26	2.505	1.699	3.017	320	50	1040	2.492	314.2	0.0134	0.0606	--
86	2004-06-16	2.462	1.732	2.899	290	54	792	2.403	255.8	0.0599	0.874	--
87	2004-06-22	1.929	3.017	2.433	85	1040	270.8	1.94	88.27	-0.011	-0.266	--
88	2004-07-27	1.681	3.767	2.126	48	5845	133.8	1.646	44.79	0.0354	0.394	--
89	2005-01-27	2.041	2.234	2.542	110	171.3	348.7	2.095	126.1	-0.054	-0.743	--
90	2005-03-23	1.799	3.766	2.355	63	5836	226.3	1.812	65.67	-0.0126	-0.308	--
91	2005-05-10	2.301	2.294	2.769	200	197	587	2.254	181.7	0.047	0.575	--
92	2005-05-27	1.959	2.862	2.484	91	727.9	305	1.993	99.6	-0.0338	-0.483	--
93	2005-06-06	1.949	3.288	2.464	89	1943	291.3	1.938	87.68	0.0119	0.0471	--
94	2005-06-09	1.38	4.076	1.748	24	11900	56	1.341	22.21	0.039	0.467	--
95	2005-08-31	2.146	2.047	2.561	140	111.5	364	2.127	135.6	0.0193	0.183	--
96	2006-05-02	2.38	2.086	2.87	240	121.8	741.9	2.348	225.6	0.0322	0.365	--
97	2006-06-08	2.431	1.415	3	270	26	1000	2.507	325.1	-0.0753	-1.14	--
98	2006-06-26	2	2.049	2.457	100	111.9	286.7	2.051	113.9	-0.0512	-0.691	--
99	2006-07-27	2.505	0.5021	2.841	320	3.177	692.7	2.478	304.5	0.027	0.28	--
100	2006-08-15	2.462	0.8451	2.818	290	7	658	2.429	271.9	0.0334	0.379	--
101	2006-08-23	2.342	1.163	2.762	220	14.56	578.2	2.358	230.7	-0.0153	-0.322	--
102	2006-09-27	2.519	0.8451	2.876	330	7	750.9	2.471	299.3	0.0478	0.64	--
103	2007-01-10	2.505	1.159	2.941	320	14.42	873	2.488	311.6	0.0169	0.142	--
104	2007-02-05	2.519	1.176	2.989	330	15	974	2.521	336.2	-0.00268	-0.183	--
105	2007-03-12	2.431	1.279	2.85	270	19	708	2.411	260.6	0.0208	0.21	--
106	2007-03-21	2.431	1.708	2.844	270	51	698	2.365	234.6	0.0663	1.02	--
107	2007-03-27	2.041	2.198	2.647	110	157.9	443.7	2.175	151.5	-0.133	-1.74	--
108	2007-04-02	1.792	3.46	2.223	62	2882	167	1.745	56.33	0.047	0.591	--
109	2007-04-18	1.886	2.935	2.364	77	861	231	1.898	80.07	-0.0116	-0.28	--
110	2007-07-11	1.69	3.284	2.206	49	1924	160.6	1.75	56.92	-0.0597	-0.874	--
111	2007-09-06	2.519	1.415	2.979	330	26	952	2.491	313.7	0.0274	0.294	--
112	2007-11-26	2.505	1.462	2.911	320	29	815	2.437	277.2	0.0677	1.07	--
113	2007-12-13	1.785	3.438	2.472	61	2740	296.5	1.929	85.93	-0.143	-1.88	--
114	2008-03-06	1.881	2.99	2.484	76	977.7	305	1.981	96.83	-0.0998	-1.38	--
115	2008-04-14	2.041	2.685	2.666	110	484	463.1	2.142	140.3	-0.1	-1.42	--
116	2008-05-29	1.892	3.454	2.336	78	2846	216.8	1.828	68.18	0.0638	0.934	--
117	2008-06-30	2.041	2.942	2.55	110	874.4	355.2	2.033	109.3	0.00804	-0.0471	--
118	2008-08-05	2.447	1.407	2.85	280	25.5	707.5	2.398	253.2	0.049	0.657	--
119	2009-04-06	2.255	2.272	2.825	180	187	668.2	2.297	200.7	-0.0419	-0.56	--
120	2009-04-13	2.176	2.933	2.737	150	856.8	545.4	2.17	149.6	0.00643	-0.0876	--
121	2009-04-28	1.82	3.963	2.314	66	9190	206	1.763	58.71	0.0562	0.816	--
122	2009-06-16	2.146	2.939	2.683	140	868.3	481.9	2.13	136.6	0.0161	0.128	--
123	2009-07-30	1.929	2.712	2.407	85	515.4	255.4	1.951	90.48	-0.0218	-0.438	--
124	2009-09-09	1.748	3.509	2.199	56	3227	158	1.723	53.53	0.025	0.252	--
125	2009-09-24	1.914	2.522	2.387	82	333	243.7	1.954	91.18	-0.0407	-0.528	--
126	2009-11-03	2	2.516	2.514	100	328	326.7	2.048	113	-0.0478	-0.64	--
127	2009-11-19	2.477	1.813	2.892	300	65	780	2.39	248.5	0.0871	1.49	--
128	2009-12-01	2.519	1.74	2.964	330	55	920.6	2.449	284.9	0.0692	1.12	--
129	2009-12-17	2.544	1.771	3.017	350	59	1040	2.485	309.2	0.0593	0.854	--
130	2010-01-06	2.568	1.981	3.061	370	95.7	1150	2.497	317.6	0.0717	1.17	--
131	2010-01-19	2.556	1.903	3.017	360	80	1040	2.472	300.3	0.0841	1.42	--
132	2010-02-04	2.477	1.806	2.977	300	64	948.6	2.452	287	0.0247	0.238	--
133	2010-02-23	2.477	1.833	2.999	300	68.13	997	2.466	295.8	0.0116	0.0202	--
134	2010-03-10	2.415	2.74	2.852	260	550	711	2.272	189.3	0.143	2.2	--
135	2010-04-14	2.556	1.724	3.017	360	53	1040	2.489	312.4	0.0669	1.04	--
136	2010-04-23	2.38	2.357	2.779	240	227.7	600.8	2.255	182.3	0.125	2.07	--
137	2010-05-13	2.079	2.733	2.543	120	541.2	349	2.048	113	0.0314	0.35	--
138	2010-06-09	1.708	3.471	2.198	51	2959	157.9	1.727	53.94	-0.019	-0.394	--
139	2010-06-10	1.929	3.505	2.348	85	3200	223	1.832	68.82	0.0971	1.58	--
140	2010-06-13	1.633	3.915	2.022	43	8227	105.3	1.556	36.43	0.0775	1.25	--
141	2010-06-14	1.663	4.063	2.018	46	11570	104.3	1.539	35.02	0.124	1.97	--

142	2010-06-14	1.69	4.178	2.035	49	15060	108.4	1.54	35.1	0.15	2.38	--
143	2010-06-15	1.826	3.809	2.281	67	6438	190.9	1.754	57.49	0.0719	1.2	--
144	2010-06-16	1.892	3.682	2.309	78	4808	203.5	1.787	61.94	0.106	1.81	--
145	2010-07-06	1.613	4.127	2.017	41	13400	104	1.532	34.44	0.0811	1.28	--
146	2010-08-19	2.431	1.785	2.801	270	61	633.1	2.327	214.8	0.105	1.74	--
147	2010-08-25	2.176	2.887	2.718	150	770	522.7	2.161	146.6	0.0155	0.101	--
148	2010-11-16	2	2.418	2.699	100	262	500.5	2.192	157.5	-0.192	-2.2	--
149	2011-01-19	2.591	1.907	3.041	390	80.75	1100	2.49	312.6	0.102	1.63	--
150	2011-03-07	2.447	1.708	2.88	280	51	759	2.391	249.4	0.0557	0.779	--
151	2011-03-16	2.462	1.681	2.906	290	48	805.2	2.413	261.9	0.0497	0.691	--
152	2011-04-06	2.491	1.58	2.981	310	38	957	2.477	303.6	0.0144	0.0876	--
153	2011-04-18	2.519	1.498	2.974	330	31.5	941.5	2.48	305.5	0.0389	0.452	--
154	2011-05-02	2.531	1.462	2.972	340	29	936.9	2.481	306.8	0.05	0.708	--
155	2011-06-07	2.415	1.342	2.839	260	21.97	691	2.397	252.5	0.0181	0.169	--
156	2011-06-21	2.342	2.041	2.95	220	109.9	890.5	2.41	260.2	-0.0676	-1.04	--
157	2011-06-22	2.204	1.659	2.93	160	45.65	850.5	2.432	273.8	-0.228	-2.72	--
158	2011-08-15	2.114	1.415	2.578	130	26	378.3	2.2	160.3	-0.0857	-1.25	--
159	2011-09-22	2.146	1.66	2.591	140	45.68	390.2	2.186	155.4	-0.0398	-0.513	--
160	2011-12-20	1.954	3.037	2.53	90	1090	339	2.009	103.5	-0.0552	-0.779	--
161	2012-02-06	2.079	2.667	2.665	120	464	461.9	2.143	140.6	-0.0635	-0.955	--
162	2012-03-01	1.851	3.117	2.63	71	1310	426.4	2.074	120.1	-0.223	-2.38	--
163	2012-04-07	2.041	2.414	2.576	110	259.4	376.9	2.103	128.2	-0.0613	-0.914	--
164	2012-04-17	2.398	1.917	2.86	250	82.69	725	2.357	230.3	0.0411	0.528	--
165	2012-06-18	2.041	2.114	2.559	110	130	362.4	2.119	133.2	-0.0776	-1.17	--
166	2012-06-19	2.114	1.886	2.71	130	76.95	513.3	2.251	180.4	-0.137	-1.81	--
167	2012-07-12	2.491	0.3424	2.894	310	2.2	782.7	2.532	344.7	-0.0407	-0.544	--
168	2012-07-19	2.447	0.2041	2.836	280	1.6	685	2.503	322.5	-0.056	-0.816	--
169	2012-09-11	2.398	0.6335	2.837	250	4.3	687.5	2.463	294.1	-0.0652	-0.977	--
170	2012-11-07	2.531	0.7924	2.917	340	6.2	825.8	2.506	324.5	0.0256	0.266	--
171	2013-01-29	2.491	0.8976	2.898	310	7.9	791	2.482	307.3	0.00921	-0.0337	--
172	2013-03-13	2.431	1.73	3.018	270	53.73	1043	2.49	312.6	-0.0582	-0.854	--
173	2013-03-27	2.431	1	3.064	270	10	1160	2.593	396.9	-0.162	-1.97	--
174	2013-04-15	2.398	1.591	3.045	250	39	1108	2.522	336.9	-0.124	-1.63	--
175	2013-04-24	2.204	1.913	2.764	160	81.85	580.8	2.287	196.2	-0.0832	-1.22	--
176	2013-05-21	2.204	1.699	2.65	160	49.97	447.1	2.225	170	-0.0211	-0.423	--
177	2013-06-05	2.146	2.064	2.692	140	116	491.9	2.22	168.2	-0.0742	-1.12	--
178	2013-07-29	1.756	3.378	2.149	57	2388	141	1.7	50.72	0.0561	0.797	--
179	2013-08-07	1.681	4.14	2.017	48	13790	104.1	1.531	34.37	0.15	2.72	--
180	2013-10-30	2.079	2.19	2.604	120	154.8	402.1	2.145	141.3	-0.0654	-0.999	--
181	2014-04-09	2.544	1.484	2.996	350	30.51	990.5	2.497	317.9	0.0471	0.608	--
182	2014-05-14	2.279	1.98	2.766	190	95.58	583.5	2.282	193.9	-0.00353	-0.21	--
183	2014-06-03	2.38	1.706	2.796	240	50.82	625.4	2.33	216.7	0.0497	0.674	--
184	2014-06-09	1.903	3.168	2.358	80	1474	228.1	1.872	75.35	0.0314	0.336	--
185	2014-07-15	2.477	1.663	2.879	300	46	757.4	2.395	251.5	0.082	1.38	--
186	2014-08-04	2.519	1.328	2.915	330	21.26	821.5	2.453	287.3	0.0656	0.999	--

Definitions

HCO3: Bicarbonate in mg/l (29806)

Q: Stream flow, mean. daily in ft3/s (00060)

SC: Specific conductance in uS/cm @25C (00095)

Model Archive Summary for Chloride at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the chloride concentration (Cl) model developed to compute hourly Cl from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: October 22, 1998 to August 7, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 203 concurrent measurements of chloride concentration, streamflow, and SC collected from October 22, 1998 through August 7, 2014. Samples were collected throughout the range of continuously observed hydrologic and specific conductance conditions. Five samples were below a laboratory detection limit of 5.0 mg/L. Summary statistics and the complete model-calibration dataset are provided below. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. No samples were deemed outliers.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating chloride concentration. A variety of models that predict Cl and models that predict $\log_{10}(\text{Cl})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted Cl were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the

range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(Cl)$.

Specific conductance and streamflow were selected as the best predictors of Cl based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for chloride concentration at site number 07144100.

Chloride concentration-based model:

$$\log_{10}(Cl) = 1.82 \times \log_{10}(SC) + 0.172 \times \log_{10}(Q) - 3.64,$$

where

Cl = chloride concentration, in milligrams per liter (mg/L);

SC = specific conductance, in microsiemens per centimeter ($\mu S/cm$) at 25 degrees Celsius; and,

Q = streamflow, in cubic feet per second (ft^3/s).

Specific conductance and streamflow make physical and statistical sense as explanatory variables for chloride concentration. Specific conductance makes physical sense because chloride is an ion, which affects the conductivity of water. This correlates well with SC because SC is a measure of the conductivity of water. Chloride concentration correlates well with streamflow because high streamflow tends to dilute chloride concentrations. Specific conductance and streamflow make statistical sense as explanatory variables because they resulted in a model with low standard error, Mallows' C_p and $PRESS$ values, and high R^2 values.

The log-transformed model may be retransformed to the original units so that Cl can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.04. The retransformed model, accounting for BCF is:

$$Cl = 0.000238 \times SC^{1.82} \times Q^{0.172}$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$Cl = 25.7 \log_{10}(Q) + 0.203 \times SC - 112$
2.0	2007	--	$\log_{10}(Cl) = 1.82 \times \log_{10}(SC) + 0.172 \times \log_{10}(Q) - 3.64$

Chloride Concentration Record

The Cl record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick

Model Statistics, Data, and Plots

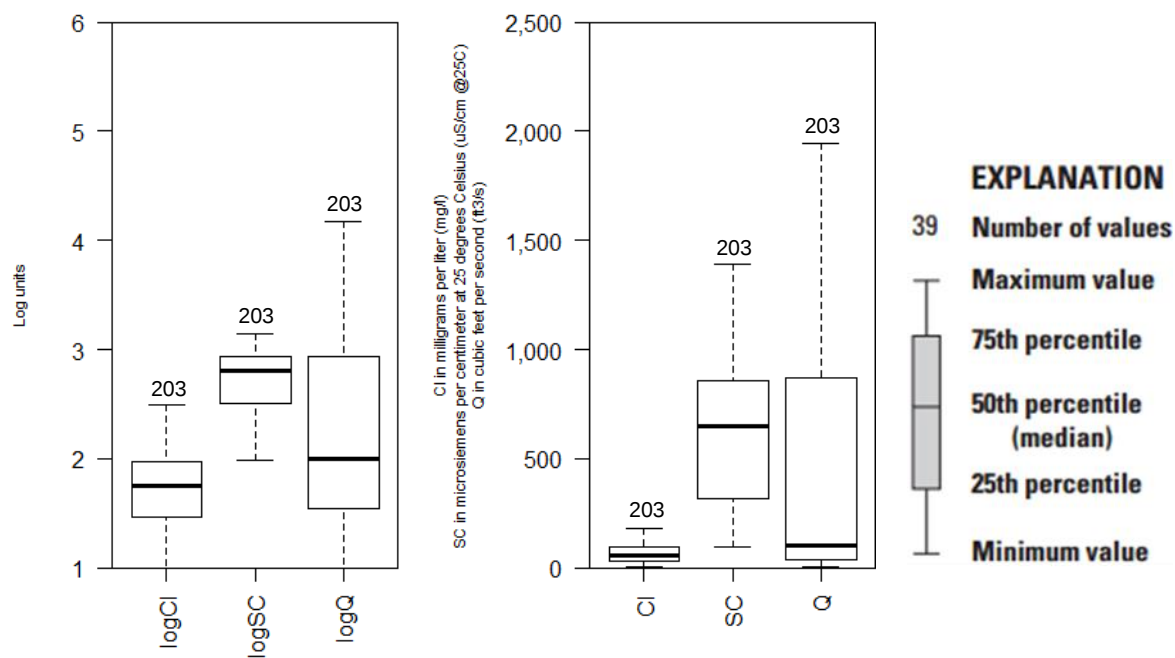
Model

$$\log Cl = + 1.82 * \log SC + 0.172 * \log Q + -3.64$$

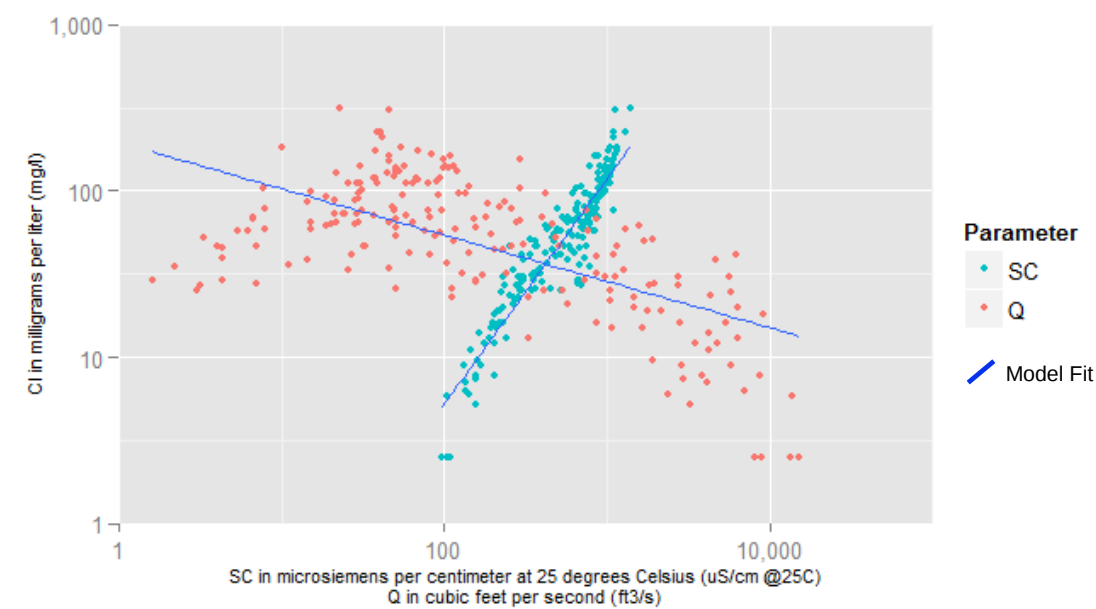
Variable Summary Statistics

	logCl	logSC	logQ	Cl	SC	Q
Minimum	0.398	1.98	0.204	2.5	95.8	1.6
1st Quartile	1.46	2.49	1.52	28.8	306	33
Median	1.76	2.81	2	57.1	646	101
Mean	1.68	2.71	2.19	67.6	610	1130
3rd Quartile	1.97	2.93	2.94	94	860	882
Maximum	2.5	3.14	4.18	315	1390	15100
Censored [< 5]	5	--	--	5	--	--

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	203
Standard error (RMSE)	0.117
Upper Model standard percentage error (MSPE)	30.8
Lower Model standard percentage error (MSPE)	23.5
Coefficient of determination (R ²)	0.918
Adjusted Coefficient of Determination (Adj. R ²)	0.917
Bias Correction Factor (BCF)	1.04
Variance Inflation Factors (VIF)	
logSC	logQ
3.080275	3.080275

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-3.640	0.1700	-21.4	9.40e-54
logSC	1.820	0.0518	35.2	1.09e-87
logQ	0.172	0.0156	11.0	1.86e-22

Correlation Matrix

	Intercept	logSC	logQ
Intercept	1.000	-0.992	-0.881
logSC	-0.992	1.000	0.822
logQ	-0.881	0.822	1.000

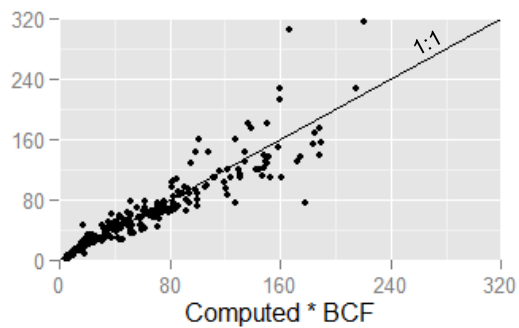
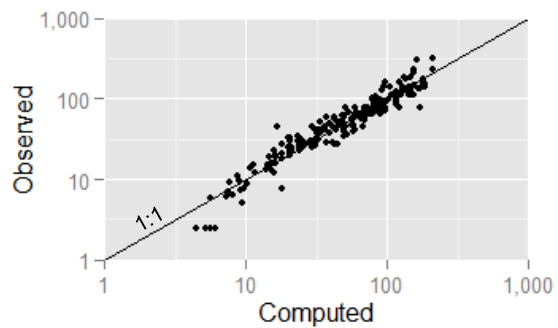
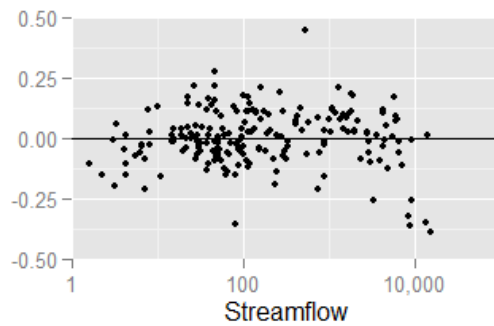
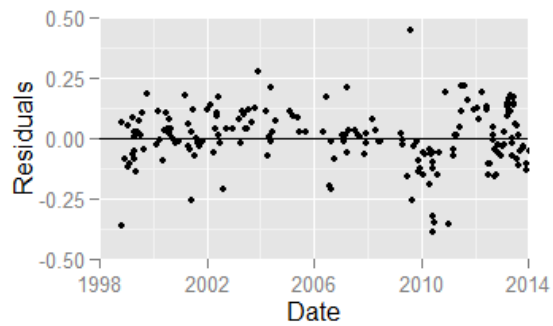
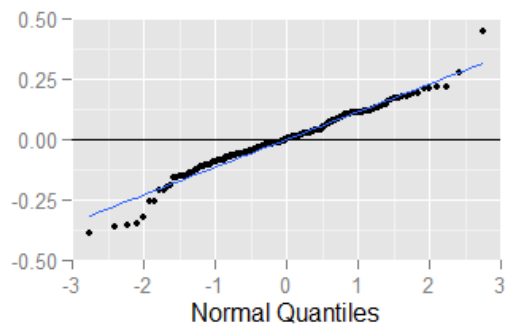
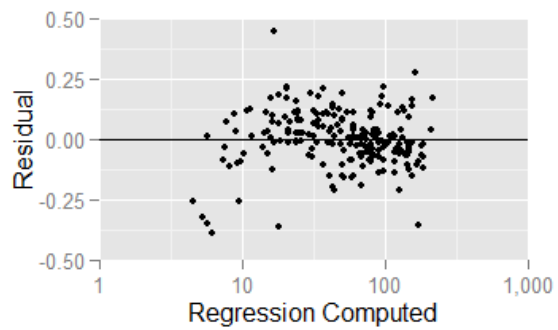
Outlier Test Criteria

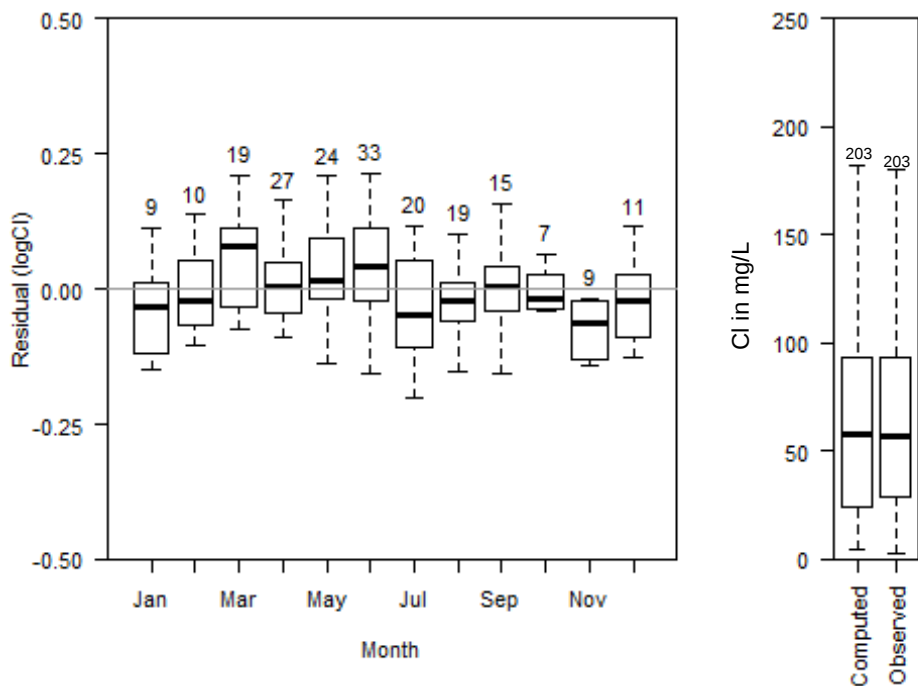
Leverage	Cook's D	DFFITS
0.02955665	0.19459125	0.19851667

Flagged Observations

	logCl	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
11/5/1998 13:45	0.8887	1.2510	-0.362600		-3.14600		-3.21900	0.02275	7.682e-02	-0.49120
6/6/2001 10:11	0.3979	0.6532	-0.255200		-2.23500		-2.25800	0.04006	6.948e-02	-0.46120
6/13/2002 9:31	1.4770	1.3110	0.166500		1.44300		1.44700	0.01939	1.372e-02	0.20340
8/15/2002 10:01	1.8810	2.0920	-0.211500		-1.84100		-1.85300	0.02907	3.385e-02	-0.32060
12/11/2003 11:31	2.4840	2.2070	0.277000		2.39400		2.42300	0.01501	2.910e-02	0.29900
3/30/2004 9:51	2.1900	2.2620	-0.071240		-0.62080		-0.61980	0.03092	4.098e-03	-0.11070
6/26/2006 12:41	1.3640	1.1950	0.168900		1.46500		1.46900	0.02149	1.571e-02	0.21770
7/27/2006 11:16	1.4280	1.6280	-0.199900		-1.74800		-1.75700	0.03765	3.986e-02	-0.34760
8/15/2006 9:16	1.4360	1.6460	-0.210100		-1.82500		-1.83600	0.02535	2.888e-02	-0.29610
7/30/2009 10:36	1.6630	1.2170	0.445700		3.84800		3.98800	0.01256	6.277e-02	0.44980
9/9/2009 12:01	0.7160	0.9735	-0.257500		-2.23400		-2.25600	0.02189	3.722e-02	-0.33760
6/13/2010 15:21	0.3979	0.7216	-0.323700		-2.82800		-2.87900	0.03581	9.897e-02	-0.55470
6/14/2010 9:41	0.3979	0.7895	-0.391600		-3.41800		-3.51400	0.03459	1.396e-01	-0.66520
7/6/2010 9:01	0.3979	0.7480	-0.350000		-3.05800		-3.12400	0.03586	1.159e-01	-0.60250
1/19/2011 11:41	1.8810	2.2360	-0.355100		-3.07500		-3.14200	0.01879	6.035e-02	-0.43480
8/15/2011 10:46	1.5190	1.3050	0.213000		1.85500		1.86600	0.02920	3.448e-02	0.32360
7/12/2012 10:16	1.5440	1.6970	-0.153300		-1.34200		-1.34500	0.03940	2.463e-02	-0.27240
7/19/2012 10:16	1.4620	1.5680	-0.105600		-0.93110		-0.93070	0.05408	1.652e-02	-0.22250
8/30/2012 8:16	1.3980	1.4070	-0.009533		-0.08414		-0.08393	0.05535	1.383e-04	-0.02032
9/11/2012 10:16	1.6530	1.6450	0.008636		0.07530		0.07511	0.03206	6.259e-05	0.01367
9/18/2012 11:21	1.6630	1.7110	-0.047940		-0.41750		-0.41660	0.02962	1.773e-03	-0.07279
10/24/2012 9:30	1.4590	1.6130	-0.154100		-1.34500		-1.34700	0.03385	2.112e-02	-0.25220
6/24/2013 9:40	2.4980	2.3280	0.169900		1.47200		1.47600	0.01913	1.408e-02	0.20610
7/9/2013 9:31	1.7220	1.6630	0.058750		0.51300		0.51210	0.03497	3.179e-03	0.09748
8/7/2013 9:46	0.7634	0.7508	0.012600		0.11010		0.10980	0.03585	1.501e-04	0.02117

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logCl ~ logSC	1	0.1476	86.73	86.66	194.1	4.48	1 ± 35	
logCl ~ SC	1	0.1876	78.55	78.45	436.3	7.247	1 ± 45	
logCl ~ Q	1	0.2842	50.77	50.52	1259	16.71	1 ± 70	
logCl ~ logSC + logQ	2	0.1166	91.76	91.68	47.14	2.827	3.08 ± 27	
logCl ~ Q + logSC	2	0.1467	86.94	86.81	189.9	4.493	2.15 ± 34	
logCl ~ logSC + SC	2	0.1476	86.79	86.66	194.3	4.531	12.5 ± 35	
logCl ~ Q + logSC + logQ	3	0.1054	93.3	93.2	3.557	2.348	2.394 ± 25	
logCl ~ logSC + logQ + SC	3	0.1123	92.39	92.27	30.51	2.659	17.79 ± 26	
logCl ~ Q + logQ + SC	3	0.1416	87.9	87.72	163.5	4.222	2.13 ± 33	
logCl ~ Q + logSC + logQ + SC	4	0.1055	93.32	93.18	5	2.383	3.416 ± 25	

Model-Calibration Data Set

0	Date	logCl	logSC	logQ	Cl	SC	Q	Computed logCl	Computed Cl	Residual	Normal Quantiles	Censored Values
1	1998-10-22	1.568	2.629	2.015	37	425.9	103.6	1.502	32.93	0.0657	0.587	--
2	1998-11-05	0.8887	2.311	3.937	7.74	204.5	8652	1.251	18.47	-0.363	-2.41	--
3	1998-12-04	1.898	2.862	2.346	79	728.3	222	1.985	99.95	-0.087	-0.934	--
4	1999-01-12	2.143	3.041	2.055	139	1100	113.5	2.261	189	-0.118	-1.22	--
5	1999-02-01	1.58	2.486	3.67	38	306.3	4680	1.526	34.74	0.0541	0.53	--
6	1999-02-19	2.117	3.017	2.079	131	1040	120	2.221	172.3	-0.104	-1.08	--
7	1999-03-23	2.185	3.041	1.991	153	1100	98	2.25	184.3	-0.0657	-0.725	--
8	1999-04-07	1.785	2.625	3.202	61	421.7	1594	1.699	51.74	0.0866	0.725	--
9	1999-04-14	1.672	2.727	2.492	47	533	310.4	1.762	59.9	-0.0902	-0.953	--
10	1999-04-16	1.204	2.302	3.733	16	200.5	5405	1.201	16.44	0.00337	0.037	--
11	1999-04-21	1.82	2.789	2.47	66	614.6	295	1.871	76.99	-0.0517	-0.53	--
12	1999-04-28	1.431	2.441	3.444	27	275.8	2779	1.404	26.24	0.0275	0.326	--
13	1999-05-05	1.929	2.905	2.377	85	804.1	238.5	2.068	121.2	-0.139	-1.33	--
14	1999-05-24	1.176	2.324	3.219	15	211	1656	1.153	14.72	0.0233	0.249	--

15	1999-06-18	1.398	2.477	2.613	25	300.3	409.8	1.328	22.05	0.0698	0.617	--
16	1999-06-21	1.279	2.344	3.334	19	220.7	2158	1.208	16.72	0.0706	0.632	--
17	1999-07-20	1.079	2.247	3.547	12	176.8	3528	1.069	12.14	0.0102	0.124	--
18	1999-08-03	1.041	2.168	3.63	11	147.3	4265	0.9386	8.99	0.103	0.842	--
19	1999-08-19	2.053	2.965	1.949	113	921.9	89	2.103	131.3	-0.0501	-0.515	--
20	1999-09-28	1.433	2.375	3.264	27.1	237.2	1835	1.253	18.56	0.18	1.72	--
21	2000-02-09	2.223	3.049	1.92	167	1118	83.15	2.251	184.7	-0.0286	-0.313	--
22	2000-03-07	1.479	2.458	3.053	30.1	287.4	1129	1.369	24.22	0.109	0.915	--
23	2000-03-28	1.365	2.407	3.639	23.2	255.5	4352	1.377	24.65	-0.0112	-0.0741	--
24	2000-05-19	2.134	3.025	2.031	136	1060	107.3	2.228	175	-0.0942	-1.01	--
25	2000-05-31	1.645	2.662	2.312	44.2	459.6	205.1	1.614	42.56	0.0315	0.366	--
26	2000-06-28	1.663	2.562	3.067	46	364.9	1168	1.561	37.67	0.102	0.825	--
27	2000-07-20	1.982	2.86	2.132	96	724.9	135.4	1.944	91.04	0.0382	0.406	--
28	2000-07-28	1.462	2.548	2.198	29	353	157.7	1.385	25.14	0.0772	0.647	--
29	2000-08-16	1.857	2.874	1.38	72	749	24	1.841	71.77	0.0165	0.186	--
30	2000-09-08	1.959	2.927	1.279	91	846	19	1.92	86.11	0.0392	0.446	--
31	2000-09-25	1.94	2.932	1.331	87	855.9	21.43	1.938	89.78	0.00148	0	--
32	2000-10-26	1.301	2.358	3.808	20	228	6430	1.315	21.41	-0.0144	-0.124	--
33	2000-11-08	1.613	2.711	1.914	41	514.6	82	1.635	44.69	-0.0223	-0.275	--
34	2000-12-04	2.173	3.037	1.663	149	1088	46	2.185	158.7	-0.0122	-0.0865	--
35	2001-03-14	1.708	2.525	3.279	51	335.3	1903	1.53	35.11	0.177	1.67	--
36	2001-04-13	1.839	2.725	2.602	69	531.3	400	1.779	62.2	0.0602	0.558	--
37	2001-04-26	2.134	2.994	2.001	136	986.6	100.3	2.166	151.7	-0.0323	-0.366	--
38	2001-05-08	1.833	2.821	2.186	68	662.5	153.3	1.882	78.91	-0.0495	-0.501	--
39	2001-06-04	1.398	2.465	3.021	25	291.9	1049	1.376	24.61	0.0219	0.237	--
40	2001-06-06	0.3979	1.981	3.952	2.5	95.82	8956	0.6532	4.659	-0.255	-1.85	< 5
41	2001-06-23	1.146	2.219	3.628	14	165.5	4250	1.031	11.12	0.115	1.12	--
42	2001-07-11	1.881	2.909	1.69	76	811.1	49	1.957	93.82	-0.0763	-0.842	--
43	2001-08-02	1.863	2.885	1.394	73	767.3	24.76	1.862	75.41	0.00105	-0.0123	--
44	2001-08-28	1.881	2.897	1.491	76	789	31	1.901	82.47	-0.0204	-0.237	--
45	2001-09-20	0.8451	2.136	3.62	7	136.7	4166	0.8778	7.816	-0.0328	-0.379	--
46	2001-10-31	1.94	2.931	1.453	87	853	28.35	1.956	93.63	-0.0168	-0.174	--
47	2002-01-10	2.243	3.014	1.574	175	1032	37.52	2.128	139.2	0.115	1.1	--
48	2002-02-21	2.326	3.041	1.623	212	1100	42	2.187	159.3	0.139	1.33	--
49	2002-04-09	2.079	2.983	1.971	120	960.7	93.59	2.14	142.8	-0.0604	-0.647	--
50	2002-04-22	1.362	2.423	3.171	23	264.9	1481	1.325	21.87	0.037	0.392	--
51	2002-05-13	1.987	2.786	2.621	97	611.6	417.9	1.893	81.01	0.0934	0.774	--
52	2002-05-22	1.623	2.625	2.152	42	422	141.9	1.519	34.2	0.104	0.878	--
53	2002-06-06	1.505	2.589	2.387	32	388.1	243.9	1.493	32.21	0.0124	0.149	--
54	2002-06-13	1.477	2.36	3.758	30	229.1	5729	1.311	21.17	0.167	1.5	--
55	2002-07-09	1.806	2.857	1.477	64	720	30	1.826	69.39	-0.02	-0.224	--
56	2002-08-15	1.881	2.872	2.875	76	744	750	2.092	128.1	-0.212	-1.78	--
57	2002-09-19	1.813	2.857	1.176	65	720	15	1.774	61.6	0.0385	0.433	--
58	2002-12-18	2.356	3.114	1.613	227	1300	41	2.318	215.2	0.0383	0.419	--
59	2003-03-20	1.613	2.479	3.799	41	301.5	6294	1.535	35.52	0.0775	0.662	--
60	2003-04-17	2.241	3.061	1.843	174	1150	69.73	2.26	188.5	-0.0196	-0.211	--
61	2003-04-23	2.017	2.808	2.464	104	642	290.9	1.905	83.17	0.112	1.01	--
62	2003-05-14	1.699	2.566	3.233	50	368	1710	1.596	40.85	0.103	0.86	--
63	2003-05-29	1.74	2.68	2.286	55	479	193	1.642	45.43	0.0982	0.808	--
64	2003-06-11	1.881	2.817	1.987	76	656	97	1.84	71.63	0.0408	0.474	--
65	2003-06-24	2.152	2.988	1.756	142	972	57	2.112	134	0.0404	0.46	--
66	2003-07-30	2.013	2.951	0.8865	103	892.6	7.7	1.895	81.31	0.118	1.17	--
67	2003-09-03	1.322	2.425	2.757	21	265.9	571.5	1.257	18.7	0.0656	0.573	--
68	2003-10-14	1.176	2.286	3.033	15	193	1079	1.05	11.63	0.126	1.22	--
69	2003-12-11	2.484	3.049	1.658	305	1120	45.48	2.207	166.9	0.277	2.41	--
70	2004-03-09	1.279	2.328	3.254	19	212.8	1794	1.166	15.17	0.113	1.06	--
71	2004-03-30	2.19	3.003	2.465	155	1007	292	2.262	189.1	-0.0712	-0.791	--
72	2004-04-26	2.117	2.994	1.708	131	986.3	51	2.115	135	0.00212	0.0247	--
73	2004-05-13	1.519	2.421	3.104	33	263.6	1270	1.309	21.12	0.209	1.92	--
74	2004-05-26	2.14	3.017	1.699	138	1040	50	2.156	148.2	-0.0158	-0.136	--
75	2004-06-22	1.342	2.433	3.017	22	270.8	1040	1.316	21.42	0.0267	0.313	--
76	2004-07-27	0.9542	2.126	3.767	9	133.8	5845	0.8857	7.959	0.0685	0.602	--
77	2005-01-27	1.491	2.542	2.234	31	348.7	171.3	1.382	24.93	0.11	0.934	--
78	2005-03-23	1.394	2.355	3.766	24.8	226.3	5836	1.302	20.77	0.0921	0.741	--

79	2005-05-27	1.465	2.484	2.862	29.2	305	727.9	1.383	25.04	0.0819	0.709	--
80	2005-06-06	1.444	2.464	3.288	27.8	291.3	1943	1.42	27.26	0.0236	0.262	--
81	2005-08-31	1.408	2.561	2.047	25.6	364	111.5	1.384	25.05	0.0246	0.275	--
82	2006-05-02	1.979	2.87	2.086	95.3	741.9	121.8	1.954	93.24	0.0246	0.288	--
83	2006-06-26	1.364	2.457	2.049	23.1	286.7	111.9	1.195	16.21	0.169	1.54	--
84	2006-07-27	1.428	2.841	0.5021	26.8	692.7	3.177	1.628	43.97	-0.2	-1.67	--
85	2006-08-15	1.436	2.818	0.8451	27.3	658	7	1.646	45.85	-0.21	-1.72	--
86	2006-08-23	1.581	2.762	1.163	38.1	578.2	14.56	1.598	41.07	-0.0174	-0.186	--
87	2006-09-27	1.667	2.876	0.8451	46.4	750.9	7	1.751	58.35	-0.0844	-0.915	--
88	2007-01-10	1.937	2.941	1.159	86.4	873	14.42	1.924	86.96	0.0123	0.136	--
89	2007-02-05	1.998	2.989	1.176	99.5	974	15	2.014	106.9	-0.0161	-0.149	--
90	2007-03-12	1.792	2.85	1.279	62	708	19	1.779	62.22	0.0136	0.174	--
91	2007-03-21	1.778	2.844	1.708	60	698	51	1.841	71.83	-0.063	-0.693	--
92	2007-03-27	1.778	2.647	2.198	60	443.7	157.9	1.566	38.16	0.212	2	--
93	2007-04-02	0.9494	2.223	3.46	8.9	167	2882	1.009	10.57	-0.0594	-0.617	--
94	2007-04-18	1.204	2.364	2.935	16	231	861	1.176	15.52	0.0283	0.339	--
95	2007-07-11	0.9823	2.206	3.284	9.6	160.6	1924	0.9479	9.184	0.0344	0.379	--
96	2007-08-16	1.848	2.837	1.771	70.5	686.4	59	1.839	71.44	0.00942	0.0988	--
97	2007-09-06	2.041	2.979	1.415	110	952	26	2.037	112.7	0.00456	0.0617	--
98	2007-11-26	1.857	2.911	1.462	72	815	29	1.922	86.5	-0.0645	-0.709	--
99	2007-12-06	1.985	2.957	1.477	96.7	906	30	2.008	105.5	-0.0228	-0.288	--
100	2007-12-13	1.477	2.472	3.438	30	296.5	2740	1.46	29.86	0.0172	0.199	--
101	2008-03-06	1.484	2.485	2.988	30.5	305.2	972.6	1.406	26.34	0.0788	0.693	--
102	2008-04-14	1.716	2.666	2.685	52	463.5	484	1.685	50.09	0.0314	0.353	--
103	2008-05-29	1.201	2.336	3.454	15.9	216.8	2842	1.215	16.98	-0.0133	-0.111	--
104	2008-06-30	1.505	2.55	2.942	32	355.2	874.4	1.518	34.12	-0.0127	-0.0988	--
105	2009-04-06	1.924	2.825	2.272	84	668.2	187	1.904	82.93	0.0207	0.224	--
106	2009-04-13	1.826	2.737	2.933	67	545.4	856.8	1.856	74.37	-0.0302	-0.326	--
107	2009-04-28	1.255	2.314	3.963	18	206	9190	1.262	18.91	-0.00638	-0.037	--
108	2009-06-16	1.602	2.683	2.939	40	481.9	868.3	1.759	59.47	-0.157	-1.58	--
109	2009-07-30	1.663	2.407	2.712	46	255.4	515.4	1.217	17.07	0.446	2.75	--
110	2009-09-09	0.716	2.199	3.509	5.2	158	3227	0.9735	9.743	-0.258	-1.92	--
111	2009-09-24	1.114	2.387	2.522	13	243.7	333	1.147	14.53	-0.0332	-0.392	--
112	2009-11-03	1.362	2.514	2.516	23	326.7	328	1.378	24.75	-0.0167	-0.161	--
113	2009-11-19	1.806	2.892	1.813	64	780	65	1.947	91.72	-0.141	-1.36	--
114	2009-12-01	1.973	2.964	1.74	94	920.6	55	2.066	120.6	-0.0931	-0.993	--
115	2009-12-17	2.041	3.017	1.771	110	1040	59	2.168	152.4	-0.126	-1.27	--
116	2010-01-19	2.041	3.017	1.903	110	1040	80	2.191	160.7	-0.149	-1.39	--
117	2010-02-04	2.041	2.977	1.806	110	948.6	64	2.101	130.7	-0.0598	-0.632	--
118	2010-02-23	2.079	2.999	1.833	120	997	68.13	2.145	144.7	-0.0661	-0.741	--
119	2010-04-14	2.114	3.017	1.724	130	1040	53	2.16	149.7	-0.0461	-0.46	--
120	2010-04-23	1.643	2.779	2.357	44	600.8	227.7	1.834	70.66	-0.191	-1.62	--
121	2010-05-13	1.398	2.543	2.733	25	349	541.2	1.468	30.43	-0.0702	-0.774	--
122	2010-06-09	0.8633	2.198	3.471	7.3	157.9	2959	0.9663	9.583	-0.103	-1.06	--
123	2010-06-13	0.3979	2.022	3.915	2.5	105.3	8227	0.7216	5.455	-0.324	-2	< 5
124	2010-06-14	0.3979	2.035	4.178	2.5	108.4	15060	0.7895	6.377	-0.392	-2.75	< 5
125	2010-06-15	1.114	2.281	3.809	13	190.9	6438	1.175	15.49	-0.061	-0.662	--
126	2010-06-16	1.079	2.309	3.682	12	203.5	4808	1.204	16.56	-0.125	-1.25	--
127	2010-07-06	0.3979	2.017	4.127	2.5	104	13400	0.748	5.796	-0.35	-2.1	< 5
128	2010-08-19	1.623	2.801	1.785	42	633.1	61	1.777	61.99	-0.154	-1.46	--
129	2010-08-25	1.756	2.718	2.887	57	522.7	770	1.814	67.55	-0.0586	-0.602	--
130	2010-11-16	1.886	2.699	2.418	77	500.5	262	1.7	51.87	0.187	1.78	--
131	2011-01-19	1.881	3.041	1.907	76	1100	80.75	2.236	178.3	-0.355	-2.23	--
132	2011-03-07	1.833	2.88	1.708	68	759	51	1.908	83.7	-0.0751	-0.825	--
133	2011-03-16	1.903	2.906	1.681	80	805.2	48	1.95	92.26	-0.0468	-0.474	--
134	2011-04-06	2.079	2.981	1.58	120	957	38	2.069	121.5	0.00988	0.111	--
135	2011-05-02	2.041	2.972	1.462	110	936.9	29	2.032	111.5	0.00908	0.0865	--
136	2011-06-07	1.813	2.839	1.342	65	691	21.97	1.77	61.02	0.0426	0.487	--
137	2011-06-21	2.204	2.95	2.041	160	890.5	109.9	2.091	127.8	0.113	1.03	--
138	2011-06-22	2.204	2.93	1.659	160	850.5	45.65	1.989	101.1	0.215	2.23	--
139	2011-08-15	1.519	2.578	1.415	33	378.3	26	1.305	20.92	0.213	2.1	--
140	2011-09-22	1.531	2.591	1.66	34	390.2	45.68	1.372	24.4	0.159	1.43	--
141	2011-12-20	1.613	2.53	3.037	41	339	1090	1.497	32.55	0.115	1.15	--
142	2012-02-06	1.799	2.665	2.667	63	461.9	464	1.679	49.42	0.121	1.19	--

143	2012-03-01	1.771	2.63	3.117	59	426.4	1310	1.693	51.05	0.078	0.678	--
144	2012-04-07	1.663	2.576	2.414	46	376.9	259.4	1.474	30.85	0.189	1.85	--
145	2012-06-18	1.505	2.559	2.114	32	362.4	130	1.392	25.51	0.114	1.08	--
146	2012-06-19	1.756	2.71	1.886	57	513.3	76.95	1.628	43.99	0.128	1.25	--
147	2012-07-05	1.591	2.867	0.6335	39	735.4	4.3	1.698	51.66	-0.107	-1.15	--
148	2012-07-12	1.544	2.894	0.3424	35	782.7	2.2	1.697	51.59	-0.153	-1.43	--
149	2012-07-19	1.462	2.836	0.2041	29	685	1.6	1.568	38.29	-0.106	-1.1	--
150	2012-08-30	1.398	2.722	0.4771	25	527.3	3	1.407	26.46	-0.00953	-0.0494	--
151	2012-09-06	1.663	2.74	1.517	46	549.8	32.92	1.619	43.1	0.0434	0.501	--
152	2012-09-11	1.653	2.837	0.6335	45	687.5	4.3	1.645	45.68	0.00864	0.0741	--
153	2012-09-18	1.663	2.876	0.6021	46	752.4	4	1.711	53.19	-0.0479	-0.487	--
154	2012-09-26	1.556	2.836	1.041	36	685.5	11	1.712	53.41	-0.156	-1.54	--
155	2012-10-24	1.459	2.82	0.6335	28.8	661	4.3	1.613	42.52	-0.154	-1.5	--
156	2012-11-07	1.756	2.917	0.7924	57	825.8	6.2	1.817	67.97	-0.0613	-0.678	--
157	2012-11-14	1.827	2.934	0.8195	67.1	859.7	6.6	1.854	73.93	-0.027	-0.301	--
158	2012-12-12	1.757	2.931	0.7324	57.1	854	5.4	1.833	70.57	-0.0768	-0.86	--
159	2013-01-16	1.841	2.945	0.8195	69.4	880.5	6.6	1.873	77.23	-0.0313	-0.353	--
160	2013-01-29	1.771	2.898	0.8976	59	791	7.9	1.801	65.51	-0.0303	-0.339	--
161	2013-02-13	1.893	2.934	0.8976	78.1	860	7.9	1.867	76.31	0.0252	0.301	--
162	2013-03-12	2.104	2.944	1.342	127	880	22	1.962	94.88	0.142	1.36	--
163	2013-03-13	2.255	3.018	1.73	180	1043	53.73	2.163	150.7	0.0922	0.757	--
164	2013-03-27	2.255	3.064	1	180	1160	10	2.122	137.2	0.133	1.27	--
165	2013-04-11	1.886	2.81	1.689	77	646	48.83	1.777	61.9	0.11	0.953	--
166	2013-04-15	2.354	3.045	1.591	226	1110	39	2.189	159.9	0.165	1.46	--
167	2013-04-24	1.839	2.764	1.913	69	580.8	81.85	1.731	55.71	0.108	0.896	--
168	2013-05-06	2.152	2.89	2.004	142	777	101	1.977	98.24	0.175	1.62	--
169	2013-05-09	1.699	2.672	2.054	50	470.2	113.3	1.588	40.07	0.111	0.973	--
170	2013-05-15	1.663	2.775	1.505	46	595.7	32	1.681	49.65	-0.018	-0.199	--
171	2013-05-21	1.415	2.65	1.699	26	447.1	49.97	1.487	31.75	-0.0717	-0.808	--
172	2013-05-28	1.765	2.854	1.181	58.2	714.2	15.16	1.769	60.81	-0.00388	-0.0247	--
173	2013-06-05	1.771	2.692	2.064	59	491.9	116	1.625	43.69	0.146	1.39	--
174	2013-06-13	2.152	2.962	1.487	142	915.3	30.66	2.018	107.9	0.134	1.3	--
175	2013-06-24	2.498	3.144	1.355	315	1393	22.66	2.328	220.6	0.17	1.58	--
176	2013-07-09	1.722	2.858	0.5185	52.7	721.4	3.3	1.663	47.67	0.0588	0.544	--
177	2013-07-25	1.613	2.718	1.433	41	522.2	27.12	1.564	37.95	0.0487	0.515	--
178	2013-07-29	0.7782	2.15	3.375	6	141.3	2370	0.862	7.536	-0.0838	-0.878	--
179	2013-08-07	0.7634	2.017	4.14	5.8	104.1	13790	0.7508	5.834	0.0126	0.161	--
180	2013-08-15	0.8	2.134	3.849	6.31	136	7070	0.9131	8.477	-0.113	-1.19	--
181	2013-08-29	1.844	2.822	2.262	69.8	664	183	1.897	81.67	-0.0531	-0.558	--
182	2013-10-24	1.948	2.943	1.477	88.8	878	30	1.983	99.66	-0.035	-0.406	--
183	2013-10-30	1.447	2.604	2.19	28	402.1	154.8	1.487	31.78	-0.0399	-0.433	--
184	2013-11-25	1.855	2.936	1.572	71.6	863	37.33	1.986	100.3	-0.131	-1.3	--
185	2013-12-11	2.045	3.025	1.591	111	1060	39	2.152	147	-0.107	-1.12	--
186	2014-01-14	2.111	3.025	1.653	129	1060	45	2.163	150.7	-0.0523	-0.544	--
187	2014-02-20	2.086	3.017	1.69	122	1040	49	2.154	147.7	-0.0678	-0.757	--
188	2014-03-17	2.079	2.999	1.568	120	997	37	2.1	130.3	-0.0206	-0.249	--
189	2014-04-09	2.041	2.996	1.484	110	990.5	30.51	2.08	124.5	-0.0388	-0.419	--
190	2014-04-14	2.009	2.985	1.496	102	966.3	31.33	2.063	119.6	-0.054	-0.573	--
191	2014-05-14	1.748	2.766	1.98	56	583.5	95.58	1.746	57.71	0.00211	0.0123	--
192	2014-05-15	1.969	2.896	1.961	93.1	787	91.5	1.98	98.86	-0.0109	-0.0617	--
193	2014-05-29	2.068	2.945	1.837	117	882	68.67	2.049	115.9	0.0194	0.211	--
194	2014-06-03	1.732	2.796	1.706	54	625.4	50.82	1.754	58.75	-0.0215	-0.262	--
195	2014-06-05	2.025	2.842	2.148	106	695.3	140.6	1.914	84.91	0.112	0.993	--
196	2014-06-09	1.301	2.358	3.168	20	228.1	1474	1.206	16.63	0.0952	0.791	--
197	2014-06-12	0.8904	2.199	3.589	7.77	158	3880	0.9871	10.05	-0.0967	-1.03	--
198	2014-06-24	1.812	2.757	2.444	64.9	571	278	1.809	66.64	0.00368	0.0494	--
199	2014-07-10	1.729	2.822	1.946	53.6	663.7	88.33	1.842	72	-0.113	-1.17	--
200	2014-07-15	1.806	2.879	1.663	64	757.4	46	1.898	81.9	-0.092	-0.973	--
201	2014-07-24	1.803	2.893	1.447	63.5	782.2	28	1.887	79.76	-0.0839	-0.896	--
202	2014-08-04	1.865	2.915	1.329	73.3	821.7	21.33	1.905	83.28	-0.0403	-0.446	--
203	2014-08-07	1.804	2.893	1.301	63.7	781	20	1.86	75.08	-0.0562	-0.587	--

Definitions

Cl: Chloride in mg/l (00940)

SC: Specific conductance in uS/cm @25C (00095)

Q: Stream flow, mean. daily in ft³/s (00060)

Model Archive Summary for Sulfate concentration at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the sulfate concentration (SO₄) model developed to compute hourly SO₄ from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 1, 1998 to August 7, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 222 concurrent measurements of sulfate concentration, streamflow, and specific conductance collected from May 1, 1998 through August 7, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. Five samples were below a laboratory detection limit of 5.0 mg/L. Summary statistics and the complete model-calibration dataset are provided below. Samples with Cook's D values greater than the outlier test criteria and studentized residual values greater than 3 or less than negative 3 were considered outliers. Samples collected April 2, 2007; July 11, 2007 and July 29, 2013 were deemed outliers and were removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating sulfate concentration. A variety of models that predict SO₄ and models that predict log₁₀(SO₄) were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted SO₄ were examined for homoscedasticity (meaning that their departures from zero did not change substantially over

the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{SO}_4)$.

Specific conductance and streamflow were selected as the best predictors of SO_4 based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error (MSPE), prediction error sum of squares (PRESS), and Mallow's C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for sulfate concentration at site number 07144100.

Sulfate concentration-based model:

$$\log_{10}(\text{SO}_4) = 0.943 \times \log_{10}(\text{SC}) - 0.112 \times \log_{10}(Q) - 0.816 ,$$

where

SO_4 = sulfate concentration in milligrams per liter (mg/L);

SC = specific conductance in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$); and,

Q = streamflow in cubic feet per second (ft^3/s).

Specific conductance and streamflow make physical and statistical sense as explanatory variables for sulfate concentration. Specific conductance makes physical sense because sulfate is an ion, which affects the conductivity of water. This correlates well with SC because SC is a measure of the conductivity of water. Streamflow correlates well with sulfate concentration because high streamflows tend to dilute sulfate concentrations. Specific conductance and streamflow make statistical sense as explanatory variables because they resulted in a model with low standard error, Mallow's C_p and PRESS values, and high R^2 values.

The log-transformed model may be retransformed to the original units so that SO_4 can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.03. The retransformed model, accounting for BCF is:

$$\text{SO}_4 = \frac{0.157 \times \text{SC}^{0.943}}{Q^{0.112}}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\text{SO}_4 = 0.0592 \times \text{SC} + 0.1$
2.1	2007	--	$\log_{10}(\text{SO}_4) = 0.943 \times \log_{10}(\text{SC}) - 0.112 \times \log_{10}(Q) - 0.816$

Sulfate Concentration Record

The SULF record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick
Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

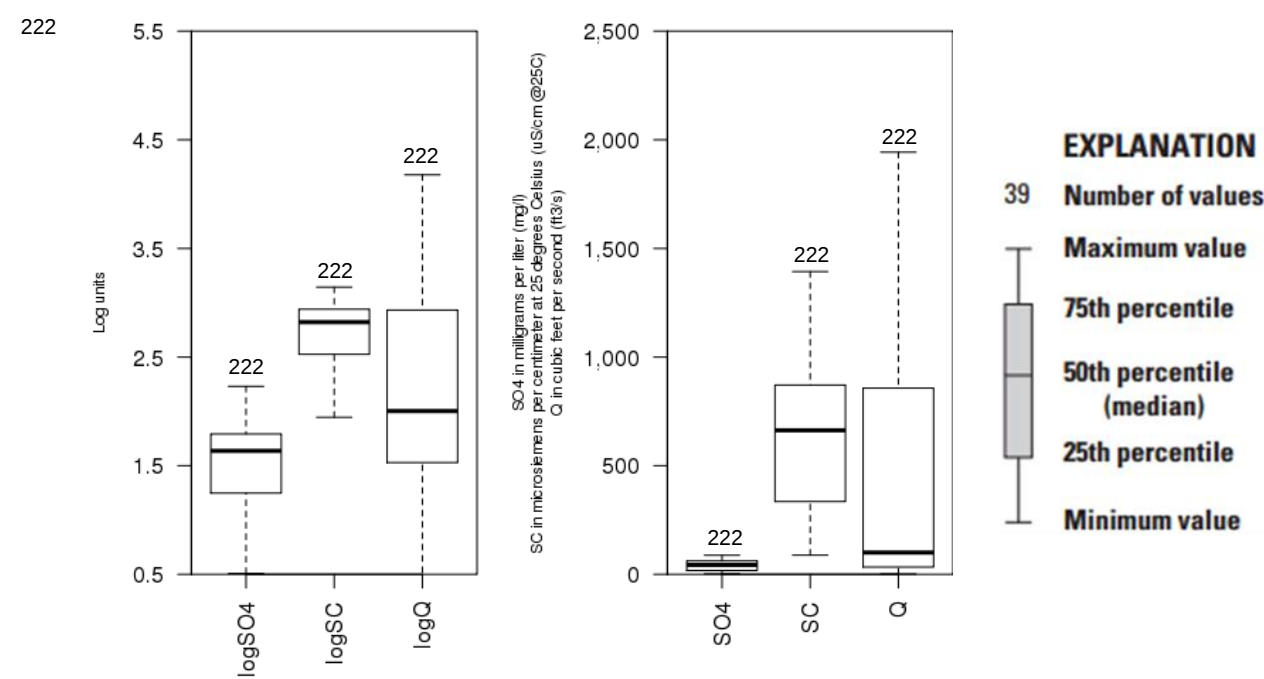
Model

$$\log\text{SO4} = + 0.943 * \log\text{SC} + -0.112 * \log\text{Q} + -0.816$$

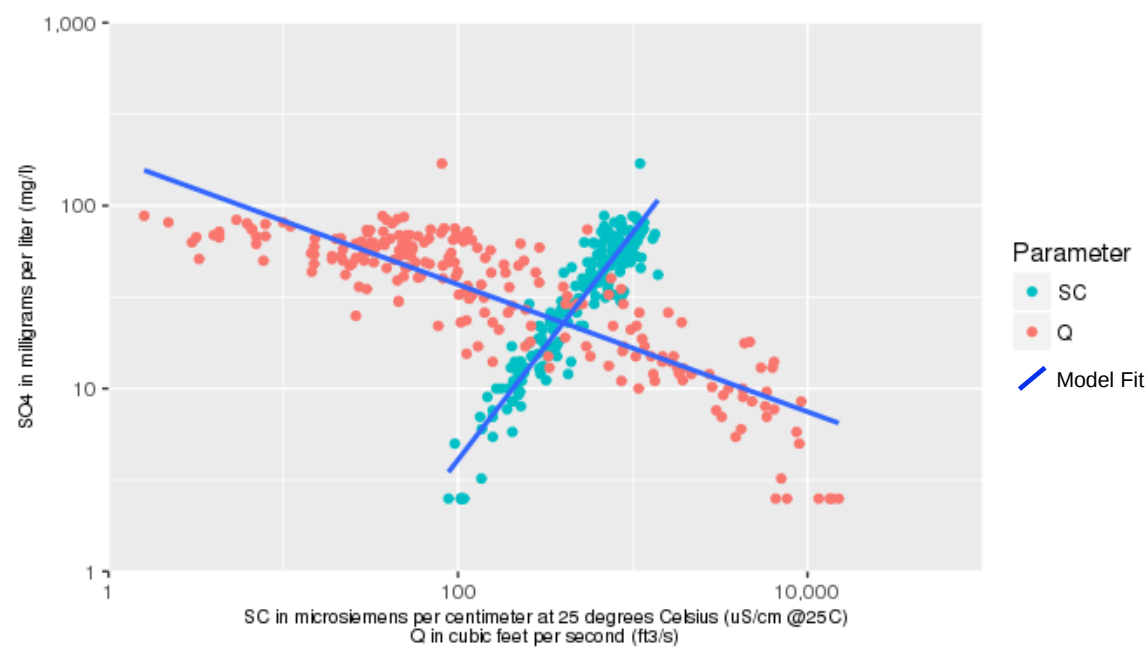
Variable Summary Statistics

	logSO4	logSC	logQ	SO4	SC	Q
Minimum	0.398	1.95	0.204	2.5	88.2	1.6
1st Quartile	1.25	2.53	1.53	17.7	335	33.8
Median	1.64	2.82	2	43.3	663	101
Mean	1.51	2.72	2.18	41.9	624	1120
3rd Quartile	1.79	2.94	2.93	62	871	857
Maximum	2.23	3.14	4.18	170	1390	15100
Censored [< 5]	5	--	--	5	--	--

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	222
Standard error (RMSE)	0.109
Upper Model standard percentage error (MSPE)	28.7
Lower Model standard percentage error (MSPE)	22.3
Coefficient of determination (R ²)	0.912
Adjusted Coefficient of Determination (Adj. R ²)	0.912
Bias Correction Factor (BCF)	1.03
Variance Inflation Factors (VIF)	
logSC	logQ
2.95	2.95

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-0.816	0.1490	-5.46	1.27e-07
logSC	0.943	0.0453	20.80	8.93e-54
logQ	-0.112	0.0139	-8.08	4.33e-14

Correlation Matrix

	Intercept	logSC	logQ
Intercept	1.000	-0.992	-0.875
logSC	-0.992	1.000	0.813
logQ	-0.875	0.813	1.000

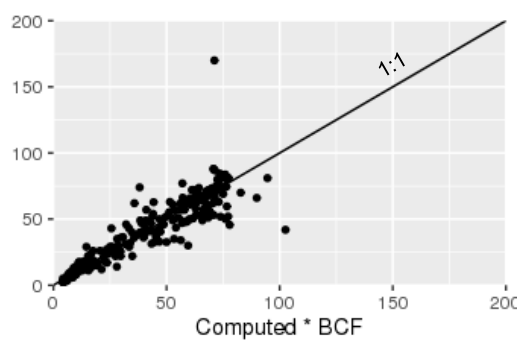
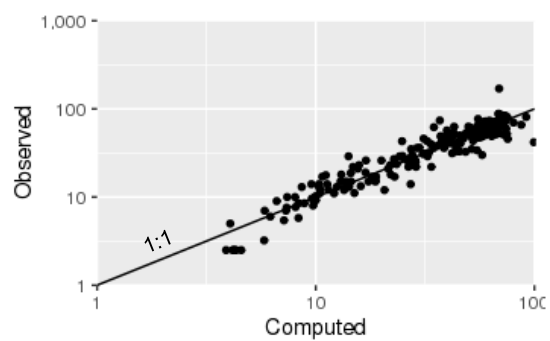
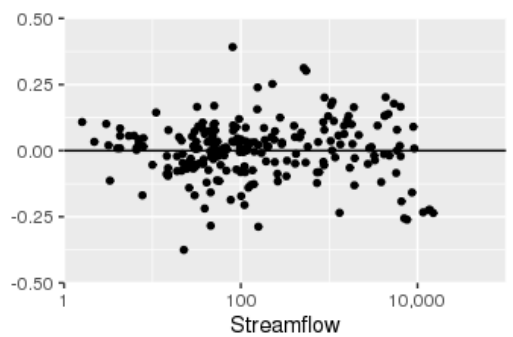
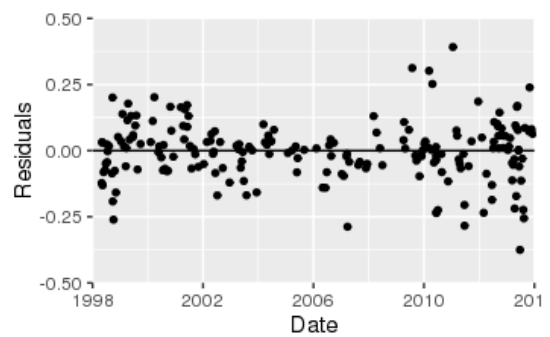
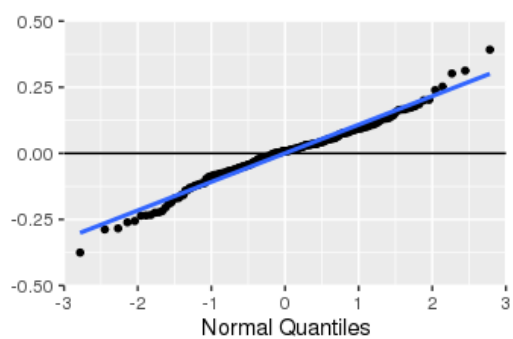
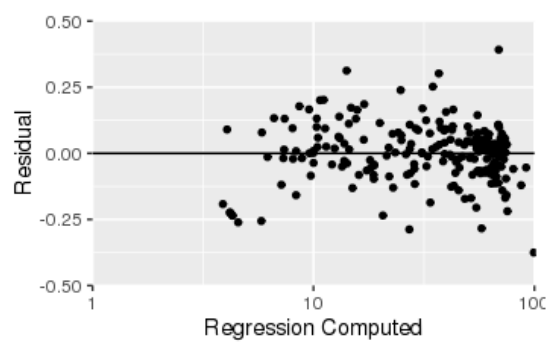
Outlier Test Criteria

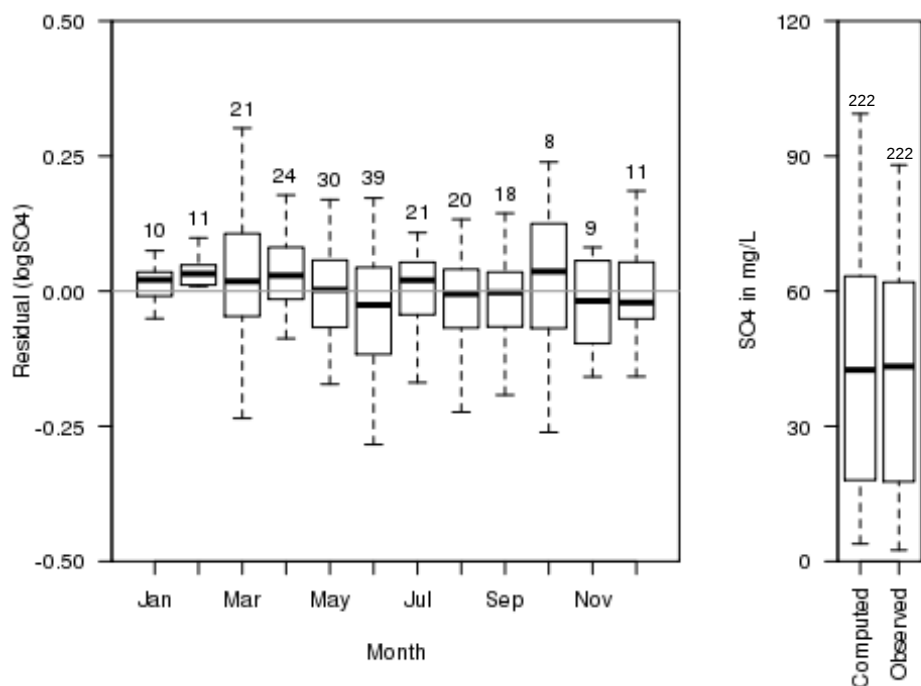
Leverage	Cook's D	DFFITS
0.027	0.195	0.190

Flagged Observations

	logS04	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
5/1/1998 13:06	1.510	1.640	-0.12200	-1.1400	-1.1400	0.03300	1.47e-02	-0.2100
9/22/1998 10:16	1.230	1.030	0.20100	1.8500	1.8600	0.01620	1.88e-02	0.2390
9/25/1998 10:11	0.398	0.590	-0.19200	-1.7900	-1.8000	0.04240	4.74e-02	-0.3790
10/5/1998 10:21	0.398	0.659	-0.26100	-2.4300	-2.4500	0.03290	6.68e-02	-0.4530
11/5/1998 13:45	0.763	0.921	-0.15800	-1.4600	-1.4700	0.02150	1.57e-02	-0.2180
3/16/1999 13:41	1.850	1.900	-0.05920	-0.5490	-0.5480	0.02820	2.92e-03	-0.0934
4/16/1999 11:16	1.110	0.936	0.17800	1.6400	1.6500	0.01790	1.63e-02	0.2220
3/28/2000 12:46	1.250	1.050	0.20200	1.8600	1.8700	0.01660	1.95e-02	0.2430
10/26/2000 11:36	1.150	0.980	0.16600	1.5300	1.5400	0.01930	1.54e-02	0.2160
6/6/2001 10:11	0.699	0.609	0.09010	0.8390	0.8390	0.03690	9.00e-03	0.1640
7/30/2003 12:21	1.700	1.870	-0.16900	-1.5500	-1.5600	0.01520	1.24e-02	-0.1940
7/27/2006 11:16	1.830	1.810	0.02020	0.1880	0.1880	0.03540	4.33e-04	0.0360
3/27/2007 11:46	1.150	1.430	-0.28800	-2.6400	-2.6700	0.00535	1.25e-02	-0.1960
7/30/2009 10:36	1.460	1.150	0.31300	2.8700	2.9200	0.01170	3.26e-02	0.3180
3/10/2010 9:11	1.870	1.570	0.30200	2.7900	2.8300	0.01880	4.96e-02	0.3920
6/13/2010 19:21	0.398	0.631	-0.23300	-2.1700	-2.1900	0.03320	5.39e-02	-0.4060
6/14/2010 9:41	0.398	0.634	-0.23600	-2.1900	-2.2100	0.03240	5.37e-02	-0.4050
7/6/2010 9:01	0.398	0.623	-0.22500	-2.0900	-2.1000	0.03350	5.04e-02	-0.3920
1/19/2011 11:41	2.230	1.840	0.39200	3.6100	3.7100	0.01580	6.97e-02	0.4700
6/21/2011 10:01	1.530	1.740	-0.20500	-1.8900	-1.9000	0.01100	1.33e-02	-0.2010
6/22/2011 10:21	1.480	1.760	-0.28400	-2.6000	-2.6400	0.00704	1.60e-02	-0.2220
3/1/2012 12:01	1.080	1.310	-0.23500	-2.1600	-2.1800	0.01280	2.02e-02	-0.2480
7/5/2012 12:36	1.830	1.820	0.00919	0.0851	0.0850	0.02760	6.86e-05	0.0143
7/12/2012 10:16	1.910	1.880	0.03330	0.3100	0.3100	0.03710	1.24e-03	0.0608
7/19/2012 10:16	1.940	1.840	0.10800	1.0200	1.0200	0.05060	1.84e-02	0.2350
8/30/2012 8:16	1.800	1.700	0.10100	0.9490	0.9490	0.05140	1.63e-02	0.2210
9/11/2012 10:16	1.850	1.790	0.05580	0.5180	0.5170	0.03020	2.78e-03	0.0912
9/18/2012 11:21	1.840	1.830	0.00907	0.0841	0.0839	0.02800	6.78e-05	0.0142
10/24/2012 9:30	1.860	1.770	0.08410	0.7820	0.7810	0.03180	6.69e-03	0.1420
4/15/2013 9:00	1.660	1.880	-0.21900	-2.0100	-2.0300	0.01180	1.61e-02	-0.2210
6/24/2013 9:40	1.620	2.000	-0.37500	-3.4600	-3.5500	0.01630	6.60e-02	-0.4570
7/9/2013 9:31	1.710	1.820	-0.11400	-1.0600	-1.0600	0.03290	1.26e-02	-0.1950
8/7/2013 9:46	0.398	0.622	-0.22400	-2.0800	-2.1000	0.03350	4.99e-02	-0.3900
8/15/2013 9:10	0.508	0.764	-0.25600	-2.3700	-2.3900	0.02480	4.76e-02	-0.3820

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logSO4 ~ logSC	1	0.124	88.6	88.6	103	3.48	<NA>	± 29
logSO4 ~ SC	1	0.185	74.7	74.6	495	7.76	<NA>	± 44
logSO4 ~ logQ	1	0.188	73.9	73.8	518	7.98	<NA>	± 45
logSO4 ~ logSC + logQ	2	0.109	91.2	91.2	31.1	2.71	2.95	± 26
logSO4 ~ Q + logSC	2	0.113	90.6	90.5	48.8	2.88	2.22	± 26
logSO4 ~ logSC + SC	2	0.116	90.2	90.1	60.2	3.03	11.9	± 27
logSO4 ~ Q + logSC + logQ	3	0.104	92.1	92	8.15	2.45	2.48	± 24
logSO4 ~ logSC + logQ + SC	3	0.105	92	91.9	10.7	2.49	17	± 24
logSO4 ~ Q + logSC + SC	3	0.112	90.9	90.7	43.6	2.83	3.52	± 26
logSO4 ~ Q + logSC + logQ + SC	4	0.103	92.3	92.2	5	2.42	3.71	± 24

Model-Calibration Data Set

0	Date	logSO4	logSC	logQ	SO4	SC	Q	Computed logSO4	Computed SO4	Residual	Normal Quantiles	Censored Values
1	1998-05-01	1.51	2.94	2.86	32.6	871	728	1.64	44.6	-0.122	-1.22	--
2	1998-05-06	1.71	2.91	2.16	51.8	804	143	1.68	49.7	0.0318	0.304	--
3	1998-05-11	1.77	2.96	2.11	58.8	912	129	1.74	56.6	0.0304	0.28	--
4	1998-05-14	1.05	2.5	3.29	11.1	319	1930	1.18	15.5	-0.131	-1.3	--
5	1998-05-27	1.64	2.93	2	43.5	844	99.6	1.72	54.1	-0.0814	-0.922	--
6	1998-06-16	1.7	2.94	1.63	50.5	878	43	1.78	61.7	-0.0737	-0.807	--
7	1998-06-24	1.46	2.78	2.61	29	601	412	1.51	33.5	-0.0491	-0.551	--

8	1998-07-10	1.04	2.32	3.13	11	207	1340	1.02	10.7	0.0238	0.222	--
9	1998-07-13	1.23	2.5	2.38	17	316	243	1.27	19.4	-0.0435	-0.499	--
10	1998-07-20	1.59	2.75	1.65	39	564	45	1.59	40.5	-0.00254	-0.153	--
11	1998-08-06	1.79	2.91	1.46	61	820	29	1.77	60.5	0.0172	0.153	--
12	1998-09-15	1.73	2.93	1.18	54	857	15	1.82	68	-0.0864	-0.994	--
13	1998-09-22	1.23	2.31	2.95	17	203	885	1.03	11	0.201	1.89	--
14	1998-09-25	0.398	1.95	3.82	2.5	88.2	6580	0.59	4.01	-0.192	-1.58	< 5
15	1998-10-05	0.398	2.03	3.88	2.5	106	7620	0.659	4.7	-0.261	-2.14	< 5
16	1998-10-22	1.36	2.63	2.02	23	426	104	1.44	28.3	-0.076	-0.855	--
17	1998-11-05	0.763	2.31	3.94	5.79	204	8650	0.921	8.6	-0.158	-1.41	--
18	1998-12-04	1.67	2.86	2.35	47	728	222	1.62	43	0.0518	0.591	--
19	1999-01-12	1.86	3.04	2.06	72	1100	114	1.82	68.5	0.0354	0.412	--
20	1999-02-01	1.26	2.49	3.67	18	306	4680	1.12	13.5	0.139	1.44	--
21	1999-02-19	1.81	3.02	2.08	65	1040	120	1.8	64.5	0.0167	0.141	--
22	1999-03-16	1.85	3.13	2.04	70	1340	110	1.9	82.8	-0.0592	-0.66	--
23	1999-03-23	1.84	3.04	1.99	69	1100	98	1.83	69.6	0.00972	0.0395	--
24	1999-04-07	1.41	2.63	3.2	26	422	1590	1.3	20.6	0.115	1.25	--
25	1999-04-16	1.11	2.3	3.73	13	201	5400	0.936	8.9	0.178	1.77	--
26	1999-05-05	1.7	2.91	2.38	50	804	238	1.66	46.9	0.0416	0.474	--
27	1999-05-24	1.15	2.32	3.22	14	211	1660	1.01	10.7	0.131	1.38	--
28	1999-06-18	1.28	2.48	2.61	19	300	410	1.23	17.4	0.0514	0.578	--
29	1999-06-21	1.08	2.34	3.33	12	221	2160	1.02	10.8	0.0591	0.688	--
30	1999-07-20	1	2.25	3.55	10	177	3530	0.905	8.29	0.0948	1.03	--
31	1999-08-03	0.954	2.17	3.63	9	147	4270	0.821	6.84	0.133	1.41	--
32	1999-08-19	1.69	2.96	1.95	49	922	89	1.76	59.6	-0.0713	-0.792	--
33	1999-09-28	1.08	2.38	3.26	12.1	237	1840	1.06	11.8	0.0251	0.245	--
34	2000-02-09	1.88	3.05	1.92	75.2	1120	83.2	1.84	72	0.0322	0.315	--
35	2000-03-07	1.27	2.46	3.05	18.7	287	1130	1.16	14.9	0.112	1.22	--
36	2000-03-28	1.25	2.41	3.64	17.7	256	4350	1.05	11.5	0.202	1.96	--
37	2000-05-19	1.8	3.03	2.03	63.7	1060	107	1.81	66.5	-0.00533	-0.187	--
38	2000-05-31	1.45	2.66	2.31	28.3	460	205	1.44	28.1	0.0162	0.13	--
39	2000-06-28	1.23	2.56	3.07	17	365	1170	1.26	18.6	-0.0256	-0.375	--
40	2000-07-20	1.57	2.86	2.13	37	725	136	1.64	45.3	-0.0742	-0.823	--
41	2000-07-28	1.36	2.55	2.2	23	353	158	1.34	22.6	0.0214	0.199	--
42	2000-08-16	1.67	2.87	1.38	47	749	24	1.74	56.7	-0.0683	-0.777	--
43	2000-09-08	1.72	2.93	1.28	53	846	19	1.8	65.4	-0.0774	-0.888	--
44	2000-09-25	1.72	2.93	1.33	53	856	21.4	1.8	65.2	-0.0763	-0.872	--
45	2000-10-26	1.15	2.36	3.81	14	228	6430	0.98	9.86	0.166	1.62	--
46	2000-11-08	1.6	2.71	1.91	40	515	82	1.53	34.7	0.0754	0.792	--
47	2000-12-04	1.84	3.04	1.66	69	1090	46	1.86	75	-0.0228	-0.363	--
48	2001-03-14	1.36	2.53	3.28	23	335	1900	1.2	16.3	0.164	1.54	--
49	2001-04-13	1.56	2.73	2.6	36	531	400	1.46	29.9	0.094	1.01	--
50	2001-04-26	1.83	2.99	2	67	987	100	1.78	62.7	0.0426	0.487	--
51	2001-05-08	1.76	2.82	2.19	57	663	153	1.6	41	0.156	1.51	--
52	2001-06-04	1.34	2.47	3.02	22	292	1050	1.17	15.3	0.172	1.71	--
53	2001-06-06	0.699	1.98	3.95	5	95.8	8960	0.609	4.19	0.0901	0.957	--
54	2001-06-23	1	2.22	3.63	10	166	4250	0.869	7.63	0.131	1.35	--
55	2001-07-11	1.76	2.91	1.69	57	811	49	1.74	56.5	0.0177	0.164	--
56	2001-08-02	1.68	2.88	1.39	48	767	24.8	1.75	57.9	-0.0675	-0.761	--
57	2001-08-28	1.76	2.9	1.49	57	789	31	1.75	57.9	0.00663	-0.0395	--
58	2001-09-20	0.778	2.14	3.62	6	137	4170	0.792	6.39	-0.0137	-0.268	--
59	2001-10-31	1.72	2.93	1.45	53	853	28.4	1.79	63	-0.0612	-0.688	--
60	2002-01-10	1.8	3.01	1.57	63	1030	37.5	1.85	73	-0.0507	-0.578	--
61	2002-02-21	1.9	3.04	1.62	80	1100	42	1.87	76.6	0.0326	0.339	--
62	2002-04-09	1.81	2.98	1.97	65	961	93.6	1.78	61.6	0.037	0.437	--
63	2002-04-22	1.18	2.42	3.17	15	265	1480	1.11	13.4	0.0628	0.702	--
64	2002-05-13	1.51	2.79	2.62	32	612	421	1.52	34	-0.0124	-0.222	--

65	2002-05-22	1.41	2.63	2.15	26	422	142	1.42	27.1	-0.00368	-0.164	--
66	2002-06-06	1.43	2.59	2.39	27	388	244	1.36	23.5	0.0735	0.761	--
67	2002-06-13	0.903	2.36	3.76	8	229	5730	0.988	10	-0.0846	-0.975	--
68	2002-07-09	1.54	2.86	1.48	35	720	30	1.71	53.3	-0.169	-1.47	--
69	2002-08-15	1.6	2.87	2.88	40	744	750	1.57	38.3	0.0325	0.327	--
70	2002-09-19	1.68	2.86	1.18	48	720	15	1.75	57.6	-0.066	-0.717	--
71	2002-12-18	1.82	3.11	1.61	66	1300	41	1.94	89.9	-0.121	-1.2	--
72	2003-03-20	1.11	2.48	3.8	13	302	6290	1.1	12.9	0.0183	0.176	--
73	2003-04-17	1.87	3.06	1.84	74	1150	69.7	1.86	75.4	0.00527	-0.0508	--
74	2003-04-23	1.58	2.81	2.46	38	642	291	1.56	37.1	0.0244	0.233	--
75	2003-05-14	1.18	2.57	3.23	15	368	1710	1.24	18	-0.0649	-0.702	--
76	2003-05-29	1.41	2.68	2.29	26	479	193	1.46	29.4	-0.0406	-0.461	--
77	2003-06-11	1.61	2.82	1.99	41	656	97	1.62	42.8	-0.00511	-0.176	--
78	2003-06-24	1.69	2.99	1.76	49	972	57	1.8	65.8	-0.115	-1.13	--
79	2003-07-30	1.7	2.95	0.886	50	893	7.7	1.87	76.1	-0.169	-1.44	--
80	2003-09-03	1.18	2.42	2.76	15	266	572	1.16	15	0.0148	0.096	--
81	2003-10-14	1	2.29	3.03	10	193	1080	0.999	10.3	0.000911	-0.119	--
82	2003-12-11	1.72	3.05	1.66	52	1120	45.5	1.87	77.2	-0.158	-1.38	--
83	2004-03-09	1.11	2.33	3.25	13	213	1790	1.01	10.7	0.0996	1.09	--
84	2004-03-30	1.77	3	2.47	59	1010	292	1.74	56.6	0.0314	0.292	--
85	2004-04-26	1.84	2.99	1.71	69	986	51	1.82	67.6	0.0225	0.21	--
86	2004-05-13	1.18	2.42	3.1	15	264	1270	1.12	13.6	0.0574	0.674	--
87	2004-05-26	1.83	3.02	1.7	67	1040	50	1.84	71.2	-0.0129	-0.245	--
88	2004-06-16	1.78	2.92	1.74	60	832	54.5	1.74	57.1	0.0347	0.375	--
89	2004-06-22	1.18	2.43	3.02	15	271	1040	1.14	14.2	0.0365	0.424	--
90	2004-07-27	0.845	2.13	3.77	7	134	5840	0.766	6.02	0.0787	0.855	--
91	2005-01-27	1.32	2.54	2.23	21	349	171	1.33	22.1	-0.009	-0.199	--
92	2005-03-23	0.982	2.35	3.77	9.6	226	5840	0.982	9.89	0.000411	-0.13	--
93	2005-05-10	1.55	2.77	2.29	35.8	587	196	1.54	35.6	0.016	0.119	--
94	2005-05-27	1.12	2.48	2.86	13.3	305	728	1.21	16.6	-0.0819	-0.957	--
95	2005-06-06	1.11	2.46	3.29	12.9	291	1940	1.14	14.2	-0.0284	-0.387	--
96	2005-08-31	1.37	2.56	2.05	23.6	364	111	1.37	24.2	0.00305	-0.0734	--
97	2006-02-09	1.8	2.94	1.52	62.5	872	33	1.79	63.2	0.00873	-0.00564	--
98	2006-05-02	1.52	2.87	2.09	32.9	742	122	1.66	46.9	-0.14	-1.32	--
99	2006-06-08	1.71	3	1.41	51.8	1000	26	1.85	73.9	-0.141	-1.35	--
100	2006-06-26	1.19	2.46	2.05	15.5	287	112	1.27	19.3	-0.0815	-0.94	--
101	2006-07-27	1.83	2.84	0.502	67.2	693	3.18	1.81	66.2	0.0202	0.187	--
102	2006-08-15	1.79	2.82	0.845	61.7	658	7	1.75	57.7	0.0428	0.512	--
103	2006-08-23	1.64	2.76	1.16	43.5	578	14.6	1.66	47	-0.0203	-0.315	--
104	2006-09-27	1.83	2.88	0.845	67.8	751	7	1.8	65.3	0.0296	0.268	--
105	2007-01-10	1.74	2.94	1.16	54.9	873	14.4	1.83	69.4	-0.0885	-1.03	--
106	2007-02-05	1.78	2.99	1.18	59.6	974	15	1.87	76.6	-0.0957	-1.05	--
107	2007-03-12	1.71	2.85	1.28	51	708	19	1.73	55.2	-0.0212	-0.351	--
108	2007-03-21	1.66	2.84	1.71	46	698	51	1.67	48.8	-0.012	-0.21	--
109	2007-03-27	1.15	2.65	2.2	14	444	158	1.43	28	-0.288	-2.45	--
110	2007-04-18	1.04	2.36	2.94	11	231	861	1.08	12.5	-0.0423	-0.474	--
111	2007-08-16	1.61	2.84	1.77	40.4	686	59	1.66	47.2	-0.0544	-0.618	--
112	2007-09-06	1.79	2.98	1.41	62	952	26	1.83	70.5	-0.0424	-0.487	--
113	2007-11-26	1.7	2.91	1.46	50	815	29	1.77	60.2	-0.0668	-0.732	--
114	2007-12-06	1.76	2.96	1.48	56.9	906	30	1.81	66.2	-0.0524	-0.591	--
115	2007-12-13	1.08	2.47	3.44	12	296	2740	1.13	13.9	-0.0502	-0.564	--
116	2008-03-06	1.32	2.48	2.99	21	305	973	1.19	16	0.13	1.32	--
117	2008-04-14	1.47	2.67	2.68	29.2	463	484	1.4	25.7	0.0683	0.732	--
118	2008-05-29	1.01	2.34	3.45	10.2	217	2840	0.999	10.3	0.00913	0.0169	--
119	2008-06-30	1.2	2.55	2.94	16	355	874	1.26	18.7	-0.0551	-0.632	--
120	2009-04-06	1.63	2.82	2.27	43	668	187	1.59	40.5	0.0401	0.461	--
121	2009-04-13	1.54	2.74	2.93	35	545	857	1.44	28.1	0.108	1.18	--

122	2009-04-28	0.929	2.31	3.96	8.5	206	9190	0.921	8.6	0.00829	-0.0169	--
123	2009-06-16	1.46	2.68	2.95	29	482	882	1.38	25	0.0786	0.839	--
124	2009-07-30	1.46	2.41	2.71	29	255	516	1.15	14.6	0.313	2.45	--
125	2009-09-09	0.845	2.2	3.51	7	158	3230	0.864	7.54	-0.0186	-0.304	--
126	2009-09-24	1.11	2.39	2.52	13	244	333	1.15	14.6	-0.038	-0.449	--
127	2009-11-03	1.18	2.51	2.52	15	327	328	1.27	19.3	-0.0967	-1.07	--
128	2009-11-19	1.69	2.89	1.81	49	780	65	1.71	52.7	-0.0182	-0.28	--
129	2009-12-01	1.76	2.96	1.74	58	921	55	1.78	62.8	-0.021	-0.339	--
130	2009-12-17	1.83	3.02	1.77	68	1040	59	1.83	69.9	0.0017	-0.107	--
131	2010-01-06	1.88	3.06	1.98	75	1150	96	1.85	72.8	0.0267	0.257	--
132	2010-01-19	1.85	3.02	1.9	71	1040	80	1.82	67.5	0.0352	0.387	--
133	2010-02-04	1.8	2.98	1.81	63	949	64	1.79	63.5	0.01	0.0508	--
134	2010-02-23	1.82	3	1.83	66	997	68.1	1.81	66.1	0.0129	0.0734	--
135	2010-03-10	1.87	2.85	2.74	74	713	549	1.57	38.1	0.302	2.27	--
136	2010-04-14	1.84	3.02	1.72	69	1040	53	1.84	70.7	0.00267	-0.0847	--
137	2010-04-23	1.79	2.78	2.36	62	601	228	1.54	35.8	0.252	2.14	--
138	2010-05-13	1.23	2.54	2.73	17	349	541	1.28	19.5	-0.045	-0.512	--
139	2010-06-09	0.881	2.2	3.48	7.6	158	3000	0.867	7.59	0.014	0.0847	--
140	2010-06-10	0.964	2.34	3.52	9.2	221	3290	1	10.3	-0.0363	-0.437	--
141	2010-06-14	0.398	2.02	4.06	2.5	104	11600	0.631	4.41	-0.233	-1.82	< 5
142	2010-06-14	0.398	2.03	4.18	2.5	108	15100	0.634	4.44	-0.236	-1.96	< 5
143	2010-06-15	0.886	2.28	3.81	7.7	191	6440	0.907	8.34	-0.021	-0.327	--
144	2010-06-16	0.929	2.31	3.68	8.5	204	4810	0.948	9.15	-0.0185	-0.292	--
145	2010-07-06	0.398	2.02	4.13	2.5	104	13400	0.623	4.33	-0.225	-1.77	< 5
146	2010-08-19	1.61	2.8	1.79	41	633	61	1.63	43.6	-0.0132	-0.257	--
147	2010-08-25	1.34	2.72	2.89	22	523	770	1.42	27.4	-0.0812	-0.905	--
148	2010-11-16	1.34	2.7	2.42	22	501	262	1.46	29.7	-0.116	-1.15	--
149	2011-01-19	2.23	3.04	1.91	170	1100	80.8	1.84	71.1	0.392	2.78	--
150	2011-03-07	1.79	2.88	1.71	61	759	51	1.71	52.8	0.0763	0.807	--
151	2011-03-16	1.79	2.91	1.68	62	805	48	1.74	56.2	0.0562	0.646	--
152	2011-04-06	1.79	2.98	1.58	61	957	38	1.82	67.9	-0.033	-0.424	--
153	2011-04-18	1.77	2.98	1.53	59	946	33.8	1.82	68.1	-0.0485	-0.538	--
154	2011-05-02	1.76	2.97	1.46	57	937	29	1.82	68.6	-0.067	-0.746	--
155	2011-06-07	1.7	2.84	1.34	50	691	22	1.71	53.1	-0.0128	-0.233	--
156	2011-06-21	1.53	2.95	2.04	34	890	110	1.74	56.3	-0.205	-1.62	--
157	2011-06-22	1.48	2.93	1.66	30	850	45.7	1.76	59.5	-0.284	-2.27	--
158	2011-08-15	1.4	2.58	1.41	25	378	26	1.46	29.5	-0.0588	-0.646	--
159	2011-09-22	1.48	2.59	1.66	30	390	45.7	1.44	28.5	0.0352	0.4	--
160	2011-12-20	1.41	2.53	3.04	26	339	1090	1.23	17.5	0.186	1.82	--
161	2012-02-06	1.45	2.66	2.67	28	462	464	1.4	25.8	0.0494	0.551	--
162	2012-03-01	1.08	2.63	3.12	12	426	1310	1.31	21.3	-0.235	-1.89	--
163	2012-04-07	1.26	2.58	2.41	18	377	259	1.34	22.7	-0.0875	-1.01	--
164	2012-06-18	1.23	2.56	2.11	17	362	130	1.36	23.7	-0.13	-1.27	--
165	2012-06-19	1.34	2.71	1.89	22	513	76.9	1.53	34.9	-0.186	-1.54	--
166	2012-07-05	1.83	2.87	0.633	67	735	4.3	1.82	67.7	0.00919	0.0282	--
167	2012-07-12	1.91	2.89	0.342	81	783	2.2	1.88	77.4	0.0333	0.351	--
168	2012-07-19	1.94	2.84	0.204	88	685	1.6	1.84	70.7	0.108	1.2	--
169	2012-08-30	1.8	2.72	0.477	63	527	3	1.7	51.5	0.101	1.11	--
170	2012-09-06	1.69	2.74	1.52	49	550	33	1.6	40.9	0.0919	0.975	--
171	2012-09-11	1.85	2.84	0.633	70	687	4.3	1.79	63.5	0.0558	0.632	--
172	2012-09-18	1.84	2.88	0.602	69	752	4	1.83	69.7	0.00907	0.00564	--
173	2012-09-26	1.89	2.84	1.04	77	686	11	1.74	57	0.144	1.47	--
174	2012-10-24	1.86	2.82	0.633	72	661	4.3	1.77	61.2	0.0841	0.888	--
175	2012-11-07	1.9	2.92	0.792	80	826	6.2	1.85	72.5	0.0566	0.66	--
176	2012-11-14	1.87	2.93	0.82	74.2	860	6.6	1.86	74.7	0.0105	0.0621	--
177	2012-12-12	1.92	2.93	0.732	83.7	854	5.4	1.87	76	0.0557	0.618	--
178	2013-01-16	1.87	2.94	0.82	74.5	880	6.6	1.87	76.4	0.00243	-0.096	--

179	2013-01-29	1.83	2.9	0.898	68	791	7.9	1.82	67.7	0.0155	0.107	--
180	2013-02-13	1.9	2.93	0.898	79.2	860	7.9	1.85	73.3	0.0474	0.538	--
181	2013-03-12	1.76	2.94	1.34	58.1	880	22	1.81	66.7	-0.0465	-0.525	--
182	2013-03-13	1.72	3.02	1.73	53	1040	53.7	1.84	70.8	-0.112	-1.09	--
183	2013-03-27	1.91	3.06	1	81	1160	10	1.96	94.6	-0.0539	-0.605	--
184	2013-04-11	1.61	2.81	1.69	41	646	48.9	1.65	45.6	-0.0323	-0.412	--
185	2013-04-15	1.66	3.05	1.59	45.6	1110	39	1.88	77.9	-0.219	-1.67	--
186	2013-04-24	1.67	2.76	1.91	47	581	81.9	1.58	38.9	0.0958	1.05	--
187	2013-05-06	1.51	2.89	2	32.6	777	101	1.69	50	-0.172	-1.51	--
188	2013-05-09	1.56	2.67	2.05	36.4	470	113	1.47	30.7	0.0872	0.922	--
189	2013-05-15	1.8	2.78	1.51	62.8	596	32	1.63	44.3	0.165	1.58	--
190	2013-05-21	1.66	2.65	1.7	46	447	50	1.49	32.1	0.17	1.67	--
191	2013-05-28	1.82	2.85	1.18	66.2	714	15.2	1.74	57.1	0.0775	0.823	--
192	2013-06-05	1.49	2.69	2.06	31	492	116	1.49	32	7.97e-05	-0.141	--
193	2013-06-05	1.49	2.69	2.06	31.2	491	116	1.49	31.9	0.00353	-0.0621	--
194	2013-06-13	1.75	2.96	1.49	56.3	915	30.7	1.81	66.7	-0.0601	-0.674	--
195	2013-06-24	1.62	3.14	1.36	41.9	1390	22.7	2	103	-0.375	-2.78	--
196	2013-07-09	1.71	2.86	0.519	51.1	721	3.3	1.82	68.5	-0.114	-1.11	--
197	2013-07-25	1.56	2.72	1.43	36	522	27.1	1.59	39.8	-0.0304	-0.4	--
198	2013-08-07	0.398	2.02	4.14	2.5	104	13800	0.622	4.32	-0.224	-1.71	< 5
199	2013-08-15	0.508	2.13	3.85	3.22	136	7070	0.764	5.99	-0.256	-2.04	--
200	2013-08-29	1.68	2.82	2.26	47.6	664	183	1.59	40.3	0.0857	0.905	--
201	2013-10-24	1.87	2.94	1.48	73.6	878	30	1.79	64.3	0.0723	0.746	--
202	2013-10-30	1.63	2.6	2.19	43	402	155	1.39	25.6	0.239	2.04	--
203	2013-11-25	1.86	2.94	1.57	72.1	863	37.3	1.78	61.7	0.0811	0.872	--
204	2013-12-11	1.92	3.03	1.59	83.6	1060	39	1.86	74.6	0.0632	0.717	--
205	2014-01-14	1.93	3.03	1.65	84.5	1060	45	1.85	73.4	0.0749	0.777	--
206	2014-02-20	1.94	3.02	1.69	86.8	1040	49	1.84	71.4	0.0985	1.07	--
207	2014-03-17	1.94	3	1.57	87.7	997	37	1.84	70.8	0.107	1.15	--
208	2014-04-09	1.85	3	1.48	71	990	30.5	1.84	71.9	0.0081	-0.0282	--
209	2014-04-14	1.87	2.99	1.5	73.4	966	31.3	1.83	70	0.0339	0.363	--
210	2014-05-14	1.69	2.77	1.98	49	584	95.6	1.57	38.4	0.12	1.27	--
211	2014-05-15	1.74	2.9	1.96	55.2	787	91.5	1.7	51.2	0.0466	0.525	--
212	2014-05-29	1.68	2.95	1.84	47.9	882	68.7	1.76	58.8	-0.0757	-0.839	--
213	2014-06-03	1.73	2.8	1.71	54	625	50.8	1.63	44	0.102	1.13	--
214	2014-06-05	1.5	2.84	2.15	31.4	695	141	1.62	43.4	-0.127	-1.25	--
215	2014-06-09	1.15	2.36	3.17	14	228	1470	1.05	11.6	0.0939	0.994	--
216	2014-06-12	0.736	2.2	3.59	5.44	158	3880	0.855	7.38	-0.119	-1.18	--
217	2014-06-24	1.63	2.76	2.44	43.1	571	278	1.51	33.4	0.125	1.3	--
218	2014-07-10	1.72	2.82	1.95	52	664	88.3	1.63	43.7	0.0888	0.94	--
219	2014-07-15	1.76	2.88	1.66	57	757	46	1.71	53.3	0.0427	0.499	--
220	2014-07-24	1.8	2.89	1.45	63.7	782	28	1.75	58.1	0.0535	0.605	--
221	2014-08-04	1.82	2.91	1.33	66.4	822	21.3	1.78	62.8	0.0381	0.449	--
222	2014-08-07	1.82	2.89	1.3	65.7	781	20	1.77	60.3	0.0511	0.564	--

Definitions

SO4: Sulfate in mg/l (00945)

SC: Specific conductance in uS/cm @25C (00095)

Q: Stream flow, mean. daily in ft3/s (00060)

Model Archive Summary for Total Organic Nitrogen at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the total organic nitrogen (TKN) model developed to compute hourly TKN from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: July 27, 2004 to September 3, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 123 concurrent measurements of total organic nitrogen, streamflow, and turbidity collected from July 27, 2004 through September 3, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. There were no samples below laboratory reporting levels. Summary statistics and the complete model-calibration dataset are provided below. Studentized residuals from the final model are inspected for values greater than 3 or less than negative 3. Values outside of that range were considered potential outliers and are investigated. A sample collected October 25, 2013 was deemed an outlier and removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating total organic nitrogen. A variety of models that predict TKN and models that predict $\log_{10}(\text{TKN})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted TKN were examined for homoscedasticity (meaning that their departures from zero did not change substantially over

the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{TKN})$.

Turbidity and the day of the year were selected as the best predictors of TKN based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for total organic nitrogen at site number 07144100.

Total organic nitrogen-based model:

$$\log_{10}(\text{TKN}) = 0.387 \times \log_{10}(\text{TURB}) + 0.077 \times \sin\left(\frac{2\pi D}{365}\right) + 0.0326 \times \cos\left(\frac{2\pi D}{365}\right) - 0.541$$

where

TKN = total organic nitrogen in milligrams per liter (mg/L);

TURB = Turbidity, YSI model 6136, in formazin nephelometric units (FNU); and,

D = day of the year.

Turbidity and the day of the year make physical and statistical sense as explanatory variables for total organic nitrogen. Turbidity makes sense physically because suspended solids (including some with attached TKN) in the water column scatter light and increase turbidity. Day of the year makes physical sense as TKN concentrations vary seasonally. The relation between turbidity, day, and TKN makes statistical sense as the resulting model has the lowest standard error, Mallows' C_p and $PRESS$ value, and highest R^2 value.

The log-transformed model may be retransformed to the original units so that TKN can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.02. The retransformed model, accounting for BCF is:

$$\text{TKN} = 0.293 \times \text{TURB}^{0.367} \times 10^{0.077 \times \sin\left(\frac{2\pi D}{365}\right) + 0.0326 \times \cos\left(\frac{2\pi D}{365}\right)}.$$

Previous models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\text{TKN} = 0.00232 \times \text{TURB} + 0.863$
2.0	2007	--	$\log_{10}(\text{TKN}) = 0.387 \times \log_{10}(\text{TURB}) + 0.077 \times \sin\left(\frac{2\pi D}{365}\right) + 0.0326 \times \cos\left(\frac{2\pi D}{365}\right) - 0.541$

Total organic nitrogen Record

The TKN record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick
Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

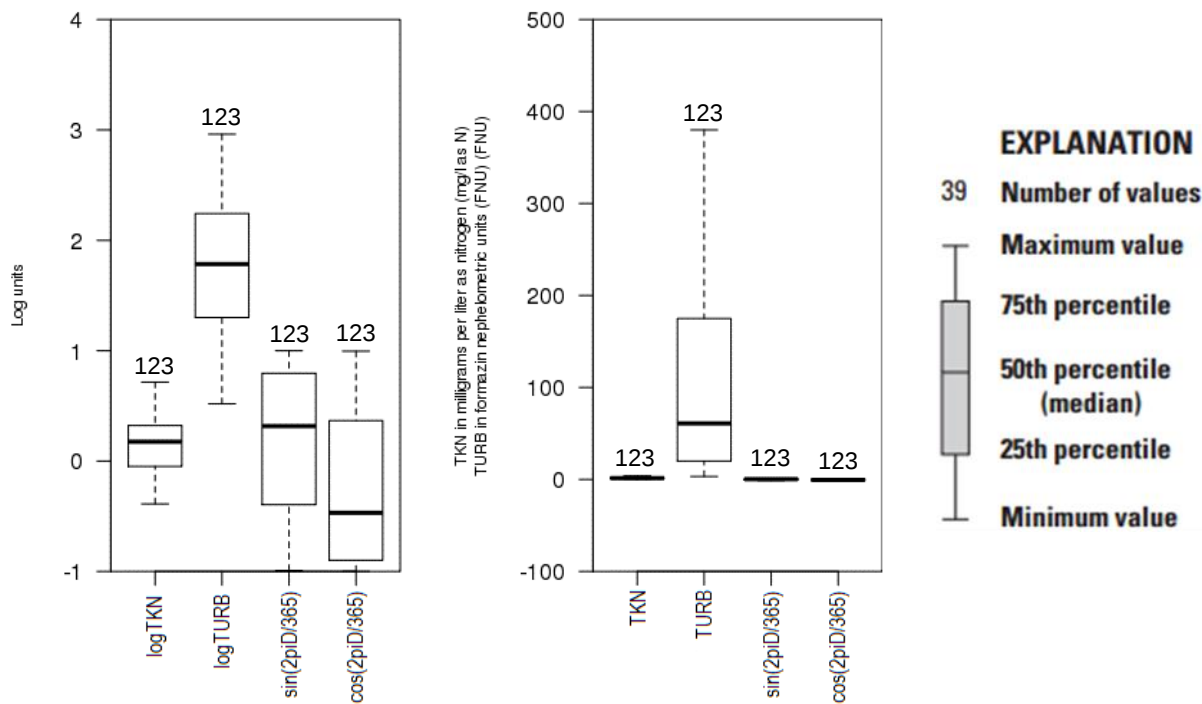
Model

$$\log\text{TKN} = + 0.387 * \log\text{TURB} + 0.077 * \sin(2\pi\text{D}/365) + 0.0326 * \cos(2\pi\text{D}/365) + -0.541$$

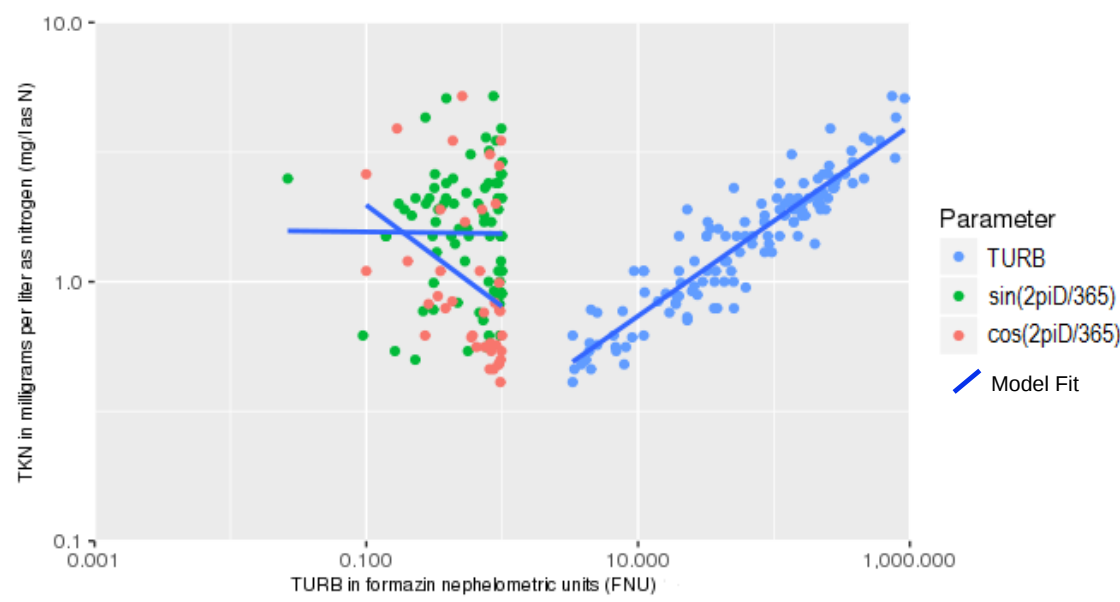
Variable Summary Statistics

	logTKN	logTURB	sin(2piD/365)	cos(2piD/365)	TKN	TURB
Minimum	-0.3870	0.519	-0.992	-1.000	0.41	3.3
1st Quartile	-0.0506	1.300	-0.422	-0.901	0.89	20.0
Median	0.1760	1.790	0.317	-0.468	1.50	61.0
Mean	0.1420	1.750	0.194	-0.245	1.62	131.0
3rd Quartile	0.3220	2.260	0.797	0.382	2.10	180.0
Maximum	0.7160	2.960	1.000	0.996	5.20	915.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	123	
Standard error (RMSE)	0.0797	
Upper Model standard percentage error (MSPE)	20.1	
Lower Model standard percentage error (MSPE)	16.8	
Coefficient of determination (R ²)	0.9	
Adjusted Coefficient of Determination (Adj. R ²)	0.898	
Bias Correction Factor (BCF)	1.02	
Variance Inflation Factors (VIF)		
logTURB	sin(2piD/365)	cos(2piD/365)
1.433417	1.000032	1.433455

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-0.5410	0.0237	-22.80	2.93e-45
logTURB	0.3870	0.0137	28.10	1.97e-54
sin(2piD/365)	0.0770	0.0111	6.92	2.43e-10
cos(2piD/365)	0.0326	0.0124	2.64	9.35e-03

Correlation Matrix

	Intercept	logTURB	sin(2piD/365)	cos(2piD/365)
Intercept	1.0000	-0.9430	-0.0899	-0.4290
logTURB	-0.9430	1.0000	-0.0018	0.5500
sin(2piD/365)	-0.0899	-0.0018	1.0000	-0.0055
cos(2piD/365)	-0.4290	0.5500	-0.0055	1.0000

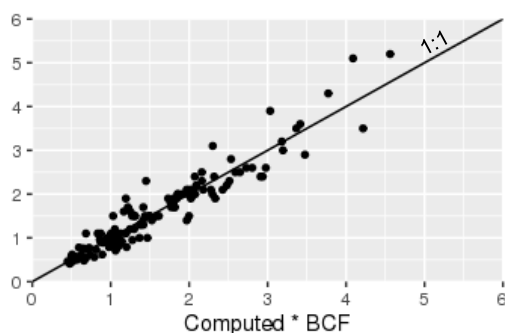
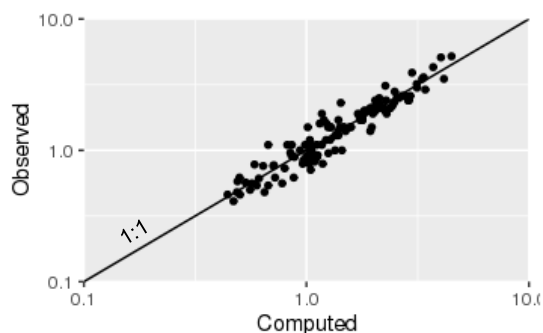
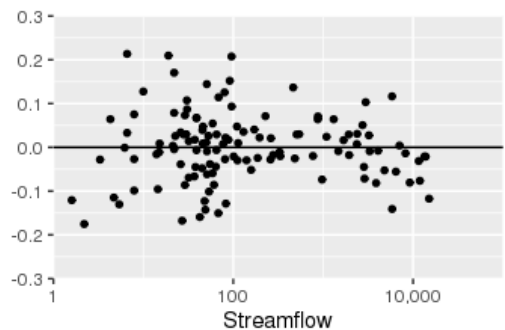
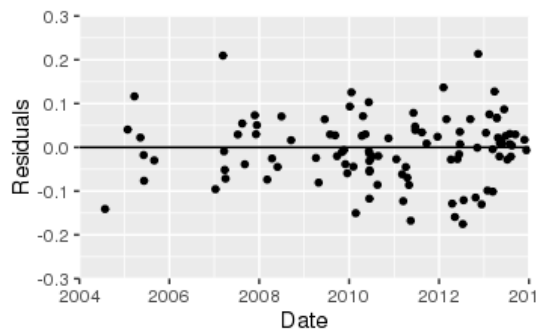
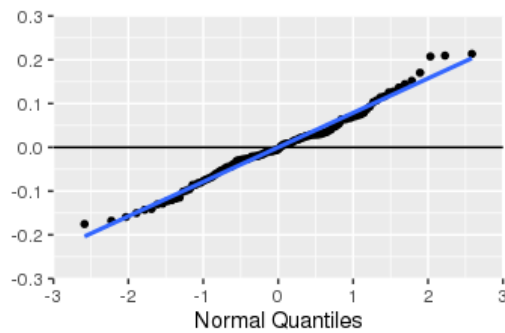
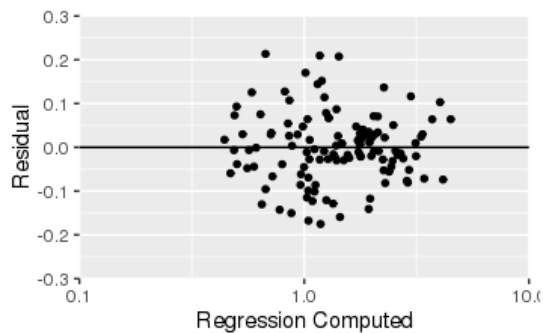
Outlier Test Criteria

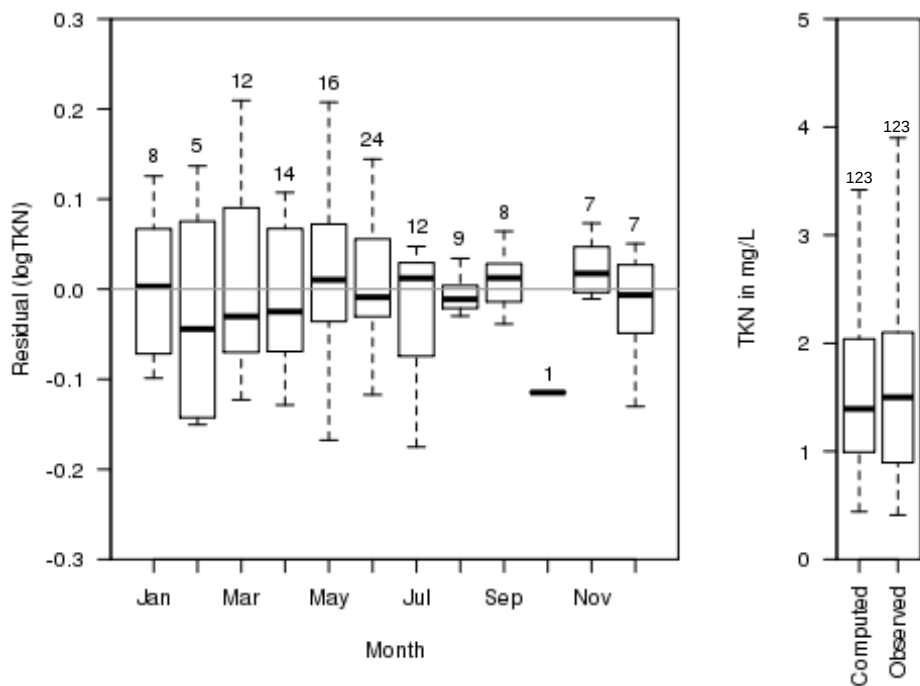
Leverage Cook's D DFFITS
0.07317073 0.26488137 0.31234752

Flagged Observations

	logTKN	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
3/23/2005 10:20	0.59110	0.474600	0.11650	1.4960	1.5040	0.04564	0.026750	0.32880
3/12/2007 12:05	0.27880	0.069230	0.20950	2.6620	2.7330	0.02499	0.045410	0.43760
12/13/2007 10:15	0.44720	0.396500	0.05067	0.6641	0.6625	0.08357	0.010050	0.20010
3/6/2008 10:35	0.54410	0.617700	-0.07367	-0.9640	-0.9637	0.08090	0.020450	-0.28590
9/24/2009 11:15	0.47710	0.497300	-0.02016	-0.2636	-0.2625	0.07897	0.001489	-0.07688
1/19/2010 10:00	-0.10790	-0.233500	0.12560	1.6080	1.6180	0.03989	0.026840	0.32990
2/23/2010 12:55	-0.20760	-0.057210	-0.15040	-1.9150	-1.9370	0.02967	0.028050	-0.33880
5/16/2011 11:30	-0.14870	0.018940	-0.16770	-2.1340	-2.1660	0.02792	0.032690	-0.36720
12/20/2011 11:15	0.54410	0.519900	0.02418	0.3213	0.3201	0.10850	0.003140	0.11160
2/6/2012 10:15	0.49140	0.354600	0.13680	1.7640	1.7800	0.05398	0.044390	0.42520
3/1/2012 12:00	0.71600	0.651900	0.06412	0.8444	0.8433	0.09241	0.018150	0.26910
7/12/2012 10:15	-0.10240	0.072860	-0.17520	-2.2260	-2.2640	0.02486	0.031590	-0.36160
11/14/2012 9:20	0.04139	-0.172100	0.21350	2.7360	2.8140	0.04119	0.080380	0.58330
12/12/2012 10:00	-0.31880	-0.188500	-0.13020	-1.6670	-1.6800	0.03935	0.028460	-0.34000
2/20/2014 10:10	-0.25180	-0.109200	-0.14270	-1.8190	-1.8370	0.03238	0.027690	-0.33610
5/8/2014 11:00	0.17610	0.005701	0.17040	2.1690	2.2040	0.02880	0.034870	0.37950
5/14/2014 13:20	0.36170	0.154200	0.20750	2.6290	2.6970	0.01897	0.033410	0.37510

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logTKN ~ logTURB	1	0.09561	85.43	85.31	55	1.14	<NA>	± 22
logTKN ~ TURB	1	0.1615	58.44	58.09	377.3	3.329	<NA>	± 38
logTKN ~ SC	1	0.1807	47.93	47.5	502.8	4.1	<NA>	± 43
logTKN ~ logTURB + sin(2piD/365)	2	0.08168	89.45	89.28	8.922	0.8384	1	± 19
logTKN ~ logTURB + logSC	2	0.0928	86.39	86.16	45.55	1.074	2.213	± 22
logTKN ~ logTURB + SC	2	0.09358	86.16	85.93	48.3	1.101	2.827	± 22
logTKN ~ logTURB + sin(2piD/365) + cos(2piD/365)	3	0.07971	90.04	89.79	3.945	0.805	1.433	± 18
logTKN ~ Q + logTURB + sin(2piD/365)	3	0.08024	89.91	89.65	5.537	0.8085	1.197	± 19
logTKN ~ TURB + logTURB + sin(2piD/365)	3	0.08078	89.77	89.51	7.165	0.8201	2.664	± 19
logTKN ~ Q + logTURB + sin(2piD/365) + cos(2piD/365)	4	0.07859	90.4	90.07	1.656	0.7828	1.208	± 18
logTKN ~ logTURB + logSC + sin(2piD/365) + cos(2piD/365)	4	0.07918	90.25	89.92	3.362	0.7953	2.789	± 18
logTKN ~ TURB + Q + logTURB + sin(2piD/365)	4	0.07945	90.19	89.85	4.175	0.7939	2.669	± 18
logTKN ~ Q + logTURB + sin(2piD/365) + cos(2piD/365) + sin(4piD/365)	5	0.07845	90.52	90.11	2.256	0.7905	1.209	± 18
logTKN ~ TURB + Q + logTURB + sin(2piD/365) + cos(2piD/365)	5	0.07869	90.46	90.05	2.959	0.7893	3.341	± 18
logTKN ~ Q + logTURB + sin(2piD/365) + cos(2piD/365) + cos(4piD/365)	5	0.07886	90.42	90.01	3.446	0.7916	1.25	± 18
logTKN ~ TURB + Q + logTURB + sin(2piD/365) + cos(2piD/365) + sin(4piD/365)	6	0.07857	90.57	90.08	3.642	0.7976	3.347	± 18
logTKN ~ Q + logTURB + logQ + sin(2piD/365) + cos(2piD/365) + sin(4piD/365)	6	0.07872	90.53	90.04	4.081	0.862	1.228	± 18
logTKN ~ Q + logTURB + SC + sin(2piD/365) + cos(2piD/365) + sin(4piD/365)	6	0.07874	90.52	90.03	4.146	0.8029	1.803	± 18

Model-Calibration Data Set

	Date	logTKN	logTURB	sin(2piD/365)	cos(2piD/365)	TKN	TURB	Computed logTKN	Computed TKN	Residual	Normal Quantiles	Censored Values
0												
1	2004-07-27	0.1461	2.301	-0.4218	-0.9067	1.4	200	0.287	1.969	-0.141	-1.69	--
2	2005-01-27	0.301	1.908	0.4401	0.898	2	81	0.2604	1.852	0.0406	0.705	--
3	2005-03-23	0.5911	2.415	0.9857	0.1682	3.9	260	0.4746	3.032	0.116	1.42	--
4	2005-05-10	0.3802	2.217	0.7924	-0.6099	2.4	165	0.3579	2.318	0.0223	0.332	--
5	2005-06-06	0.3979	2.462	0.4345	-0.9007	2.5	290	0.4156	2.647	-0.0177	-0.247	--
6	2005-06-09	0.3802	2.58	0.387	-0.9221	2.4	380	0.4567	2.91	-0.0765	-0.998	--
7	2005-08-31	0.1139	1.985	-0.8582	-0.5133	1.3	96.5	0.1438	1.416	-0.0298	-0.533	--
8	2007-01-10	-0.2676	0.8388	0.1624	0.9867	0.54	6.9	-0.1719	0.6843	-0.0957	-1.18	--
9	2007-03-12	0.2788	1.362	0.9367	0.3503	1.9	23	0.06923	1.192	0.21	2.23	--
10	2007-03-21	0.07918	1.415	0.9795	0.2015	1.2	26	0.08827	1.246	-0.00909	-0.122	--
11	2007-03-27	0.415	2.398	0.995	0.09971	2.6	250	0.4665	2.976	-0.0515	-0.732	--

12	2007-04-02	0.4624	2.58	1	-0.003467	2.9	380	0.5339	3.476	-0.0715	-0.933	--
13	2007-07-11	0.3424	2.322	-0.1537	-0.9881	2.2	210	0.3132	2.091	0.0292	0.441	--
14	2007-08-16	-0.01773	1.412	-0.6976	-0.7165	0.96	25.8	-0.07216	0.861	0.0544	0.814	--
15	2007-09-06	-0.1367	1.362	-0.906	-0.4233	0.73	23	-0.09794	0.8114	-0.0387	-0.605	--
16	2007-11-26	-0.2366	0.6435	-0.5746	0.8185	0.58	4.4	-0.3098	0.4982	0.0732	1.07	--
17	2007-12-06	-0.2441	0.699	-0.4252	0.9051	0.57	5	-0.274	0.541	0.0299	0.533	--
18	2007-12-13	0.4472	2.406	-0.3143	0.9493	2.8	254.7	0.3965	2.533	0.0507	0.786	--
19	2008-03-06	0.5441	2.779	0.9016	0.4326	3.5	601.7	0.6177	4.216	-0.0737	-0.965	--
20	2008-04-14	0.415	2.362	0.9753	-0.2208	2.6	230	0.4405	2.803	-0.0255	-0.397	--
21	2008-05-29	0.3424	2.362	0.5446	-0.8387	2.2	230	0.3872	2.479	-0.0447	-0.654	--
22	2008-06-30	0.3979	2.324	0.0264	-0.9997	2.5	210.8	0.3274	2.16	0.0706	0.998	--
23	2008-09-16	0.2553	2.23	-0.9667	-0.2558	1.8	170	0.239	1.763	0.0163	0.226	--
24	2009-04-06	0.1761	1.724	0.9973	-0.07315	1.5	53	0.2004	1.613	-0.0243	-0.375	--
25	2009-04-28	0.3802	2.447	0.9005	-0.4348	2.4	280	0.4608	2.938	-0.0806	-1.03	--
26	2009-06-16	0.6335	2.898	0.2721	-0.9623	4.3	790	0.5695	3.773	0.064	0.843	--
27	2009-07-30	0.3222	2.322	-0.462	-0.8869	2.1	210	0.2928	1.995	0.0295	0.51	--
28	2009-09-09	0.301	2.322	-0.9273	-0.3744	2	210	0.2737	1.909	0.0274	0.419	--
29	2009-09-24	0.4771	2.892	-0.9921	-0.1257	3	780	0.4973	3.195	-0.0202	-0.289	--
30	2009-11-03	0.2304	2.146	-0.8463	0.5328	1.7	140	0.2414	1.772	-0.0109	-0.143	--
31	2009-11-19	-0.2518	0.8346	-0.6682	0.7439	0.56	6.833	-0.2455	0.5777	-0.00634	-0.0203	--
32	2009-12-01	-0.3372	0.6532	-0.5008	0.8655	0.46	4.5	-0.2988	0.5109	-0.0384	-0.58	--
33	2009-12-17	-0.3872	0.5185	-0.247	0.969	0.41	3.3	-0.328	0.4777	-0.0592	-0.814	--
34	2010-01-06	-0.2076	0.5185	0.09442	0.9955	0.62	3.3	-0.3008	0.5086	0.0932	1.22	--
35	2010-01-19	-0.1079	0.6532	0.3117	0.9502	0.78	4.5	-0.2335	0.5939	0.126	1.48	--
36	2010-02-04	-0.2676	0.6402	0.5588	0.8293	0.54	4.367	-0.2234	0.6078	-0.0442	-0.629	--
37	2010-02-23	-0.2076	1.041	0.7966	0.6045	0.62	11	-0.05721	0.8912	-0.15	-1.89	--
38	2010-04-14	-0.04096	1.048	0.9784	-0.2066	0.91	11.17	-0.06715	0.871	0.0262	0.397	--
39	2010-04-23	0.3802	2.041	0.9346	-0.3557	2.4	110	0.309	2.071	0.0712	1.03	--
40	2010-05-13	0.5563	2.663	0.7596	-0.6504	3.6	460	0.5263	3.416	0.03	0.556	--
41	2010-06-09	0.7076	2.961	0.3878	-0.9217	5.1	915	0.6044	4.089	0.103	1.27	--
42	2010-06-10	0.301	2.204	0.3723	-0.9281	2	160	0.31	2.076	-0.00894	-0.102	--
43	2010-06-13	0.415	2.523	0.3197	-0.9475	2.6	333.3	0.4286	2.728	-0.0137	-0.184	--
44	2010-06-14	0.3617	2.431	0.317	-0.9484	2.3	270	0.393	2.513	-0.0313	-0.556	--
45	2010-06-14	0.1761	2.176	0.3072	-0.9516	1.5	150	0.2933	1.998	-0.117	-1.37	--
46	2010-06-15	0.3222	2.398	0.291	-0.9567	2.1	250	0.3778	2.426	-0.0556	-0.786	--
47	2010-06-16	0.301	2.339	0.2746	-0.9616	2	218.3	0.3536	2.295	-0.0526	-0.759	--
48	2010-07-06	0.2304	2.146	-0.06594	-0.9978	1.7	140	0.2515	1.814	-0.0211	-0.332	--
49	2010-08-19	-0.1024	1.559	-0.7351	-0.678	0.79	36.25	-0.01664	0.9785	-0.0857	-1.1	--
50	2010-08-25	0.2788	2.38	-0.8005	-0.5993	1.9	240	0.2985	2.022	-0.0198	-0.268	--
51	2010-11-16	0.2788	2.146	-0.7054	0.7088	1.9	140	0.258	1.841	0.0208	0.289	--
52	2011-01-19	-0.004365	1.315	0.3129	0.9498	0.99	20.67	0.02278	1.071	-0.0271	-0.441	--
53	2011-03-07	-0.07572	1.146	0.9033	0.4291	0.84	14	-0.01419	0.984	-0.0615	-0.843	--
54	2011-03-16	-0.08619	1.279	0.9579	0.2871	0.82	19	0.0367	1.106	-0.123	-1.48	--
55	2011-04-06	-0.04576	1.204	0.9975	-0.07059	0.9	16	-0.0008062	1.015	-0.045	-0.68	--
56	2011-04-18	-0.05061	1.279	0.9612	-0.2759	0.89	19	0.01857	1.061	-0.0692	-0.902	--
57	2011-05-02	-0.03621	1.396	0.8689	-0.4951	0.92	24.92	0.04986	1.14	-0.0861	-1.14	--
58	2011-05-16	-0.1487	1.362	0.7244	-0.6894	0.71	23	0.01894	1.062	-0.168	-2.23	--
59	2011-06-07	0.1761	1.643	0.4201	-0.9075	1.5	44	0.0974	1.272	0.0787	1.14	--
60	2011-06-21	0.2788	2.041	0.1903	-0.9817	1.9	110	0.2312	1.732	0.0475	0.759	--
61	2011-06-22	0.301	2.124	0.1732	-0.9849	2	133	0.2617	1.857	0.0393	0.68	--
62	2011-08-15	0.3617	2.443	-0.6859	-0.7277	2.3	277.5	0.3276	2.161	0.0342	0.629	--
63	2011-09-22	0.1761	2.041	-0.987	-0.1609	1.5	110	0.1674	1.495	0.00872	0.122	--
64	2011-12-20	0.5441	2.699	-0.1972	0.9804	3.5	500	0.5199	3.366	0.0242	0.353	--
65	2012-02-06	0.4914	2.13	0.5854	0.8108	3.1	135	0.3546	2.3	0.137	1.61	--
66	2012-03-01	0.716	2.869	0.8617	0.5074	5.2	740	0.6519	4.561	0.0641	0.872	--
67	2012-04-07	0.3222	2.114	0.9949	-0.101	2.1	130	0.35	2.276	-0.0278	-0.464	--
68	2012-04-17	0	1.562	0.9629	-0.2697	1	36.5	0.1286	1.367	-0.129	-1.54	--
69	2012-05-09	0	1.703	0.7949	-0.6068	1	50.5	0.1592	1.467	-0.159	-2.03	--
70	2012-05-30	0.07918	1.638	0.5318	-0.8469	1.2	43.5	0.1061	1.298	-0.0269	-0.419	--
71	2012-06-12	0.1139	1.748	0.3292	-0.9443	1.3	56	0.1297	1.371	-0.0158	-0.205	--
72	2012-06-18	0.3222	2.176	0.2302	-0.9731	2.1	150	0.2867	1.967	0.0355	0.654	--
73	2012-06-19	0.2553	2.079	0.2157	-0.9765	1.8	120	0.248	1.8	0.00727	0.0815	--
74	2012-07-12	-0.1024	1.705	-0.1773	-0.9841	0.79	50.75	0.07286	1.202	-0.175	-2.58	--
75	2012-07-19	-0.02228	1.792	-0.294	-0.9558	0.95	62	0.09844	1.275	-0.121	-1.42	--
76	2012-09-11	0.07918	1.653	-0.941	-0.3385	1.2	45	0.01492	1.052	0.0643	0.902	--
77	2012-10-24	-0.1024	1.583	-0.924	0.3824	0.79	38.25	0.01244	1.046	-0.115	-1.32	--
78	2012-11-07	-0.2147	0.9566	-0.8053	0.5928	0.61	9.05	-0.2138	0.6215	-0.000917	0.0203	--
79	2012-11-14	0.04139	1.041	-0.7293	0.6842	1.1	11	-0.1721	0.684	0.214	2.58	--
80	2012-12-12	-0.3188	0.8976	-0.3299	0.944	0.48	7.9	-0.1885	0.6587	-0.13	-1.61	--
81	2013-01-16	-0.1135	0.8865	0.2619	0.9651	0.77	7.7	-0.1466	0.7255	0.033	0.605	--
82	2013-01-29	-0.08092	1.277	0.4699	0.8827	0.83	18.92	0.01782	1.059	-0.0987	-1.22	--
83	2013-02-13	-0.1192	0.699	0.6795	0.7337	0.76	5	-0.1945	0.6497	0.0753	1.1	--

84	2013-03-12	0.04139	1.301	0.9364	0.351	1.1	20	0.04574	1.13	-0.00435	0	--
85	2013-03-13	-0.05552	1.301	0.9419	0.336	0.88	20	0.04568	1.129	-0.101	-1.27	--
86	2013-03-27	0.04139	0.9696	0.995	0.09983	1.1	9.325	-0.08616	0.8337	0.128	1.54	--
87	2013-04-15	0.1761	1.505	0.9747	-0.2233	1.5	32	0.1089	1.307	0.0672	0.933	--
88	2013-04-15	0.1761	1.505	0.9747	-0.2234	1.5	32	0.1089	1.307	0.0672	0.965	--
89	2013-04-24	0.3222	2.021	0.9285	-0.3714	2.1	105	0.3002	2.03	0.022	0.31	--
90	2013-05-06	0.2304	1.929	0.832	-0.5548	1.7	85	0.2513	1.813	-0.0208	-0.31	--
91	2013-05-09	0.5051	2.57	0.801	-0.5987	3.2	371.7	0.4954	3.181	0.00977	0.163	--
92	2013-05-15	0.2553	1.932	0.7373	-0.6756	1.8	85.5	0.241	1.771	0.0142	0.205	--
93	2013-05-21	0.301	2.079	0.6638	-0.7479	2	120	0.29	1.982	0.0111	0.184	--
94	2013-05-28	0.1761	1.788	0.568	-0.823	1.5	61.33	0.1674	1.495	0.00874	0.143	--
95	2013-06-13	0.2304	1.785	0.3238	-0.9461	1.7	61	0.1436	1.415	0.0868	1.18	--
96	2013-06-24	0.1761	1.843	0.1396	-0.9902	1.5	69.67	0.1503	1.437	0.0258	0.375	--
97	2013-07-09	0.04139	1.685	-0.1177	-0.993	1.1	48.45	0.06937	1.193	-0.028	-0.486	--
98	2013-07-29	0.2788	2.204	-0.4466	-0.8947	1.9	160	0.248	1.8	0.0308	0.58	--
99	2013-07-29	0.2553	2.204	-0.4467	-0.8947	1.8	160	0.248	1.8	0.00728	0.102	--
100	2013-08-07	0.1139	1.932	-0.5789	-0.8154	1.3	85.5	0.1351	1.388	-0.0211	-0.353	--
101	2013-08-15	0.1461	1.964	-0.6851	-0.7285	1.4	92	0.1421	1.41	0.00406	0.0611	--
102	2013-09-12	-0.1192	1.23	-0.9446	-0.3282	0.76	17	-0.1486	0.7221	0.0294	0.486	--
103	2013-11-25	-0.3372	0.5315	-0.5894	0.8078	0.46	3.4	-0.3546	0.4493	0.0174	0.268	--
104	2013-12-11	-0.3188	0.5817	-0.3462	0.9382	0.48	3.817	-0.3122	0.4954	-0.00656	-0.0407	--
105	2014-01-14	-0.301	0.6163	0.2291	0.9734	0.5	4.133	-0.2533	0.5673	-0.0477	-0.705	--
106	2014-02-20	-0.2518	0.9103	0.763	0.6464	0.56	8.133	-0.1092	0.7907	-0.143	-1.78	--
107	2014-03-17	-0.2076	0.8195	0.9627	0.2706	0.62	6.6	-0.1412	0.7346	-0.0665	-0.872	--
108	2014-04-09	0.04139	1.041	0.9923	-0.1241	1.1	11	-0.06592	0.8735	0.107	1.32	--
109	2014-05-08	0.1761	1.301	0.8124	-0.5831	1.5	20	0.005701	1.03	0.17	1.89	--
110	2014-05-14	0.3617	1.705	0.7468	-0.665	2.3	50.67	0.1542	1.45	0.208	2.03	--
111	2014-05-15	0.2304	1.512	0.7366	-0.6763	1.7	32.5	0.07841	1.218	0.152	1.78	--
112	2014-05-29	0.2041	1.591	0.554	-0.8325	1.6	39	0.08989	1.25	0.114	1.37	--
113	2014-06-03	0.2041	1.531	0.4805	-0.877	1.6	34	0.05972	1.167	0.144	1.69	--
114	2014-06-05	0.1461	1.839	0.4497	-0.8932	1.4	69	0.1757	1.524	-0.0296	-0.51	--
115	2014-06-09	0.3222	2.255	0.3853	-0.9228	2.1	180	0.3309	2.178	-0.00873	-0.0815	--
116	2014-06-12	0.2788	2.342	0.3384	-0.941	1.9	220	0.3605	2.332	-0.0817	-1.07	--
117	2014-06-24	0.1761	1.954	0.1394	-0.9902	1.5	90	0.1933	1.587	-0.0172	-0.226	--
118	2014-07-10	0.04139	1.572	-0.1349	-0.9909	1.1	37.33	0.02432	1.075	0.0171	0.247	--
119	2014-07-15	0.04139	1.51	-0.2224	-0.975	1.1	32.33	-0.006064	1.003	0.0475	0.732	--
120	2014-07-24	0	1.475	-0.3672	-0.9302	1	29.83	-0.02927	0.9504	0.0293	0.464	--
121	2014-08-04	-0.05061	1.437	-0.5358	-0.8444	0.89	27.33	-0.05417	0.8975	0.00356	0.0407	--
122	2014-08-21	0	1.633	-0.756	-0.6545	1	43	0.0112	1.043	-0.0112	-0.163	--
123	2014-09-03	0.3979	2.663	-0.8837	-0.468	2.5	460	0.4057	2.588	-0.00778	-0.0611	--

Definitions

TKN: Kjeldahl nitrogen in mg/l as N (00625)

TURB: Turbidity in FNU (63680)

DY: Date in decimal years

Model Archive Summary for Total Phosphorus Concentration at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the total phosphorus concentration (TP) model developed to compute hourly TP from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: July 27, 2004 to September 3, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 120 concurrent measurements of Phosphorus concentration, streamflow, and turbidity collected from July 27, 2004 through September 3, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. No samples were below laboratory reporting levels. Summary statistics and the complete model-calibration dataset are provided below. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. Samples taken November 14, 2012; January 16, 2013; February 13, 2013; and March 27, 2013 were deemed outliers and were removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating phosphorus concentration. A variety of models that predict TP and models that predict $\log_{10}(\text{TP})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted TP were

examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(TP)$.

Turbidity was selected as the best predictor of TP based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for phosphorus concentration at site number 07144100.

Phosphorus concentration-based model:

$$\log_{10}(TP) = 0.2 \times \log_{10}(TURB) - 0.493,$$

where

TP = Phosphorus concentration in milligrams per liter (mg/L); and,

$TURB$ = Turbidity, YSI model 6136, in formazin nephelometric units (FNU).

Turbidity makes physical and statistical sense as an explanatory variable for total phosphorus. Turbidity makes sense physically because suspended solids (including some with attached TP) in the water column scatter light and increase turbidity. The relation between turbidity and TP makes statistical sense as the resulting model has the lowest standard error, Mallows' C_p and $PRESS$ values, and highest R^2 values.

The log-transformed model may be retransformed to the original units so that TP can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.03. The retransformed model, accounting for BCF is:

$$TP = 0.331 \times TURB^{0.2}.$$

Previous Model

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$TP = 0.000567 \times TURB + 0.3246$
2.0	2007	--	$\log_{10}(TP) = 0.2 \times \log_{10}(TURB) - 0.493$

Phosphorus Concentration Record

The TP record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick

Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

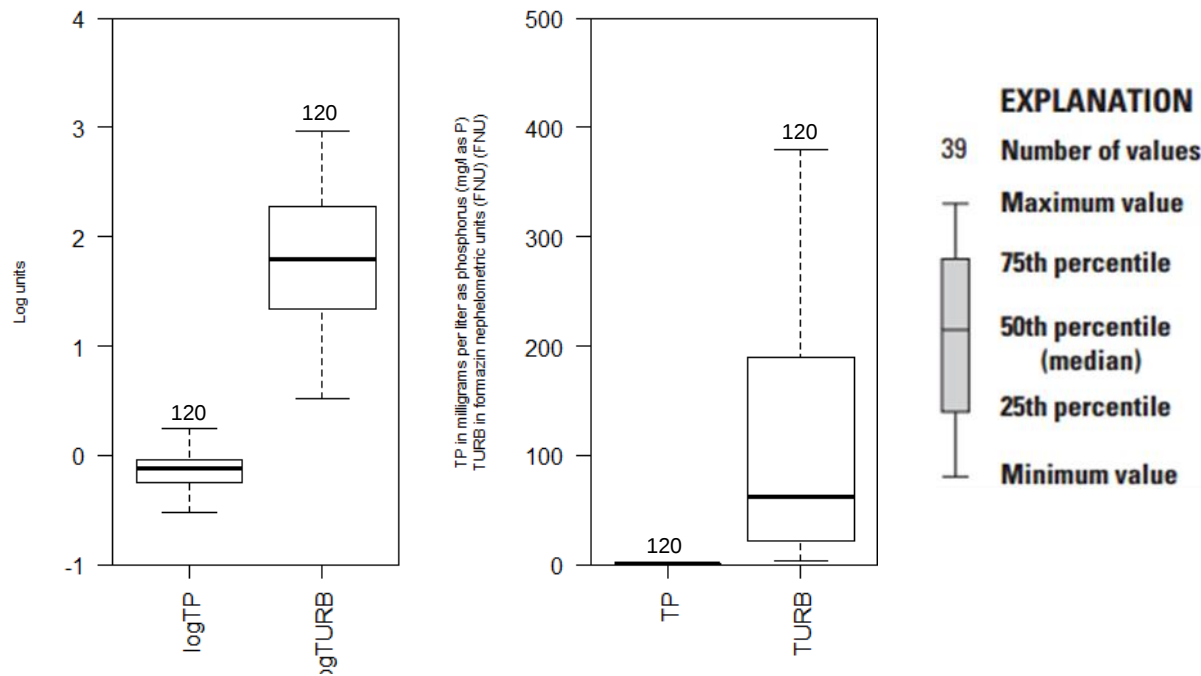
Model

$\log TP = + 0.2 * \log TURB + -0.493$

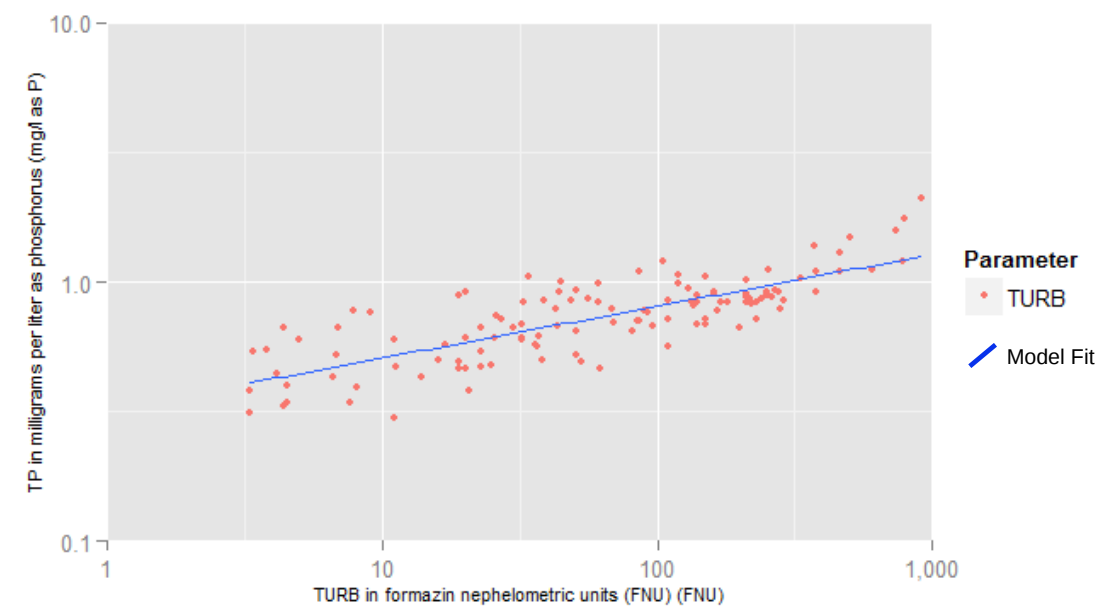
Variable Summary Statistics

	logTP	logTURB	TP	TURB
Minimum	-0.5230	0.519	0.300	3.3
1st Quartile	-0.2440	1.340	0.570	21.8
Median	-0.1160	1.790	0.765	61.7
Mean	-0.1390	1.770	0.774	134.0
3rd Quartile	-0.0434	2.280	0.905	190.0
Maximum	0.3240	2.960	2.110	915.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	120
Standard error (RMSE)	0.0982
Upper Model standard percentage error (MSPE)	25.4
Lower Model standard percentage error (MSPE)	20.2
Coefficient of determination (R ²)	0.617
Adjusted Coefficient of Determination (Adj. R ²)	0.614
Bias Correction Factor (BCF)	1.03

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-0.493	0.0272	-18.1	6.36e-36
logTURB	0.200	0.0145	13.8	2.41e-26

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.944
E.vars	-0.944	1.000

Outlier Test Criteria

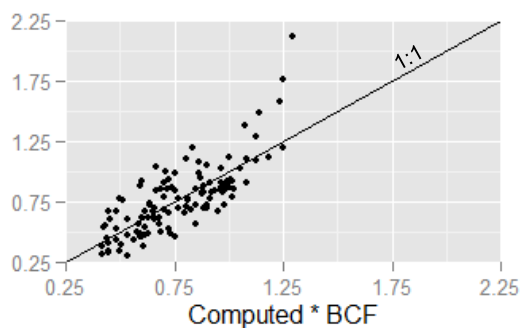
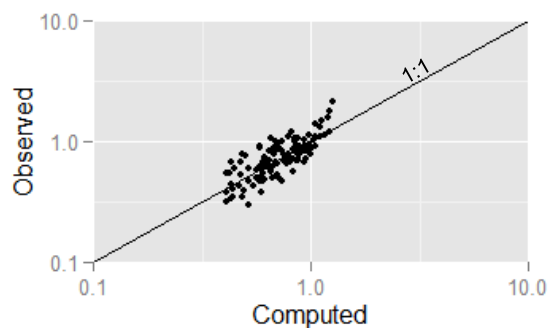
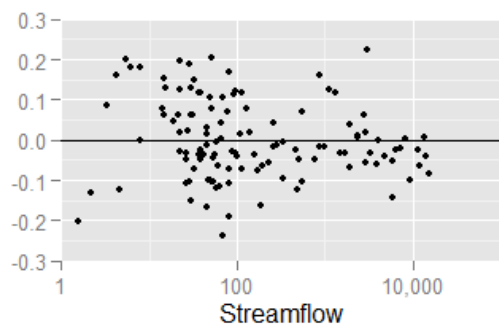
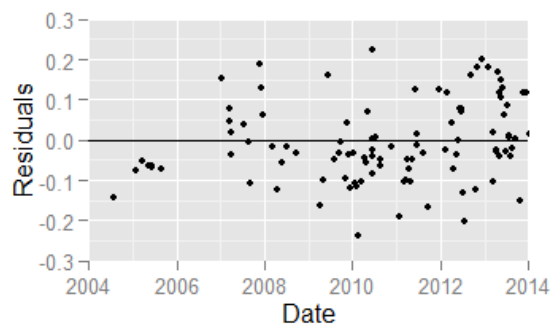
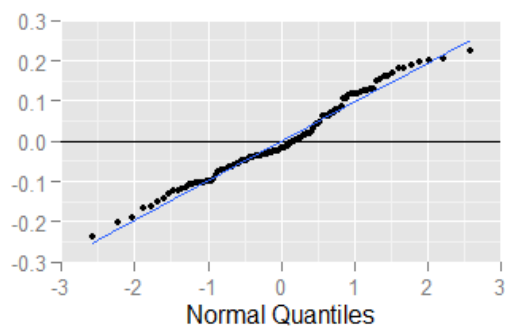
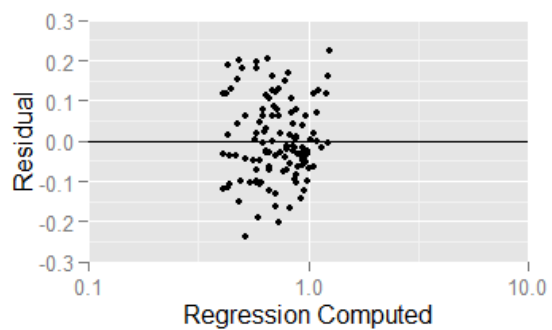
Leverage	Cook's D	DFFITS
0.0250000	0.1054539	0.1825742

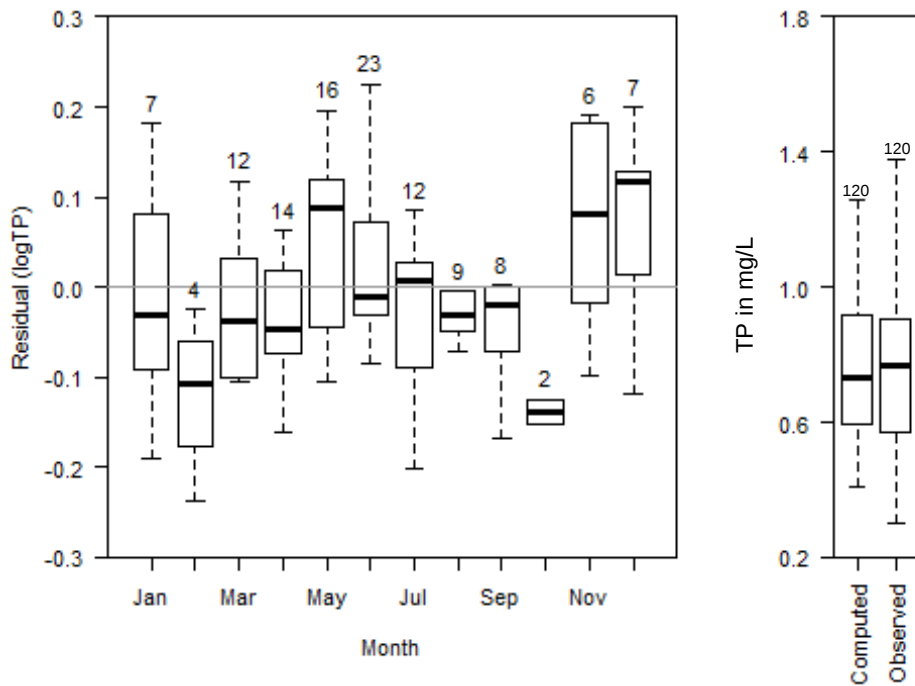
Flagged Observations

	logTP	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
1/10/2007 11:25	-0.17390	-0.32510	0.151200		1.56100		1.57100	0.027190	3.404e-02	0.26260
11/26/2007 10:40	-0.17390	-0.36410	0.190200		1.97300		1.99800	0.035940	7.254e-02	0.38570
12/6/2007 11:45	-0.22180	-0.35310	0.131200		1.35900		1.36400	0.033280	3.179e-02	0.25310

3/6/2008 10:35	0.04532	0.06260	-0.017270	-0.17870	-0.17790	0.030560	5.031e-04	-0.03159
6/16/2009 12:50	0.24550	0.08623	0.159300	1.65200	1.66400	0.036070	5.106e-02	0.32200
9/24/2009 11:15	0.07918	0.08512	-0.005941	-0.06161	-0.06135	0.035800	7.046e-05	-0.01182
11/19/2009 11:40	-0.28400	-0.32590	0.041950	0.43320	0.43170	0.027360	2.639e-03	0.07240
12/1/2009 12:40	-0.39790	-0.36220	-0.035740	-0.37060	-0.36930	0.035460	2.525e-03	-0.07080
12/17/2009 12:00	-0.50860	-0.38910	-0.119500	-1.24400	-1.24700	0.042410	3.426e-02	-0.26240
1/6/2010 11:50	-0.42020	-0.38910	-0.031110	-0.32370	-0.32250	0.042410	2.320e-03	-0.06786
1/19/2010 10:00	-0.46850	-0.36220	-0.106300	-1.10200	-1.10300	0.035460	2.234e-02	-0.21160
2/4/2010 10:40	-0.48150	-0.36480	-0.116700	-1.21000	-1.21300	0.036100	2.743e-02	-0.23470
2/23/2010 12:55	-0.52290	-0.28460	-0.238200	-2.45000	-2.50500	0.019870	6.087e-02	-0.35660
5/13/2010 10:15	0.11060	0.03930	0.071290	0.73550	0.73400	0.025720	7.141e-03	0.11930
6/9/2010 9:45	0.32430	0.09897	0.225300	2.34100	2.38700	0.039290	1.121e-01	0.48270
1/19/2011 11:40	-0.42020	-0.22990	-0.190300	-1.95000	-1.97400	0.012820	2.470e-02	-0.22500
12/20/2011 11:15	0.17320	0.04654	0.126600	1.30800	1.31200	0.027160	2.387e-02	0.21920
3/1/2012 12:00	0.19870	0.08055	0.118100	1.22400	1.22700	0.034690	2.692e-02	0.23250
7/19/2012 10:15	-0.33720	-0.13460	-0.202600	-2.07200	-2.10200	0.008345	1.807e-02	-0.19280
11/7/2012 11:10	-0.11920	-0.30160	0.182400	1.87900	1.89900	0.022720	4.102e-02	0.28960
12/12/2012 10:00	-0.11350	-0.31340	0.199900	2.06100	2.09000	0.024880	5.419e-02	0.33390
1/29/2013 10:05	-0.05552	-0.23760	0.182100	1.86700	1.88700	0.013610	2.405e-02	0.22170
5/9/2013 13:50	0.13990	0.02080	0.119100	1.22600	1.22900	0.022310	1.716e-02	0.18560
10/24/2013 9:20	-0.46850	-0.31630	-0.152200	-1.57000	-1.58000	0.025450	3.218e-02	-0.25530
11/25/2013 9:10	-0.26760	-0.38650	0.118900	1.23700	1.24000	0.041700	3.329e-02	0.25860
12/11/2013 11:10	-0.25960	-0.37650	0.116800	1.21400	1.21600	0.039050	2.994e-02	0.24520
1/14/2014 10:20	-0.35650	-0.36960	0.013020	0.13520	0.13460	0.037290	3.538e-04	0.02649
3/17/2014 9:00	-0.36650	-0.32900	-0.037570	-0.38800	-0.38660	0.027980	2.167e-03	-0.06559
5/8/2014 11:00	-0.03621	-0.23280	0.196600	2.01500	2.04200	0.013110	2.696e-02	0.23530
6/3/2014 10:10	0.01703	-0.18670	0.203800	2.08500	2.11500	0.009564	2.099e-02	0.20790
9/3/2014 12:00	0.03743	0.03930	-0.001875	-0.01935	-0.01926	0.025720	4.941e-06	-0.00313

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logTP ~ logTURB	1	0.0982	61.69	61.37	17.97	1.182	1 ± 23	
logTP ~ TURB	1	0.1113	50.82	50.4	56.01	1.511	1 ± 26	
logTP ~ SC	1	0.124	38.89	38.37	97.72	1.882	1 ± 29	
logTP ~ TURB + logTURB	2	0.09564	63.97	63.35	12	1.13	2.657 ± 22	
logTP ~ logTURB + logQ	2	0.09639	63.41	62.78	13.97	1.154	1.751 ± 22	
logTP ~ logTURB + Q	2	0.09751	62.55	61.91	16.97	1.162	1.182 ± 23	
logTP ~ TURB + logTURB + logQ	3	0.09285	66.33	65.46	5.737	1.081	2.71 ± 22	
logTP ~ TURB + logTURB + Q	3	0.09506	64.71	63.8	11.41	1.115	2.661 ± 22	
logTP ~ TURB + logTURB + logSC	3	0.09562	64.29	63.37	12.88	1.129	2.657 ± 22	
logTP ~ TURB + logTURB + logQ + SC	4	0.09154	67.56	66.43	3.453	1.066	2.766 ± 21	
logTP ~ TURB + logTURB + logQ + logSC	4	0.09226	67.05	65.9	5.25	1.085	2.76 ± 21	
logTP ~ TURB + logTURB + Q + logQ	4	0.09307	66.47	65.3	7.271	1.095	2.828 ± 22	
logTP ~ TURB + logTURB + logQ + SC + logSC	5	0.09189	67.59	66.17	5.338	1.081	2.768 ± 21	
logTP ~ TURB + logTURB + Q + logQ + SC	5	0.09192	67.57	66.15	5.408	1.081	2.854 ± 21	
logTP ~ TURB + logTURB + Q + logQ + logSC	5	0.09265	67.06	65.61	7.213	1.095	2.83 ± 22	
logTP ~ TURB + logTURB + Q + logQ + SC + logSC	6	0.09216	67.69	65.97	7	1.088	2.897 ± 21	

Model-Calibration Data Set

	Date	logTP	logTURB	TP	TURB	Computed logTP	Computed TP	Residual	Normal Quantiles	Censored Values
0										
1	2004-07-27	-0.1739	2.301	0.67	200	-0.03297	0.9509	-0.141	-1.6	--
2	2005-01-27	-0.1871	1.908	0.65	81	-0.1114	0.7938	-0.0757	-0.855	--
3	2005-03-23	-0.06048	2.415	0.87	260	-0.0102	1.002	-0.0503	-0.56	--
4	2005-05-10	-0.1135	2.217	0.77	165	-0.04966	0.9151	-0.0638	-0.713	--
5	2005-06-06	-0.07058	2.462	0.85	290	-0.0007292	1.024	-0.0699	-0.74	--
6	2005-06-09	-0.04096	2.58	0.91	380	0.02272	1.081	-0.0637	-0.686	--
7	2005-08-31	-0.1675	1.985	0.68	96.5	-0.09621	0.8221	-0.0713	-0.796	--

8	2007-01-10	-0.1739	0.8388	0.67	6.9	-0.3251	0.4853	0.151	1.35	--
9	2007-03-12	-0.1739	1.362	0.67	23	-0.2206	0.6173	0.0467	0.535	--
10	2007-03-21	-0.1308	1.415	0.74	26	-0.21	0.6326	0.0792	0.796	--
11	2007-03-27	-0.05061	2.398	0.89	250	-0.01361	0.9943	-0.037	-0.329	--
12	2007-04-02	0.04139	2.58	1.1	380	0.02272	1.081	0.0187	0.396	--
13	2007-07-11	0.0086	2.322	1.02	210	-0.02874	0.9602	0.0373	0.465	--
14	2007-08-16	-0.2147	1.412	0.61	25.8	-0.2107	0.6316	-0.004	0.136	--
15	2007-09-06	-0.3279	1.362	0.47	23	-0.2206	0.6173	-0.107	-1.25	--
16	2007-11-26	-0.1739	0.6435	0.67	4.4	-0.3641	0.4436	0.19	1.77	--
17	2007-12-06	-0.2218	0.699	0.6	5	-0.3531	0.4551	0.131	1.25	--
18	2007-12-13	0.04922	2.406	1.12	254.7	-0.012	0.998	0.0612	0.584	--
19	2008-03-06	0.04532	2.779	1.11	601.7	0.0626	1.185	-0.0173	0.0313	--
20	2008-04-14	-0.1427	2.362	0.72	230	-0.02084	0.9779	-0.122	-1.41	--
21	2008-05-29	-0.07572	2.362	0.84	230	-0.02084	0.9779	-0.0549	-0.584	--
22	2008-06-30	-0.04576	2.324	0.9	210.8	-0.02839	0.961	-0.0174	0.0104	--
23	2008-09-16	-0.08092	2.23	0.83	170	-0.04707	0.9205	-0.0339	-0.264	--
24	2009-04-06	-0.3098	1.724	0.49	53	-0.1482	0.7293	-0.162	-1.77	--
25	2009-04-28	-0.1024	2.447	0.79	280	-0.003774	1.017	-0.0986	-0.982	--
26	2009-06-16	0.2455	2.898	1.76	790	0.08623	1.251	0.159	1.41	--
27	2009-07-30	-0.07572	2.322	0.84	210	-0.02874	0.9602	-0.047	-0.488	--
28	2009-09-09	-0.06048	2.322	0.87	210	-0.02874	0.9602	-0.0317	-0.221	--
29	2009-09-24	0.07918	2.892	1.2	780	0.08512	1.248	-0.00594	0.115	--
30	2009-11-03	-0.1612	2.146	0.69	140	-0.06392	0.8855	-0.0972	-0.917	--
31	2009-11-19	-0.284	0.8346	0.52	6.833	-0.3259	0.4844	0.042	0.488	--
32	2009-12-01	-0.3979	0.6532	0.4	4.5	-0.3622	0.4456	-0.0357	-0.307	--
33	2009-12-17	-0.5086	0.5185	0.31	3.3	-0.3891	0.4188	-0.12	-1.35	--
34	2010-01-06	-0.4202	0.5185	0.38	3.3	-0.3891	0.4188	-0.0311	-0.178	--
35	2010-01-19	-0.4685	0.6532	0.34	4.5	-0.3622	0.4456	-0.106	-1.21	--
36	2010-02-04	-0.4815	0.6402	0.33	4.367	-0.3648	0.4429	-0.117	-1.3	--
37	2010-02-23	-0.5229	1.041	0.3	11	-0.2846	0.5327	-0.238	-2.58	--
38	2010-03-10	-0.1612	2.176	0.69	150	-0.05793	0.8978	-0.103	-1.09	--
39	2010-04-14	-0.3279	1.048	0.47	11.17	-0.2833	0.5343	-0.0446	-0.441	--
40	2010-04-23	-0.1427	2.041	0.72	110	-0.08484	0.8439	-0.0578	-0.609	--
41	2010-05-13	0.1106	2.663	1.29	460	0.0393	1.123	0.0713	0.713	--
42	2010-06-09	0.3243	2.961	2.11	915	0.09897	1.289	0.225	2.58	--
43	2010-06-13	0.01284	2.523	1.03	333.3	0.01135	1.053	0.00148	0.199	--
44	2010-06-14	-0.03152	2.431	0.93	270	-0.00693	1.01	-0.0246	-0.094	--
45	2010-06-14	-0.1427	2.176	0.72	150	-0.05793	0.8978	-0.0847	-0.885	--
46	2010-06-15	-0.03621	2.398	0.92	250	-0.01361	0.9943	-0.0226	-0.0313	--
47	2010-06-16	-0.0655	2.339	0.86	218.3	-0.02536	0.9677	-0.0401	-0.373	--
48	2010-07-06	-0.05552	2.146	0.88	140	-0.06392	0.8855	0.0084	0.264	--
49	2010-08-19	-0.2441	1.559	0.57	36.25	-0.1812	0.676	-0.063	-0.66	--
50	2010-08-25	-0.0655	2.38	0.86	240	-0.01715	0.9862	-0.0484	-0.512	--
51	2010-11-16	-0.08092	2.146	0.83	140	-0.06392	0.8855	-0.017	0.0522	--
52	2011-01-19	-0.4202	1.315	0.38	20.67	-0.2299	0.6042	-0.19	-2.02	--
53	2011-03-07	-0.3665	1.146	0.43	14	-0.2637	0.559	-0.103	-1.05	--
54	2011-03-16	-0.3372	1.279	0.46	19	-0.2372	0.5942	-0.1	-1.02	--
55	2011-04-06	-0.301	1.204	0.5	16	-0.2521	0.5741	-0.0489	-0.535	--
56	2011-04-18	-0.3098	1.279	0.49	19	-0.2372	0.5942	-0.0726	-0.825	--
57	2011-05-02	-0.3188	1.396	0.48	24.92	-0.2137	0.6272	-0.105	-1.17	--
58	2011-05-16	-0.2676	1.362	0.54	23	-0.2206	0.6173	-0.047	-0.465	--
59	2011-06-07	-0.04096	1.643	0.91	44	-0.1644	0.7027	0.123	1.13	--
60	2011-06-21	-0.07058	2.041	0.85	110	-0.08484	0.8439	0.0143	0.329	--
61	2011-06-22	-0.08092	2.124	0.83	133	-0.06837	0.8765	-0.0126	0.0731	--
62	2011-08-15	-0.03621	2.443	0.92	277.5	-0.004552	1.015	-0.0317	-0.199	--
63	2011-09-22	-0.2518	2.041	0.56	110	-0.08484	0.8439	-0.167	-1.88	--
64	2011-12-20	0.1732	2.699	1.49	500	0.04654	1.142	0.127	1.17	--

65	2012-02-06	-0.09151	2.13	0.81	135	-0.06707	0.8791	-0.0244	-0.0731	--
66	2012-03-01	0.1987	2.869	1.58	740	0.08055	1.235	0.118	0.982	--
67	2012-04-07	-0.02687	2.114	0.94	130	-0.07035	0.8725	0.0435	0.512	--
68	2012-04-17	-0.2518	1.562	0.56	36.5	-0.1806	0.6769	-0.0712	-0.768	--
69	2012-05-09	-0.1871	1.703	0.65	50.5	-0.1524	0.7223	-0.0347	-0.285	--
70	2012-05-30	-0.1675	1.638	0.68	43.5	-0.1653	0.7011	-0.00215	0.157	--
71	2012-06-12	-0.0655	1.748	0.86	56	-0.1434	0.7374	0.0779	0.74	--
72	2012-06-18	0.02119	2.176	1.05	150	-0.05793	0.8978	0.0791	0.768	--
73	2012-06-19	-0.008774	2.079	0.98	120	-0.07729	0.8587	0.0685	0.686	--
74	2012-07-12	-0.284	1.705	0.52	50.75	-0.152	0.723	-0.132	-1.53	--
75	2012-07-19	-0.3372	1.792	0.46	62	-0.1346	0.7525	-0.203	-2.22	--
76	2012-09-11	0	1.653	1	45	-0.1624	0.7059	0.162	1.46	--
77	2012-10-24	-0.301	1.583	0.5	38.25	-0.1765	0.6833	-0.125	-1.46	--
78	2012-11-07	-0.1192	0.9566	0.76	9.05	-0.3016	0.5123	0.182	1.68	--
79	2012-12-12	-0.1135	0.8976	0.77	7.9	-0.3134	0.4986	0.2	2.02	--
80	2013-01-29	-0.05552	1.277	0.88	18.92	-0.2376	0.5936	0.182	1.6	--
81	2013-03-12	-0.2147	1.301	0.61	20	-0.2328	0.6003	0.0181	0.373	--
82	2013-03-13	-0.3372	1.301	0.46	20	-0.2328	0.6003	-0.104	-1.13	--
83	2013-04-15	-0.2218	1.505	0.6	32	-0.192	0.6594	-0.0299	-0.136	--
84	2013-04-15	-0.2147	1.505	0.61	32	-0.192	0.6594	-0.0227	-0.0522	--
85	2013-04-24	0.07918	2.021	1.2	105	-0.08888	0.8361	0.168	1.53	--
86	2013-05-06	-0.1487	1.929	0.71	85	-0.1072	0.8015	-0.0415	-0.396	--
87	2013-05-09	0.1399	2.57	1.38	371.7	0.0208	1.076	0.119	1.05	--
88	2013-05-15	0.04139	1.932	1.1	85.5	-0.1067	0.8024	0.148	1.3	--
89	2013-05-21	0.02938	2.079	1.07	120	-0.07729	0.8587	0.107	0.885	--
90	2013-05-28	-0.004365	1.788	0.99	61.33	-0.1355	0.7509	0.131	1.21	--
91	2013-06-13	-0.07572	1.785	0.84	61	-0.136	0.7501	0.0603	0.56	--
92	2013-06-24	-0.1549	1.843	0.7	69.67	-0.1245	0.7703	-0.0304	-0.157	--
93	2013-07-09	-0.07058	1.685	0.85	48.45	-0.156	0.7164	0.0854	0.825	--
94	2013-07-29	-0.04576	2.204	0.9	160	-0.05233	0.9095	0.00657	0.242	--
95	2013-07-29	-0.04096	2.204	0.91	160	-0.05233	0.9095	0.0114	0.285	--
96	2013-08-07	-0.1487	1.932	0.71	85.5	-0.1067	0.8024	-0.042	-0.419	--
97	2013-08-15	-0.1192	1.964	0.76	92	-0.1003	0.8143	-0.0188	-0.0104	--
98	2013-09-12	-0.2441	1.23	0.57	17	-0.2469	0.5811	0.00274	0.221	--
99	2013-10-24	-0.4685	0.8827	0.34	7.633	-0.3163	0.4952	-0.152	-1.68	--
100	2013-11-25	-0.2676	0.5315	0.54	3.4	-0.3865	0.4213	0.119	1.02	--
101	2013-12-11	-0.2596	0.5817	0.55	3.817	-0.3765	0.4312	0.117	0.949	--
102	2014-01-14	-0.3565	0.6163	0.44	4.133	-0.3696	0.4381	0.013	0.307	--
103	2014-02-20	-0.4089	0.9103	0.39	8.133	-0.3108	0.5015	-0.0981	-0.949	--
104	2014-03-17	-0.3665	0.8195	0.43	6.6	-0.329	0.481	-0.0376	-0.351	--
105	2014-04-09	-0.2218	1.041	0.6	11	-0.2846	0.5327	0.0628	0.609	--
106	2014-05-08	-0.03621	1.301	0.92	20	-0.2328	0.6003	0.197	1.88	--
107	2014-05-14	-0.03152	1.705	0.93	50.67	-0.1521	0.7228	0.121	1.09	--
108	2014-05-15	-0.07572	1.512	0.84	32.5	-0.1906	0.6614	0.115	0.917	--
109	2014-05-29	-0.07058	1.591	0.85	39	-0.1748	0.686	0.104	0.855	--
110	2014-06-03	0.01703	1.531	1.04	34	-0.1867	0.6674	0.204	2.22	--
111	2014-06-05	-0.1079	1.839	0.78	69	-0.1253	0.7688	0.0174	0.351	--
112	2014-06-09	-0.07572	2.255	0.84	180	-0.04211	0.9311	-0.0336	-0.242	--
113	2014-06-12	-0.08619	2.342	0.82	220	-0.0247	0.9692	-0.0615	-0.634	--
114	2014-06-24	-0.1135	1.954	0.77	90	-0.1023	0.8107	-0.0113	0.094	--
115	2014-07-10	-0.2076	1.572	0.62	37.33	-0.1786	0.68	-0.029	-0.115	--
116	2014-07-15	-0.1612	1.51	0.69	32.33	-0.1911	0.6607	0.0299	0.441	--
117	2014-07-24	-0.1739	1.475	0.67	29.83	-0.1981	0.6502	0.0241	0.419	--
118	2014-08-04	-0.1427	1.437	0.72	27.33	-0.2057	0.6389	0.063	0.634	--
119	2014-08-21	-0.1024	1.633	0.79	43	-0.1663	0.6995	0.064	0.66	--
120	2014-09-03	0.03743	2.663	1.09	460	0.0393	1.123	-0.00188	0.178	--

Definitions

TP: Phosphorus in mg/l as P (00665)

TURB: Turbidity in FNU (63680)

Model Archive Summary for *Escherichia Coli* Bacteria at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the *Escherichia coli* Bacteria (ECB) model developed to compute hourly ECB from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: December 26, 2014

Model calibration data period: July, 27 2004 to September 3, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in National Water Information System (NWIS) database. The regression model is based on 96 concurrent measurements of *E. coli* bacteria, streamflow, and turbidity samples collected from July 27, 2004 through September 3, 2014. There were no samples below laboratory reporting levels. Samples were collected throughout the range of continuously observed hydrologic and turbidity conditions. Summary statistics and complete model-calibration dataset are provided in the dataset. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. None of the residuals for ECB were beyond ± 3 .

Sampling Details

Samples are collected either from the downstream side from the bridge or instream within 300 feet of the bridge. Samples are collected approximately quarterly and during selected runoff events. A weighted bottle sampler is used from the bridge; and hand dipped bottle for wading samples. Samples are analyzed for ECB at the USGS water quality laboratory in Wichita, Kansas.

Model Development

Regression analysis was done using R by examining turbidity and other continuously measured data as an explanatory variables for estimating *Escherichia coli* bacteria concentration. A variety of models that predict ECB and models that predict $\log_{10}(\text{ECB})$ were evaluated. The distribution of residuals was examined for normality and plots of residuals (the difference between the measured and predicted values) as compared to predicted ECB were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison of several models led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{ECB})$.

Turbidity was selected as the best predictor of $\log_{10}(\text{ECB})$ based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallow's C_p . Values for all of the aforementioned statistics and

metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for *Escherichia coli* bacteria at site number 07144100.
Escherichia coli bacteria-based model:

$$\log_{10}(ECB) = 1.35 \times \log_{10}(TURB) + 0.174$$

where

ECB = *Escherichia coli* in colony forming units per 100 milliliters (cfu/100mL); and
TURB = Turbidity, YSI model 6136, in formazin nephelometric units (FNU).

Turbidity makes physical and statistical sense as an explanatory variable for *Escherichia coli* bacteria. It makes physical sense because bacterial colonies become suspended in water in the same manner that light-scattering particles, which increase turbidity, become suspended. Turbidity makes statistical sense as an explanatory variable because it resulted in a model with low standard error, Mallows' C_p and PRESS values, and high R^2 values. The model selected was the simplest model (one explanatory variable) even though some of the other models were marginally better statistically.

The log-transformed model may be retransformed to the original units so that ECB can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.99. The retransformed model, accounting for BCF is:

$$ECB = 2.971 \times TURB^{1.35}$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(ECB) = 1.17 \times \log_{10}(TURB) + 0.111$
1.1	2007	--	$\log_{10}(ECB) = 1.35 \times \log_{10}(TURB) + 0.174$

ECB Record

The ECB record is computed using this regression model in the National Real-Time Water Quality (NRTWQ) Web site from 2015 onward. Data are computed at hourly intervals. The complete water quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick
Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

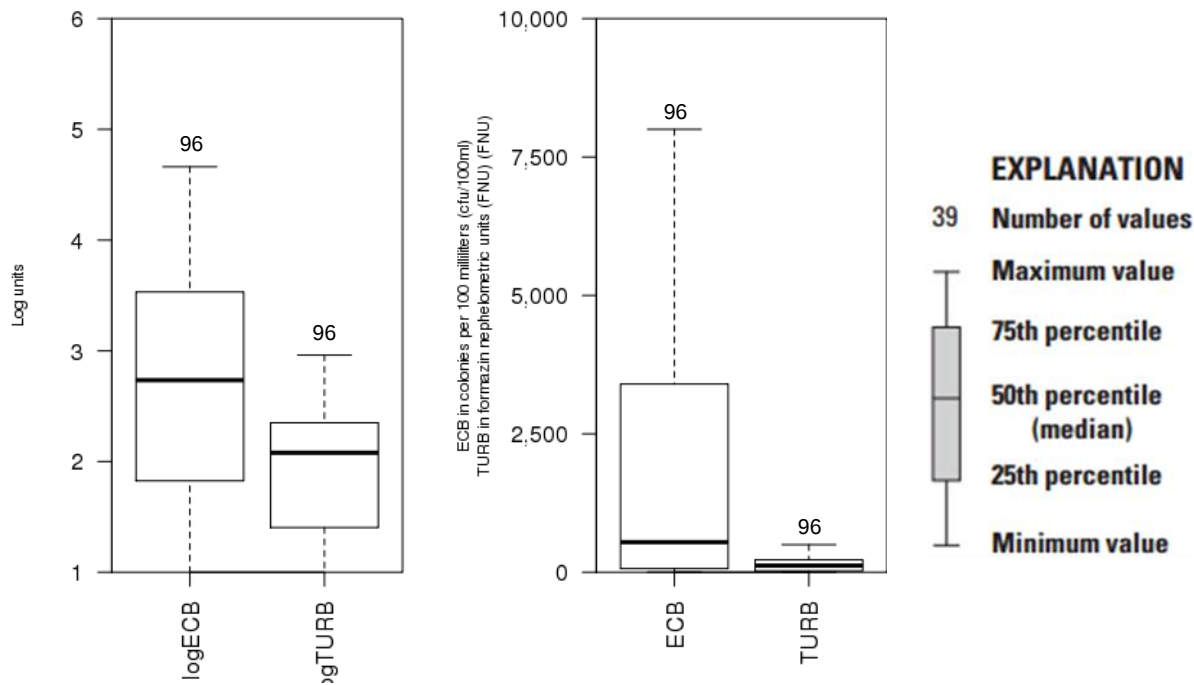
Model

$$\log ECB = + 1.35 * \log TURB + 0.174$$

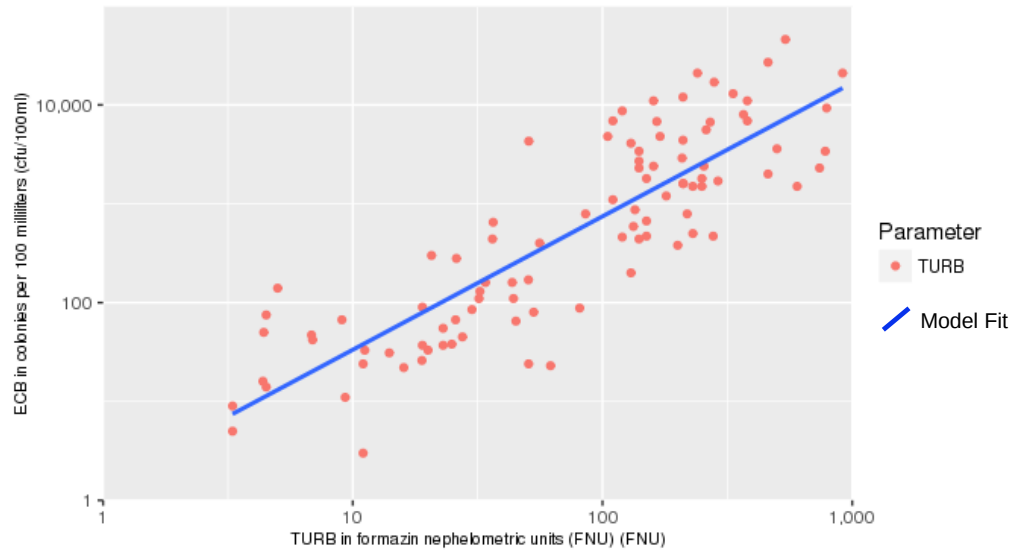
Variable Summary Statistics

	logECB	logTURB	ECB	TURB
Minimum	0.477	0.519	3	3.3
1st Quartile	1.830	1.400	67	25.4
Median	2.730	2.080	545	120.0
Mean	2.700	1.870	3270	163.0
3rd Quartile	3.530	2.350	3400	224.0
Maximum	4.660	2.960	46000	915.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	96
Standard error (RMSE)	0.523
Upper Model standard percentage error (MSPE)	233
Lower Model standard percentage error (MSPE)	70
Coefficient of determination (R^2)	0.728
Adjusted Coefficient of Determination (Adj. R^2)	0.725
Bias Correction Factor (BCF)	1.99

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.174	0.168	1.04	3.03e-01
logTURB	1.350	0.085	15.90	2.48e-28

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.948
E.vars	-0.948	1.000

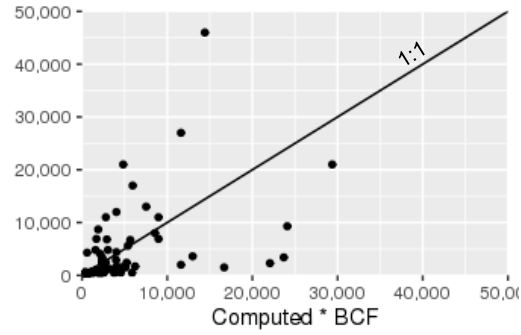
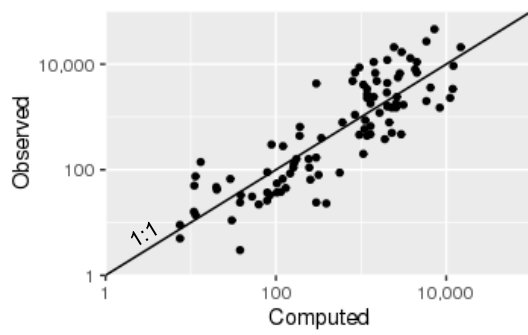
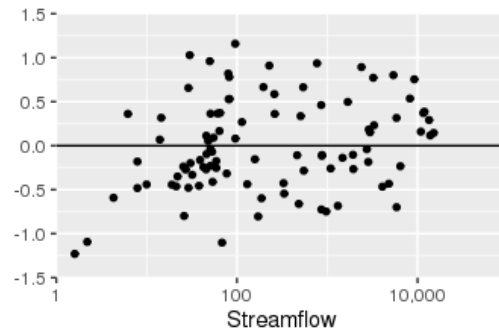
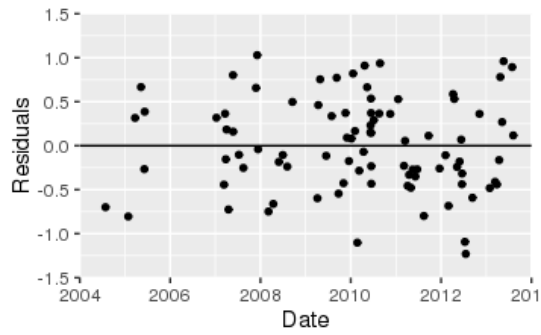
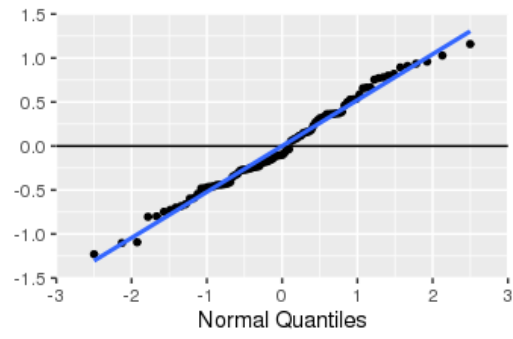
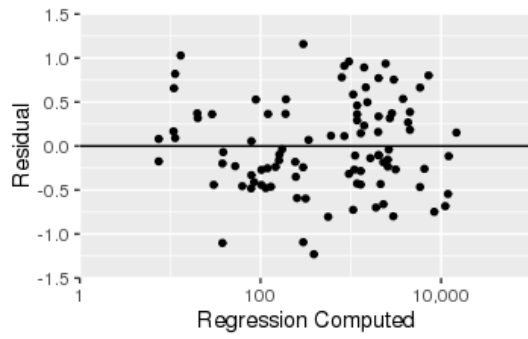
Outlier Test Criteria

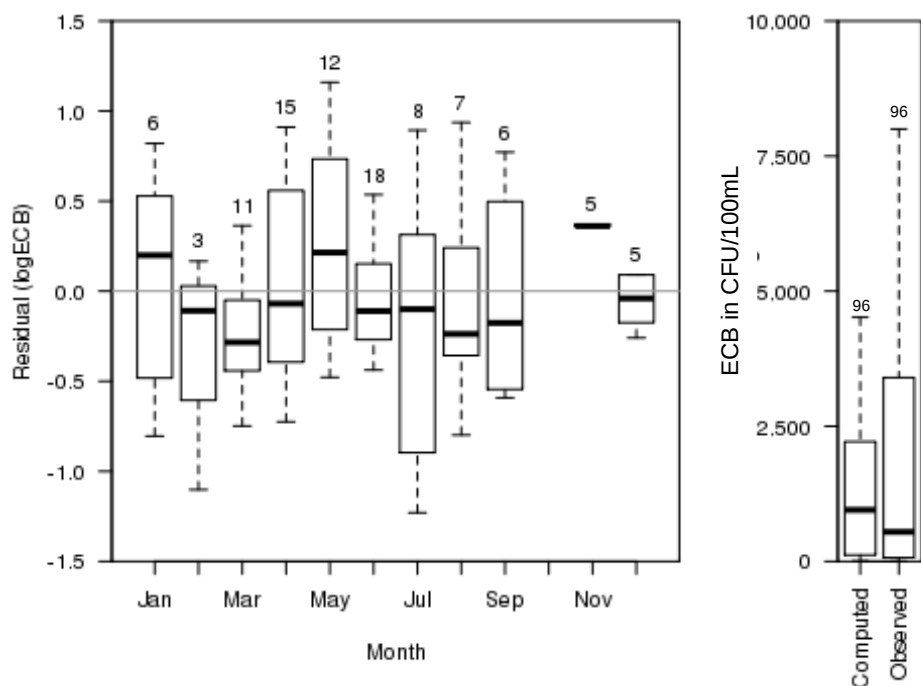
Leverage	Cook's D	DFFITS
0.0312500	0.1054775	0.2041241

Flagged Observations

	logECB	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
1/10/2007 11:25	1.6230	1.3060	0.31750	0.6192	0.6172	0.03861	0.0077000	0.12370
5/24/2007 13:15	4.6630	3.8610	0.80190	1.5570	1.5690	0.03001	0.0375000	0.27600
11/26/2007 10:40	1.6990	1.0420	0.65690	1.2890	1.2940	0.05029	0.0439900	0.29770
12/6/2007 11:45	2.1460	1.1170	1.02900	2.0160	2.0500	0.04677	0.0996500	0.45400
3/6/2008 10:35	3.1760	3.9240	-0.74810	-1.4540	-1.4630	0.03221	0.0351800	-0.26690
4/28/2009 10:05	4.2300	3.4760	0.75450	1.4570	1.4660	0.01918	0.0207400	0.20490
6/16/2009 12:50	3.9680	4.0840	-0.11530	-0.2249	-0.2237	0.03826	0.0010060	-0.04463
9/24/2009 11:15	3.5310	4.0760	-0.54490	-1.0620	-1.0630	0.03796	0.0222600	-0.21110
11/19/2009 11:40	1.6720	1.3000	0.37210	0.7257	0.7238	0.03884	0.0106400	0.14550
12/1/2009 12:40	1.1460	1.0550	0.09091	0.1783	0.1774	0.04966	0.0008308	0.04055
12/17/2009 12:00	0.6990	0.8735	-0.17450	-0.3439	-0.3423	0.05882	0.0036950	-0.08556
1/6/2010 11:50	0.9542	0.8735	0.08079	0.1592	0.1584	0.05882	0.0007922	0.03960
1/19/2010 10:00	1.8750	1.0550	0.81980	1.6080	1.6220	0.04966	0.0675600	0.37080
2/4/2010 10:40	1.2040	1.0380	0.16650	0.3268	0.3252	0.05051	0.0028400	0.07501
2/23/2010 12:50	0.4771	1.5790	-1.10200	-2.1380	-2.1800	0.02864	0.0673600	-0.37430
5/13/2010 10:15	4.4310	3.7670	0.66450	1.2880	1.2930	0.02697	0.0229900	0.21520
6/9/2010 9:45	4.3220	4.1700	0.15230	0.2975	0.2961	0.04183	0.0019320	0.06186
8/25/2010 11:00	4.3220	3.3860	0.93660	1.8060	1.8290	0.01726	0.0286600	0.24240
8/15/2011 10:45	2.6720	3.4710	-0.79860	-1.5420	-1.5530	0.01906	0.0230900	-0.21650
3/1/2012 12:00	3.3620	4.0460	-0.68380	-1.3320	-1.3380	0.03674	0.0338400	-0.26120
7/12/2012 10:15	1.3800	2.4730	-1.09300	-2.1020	-2.1410	0.01116	0.0249200	-0.22750
7/19/2012 10:15	1.3620	2.5920	-1.23000	-2.3640	-2.4250	0.01058	0.0299000	-0.25080
11/7/2012 11:10	1.8260	1.4640	0.36180	0.7033	0.7014	0.03256	0.0083240	0.12870
3/27/2013 11:35	1.0410	1.4820	-0.44070	-0.8565	-0.8553	0.03192	0.0121000	-0.15530
5/14/2014 13:20	3.6330	2.4740	1.15900	2.2290	2.2780	0.01115	0.0280200	0.24200

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logECB ~ logTURB	1	0.523	72.81	72.53	20.86	26.79	<NA>	± 150
logECB ~ SC	1	0.6239	61.31	60.9	68.61	38.11	<NA>	± 200
logECB ~ logSC	1	0.6983	51.54	51.03	109.2	47.72	<NA>	± 240
logECB ~ logTURB + logQ	2	0.4929	76.11	75.59	9.191	24	1.866	± 140
logECB ~ logTURB + sin4DY	2	0.5014	75.28	74.75	12.62	24.93	1.007	± 140
logECB ~ logTURB + SC	2	0.5092	74.51	73.96	15.84	25.46	3.274	± 150
logECB ~ logTURB + logQ + sin4DY	3	0.4726	78.28	77.57	2.182	22.31	1.868	± 130
logECB ~ logTURB + SC + sin4DY	3	0.486	77.02	76.27	7.404	23.54	3.284	± 140
logECB ~ logTURB + logSC + sin4DY	3	0.4884	76.79	76.04	8.347	23.78	2.234	± 140
logECB ~ logTURB + logQ + sin2DY + sin4DY	4	0.4718	78.58	77.64	2.91	22.47	1.868	± 130
logECB ~ logTURB + Q + logQ + sin4DY	4	0.4725	78.52	77.57	3.186	22.32	2.003	± 130
logECB ~ logTURB + logQ + cos4DY + sin4DY	4	0.4732	78.46	77.51	3.435	22.54	1.89	± 130
logECB ~ logTURB + logQ + sin2DY + cos4DY + sin4DY	5	0.4691	79.06	77.89	2.949	22.42	1.898	± 130
logECB ~ logTURB + Q + logQ + sin2DY + sin4DY	5	0.4711	78.88	77.7	3.692	22.42	2.007	± 130
logECB ~ logTURB + logQ + SC + logSC + sin4DY	5	0.4712	78.87	77.7	3.713	22.53	3.717	± 130
logECB ~ logTURB + Q + logQ + sin2DY + cos4DY + sin4DY	6	0.4698	79.23	77.83	4.215	22.47	2.018	± 130
logECB ~ logTURB + logQ + sin2DY + cos4DY + sin4DY	6	0.4712	79.11	77.7	4.737	22.75	2.817	± 130
logECB ~ logTURB + logQ + SC + sin2DY + cos4DY + sin4DY	6	0.4713	79.1	77.69	4.769	22.96	3.647	± 130

Model-Calibration Data Set

	Date	logECB	logTURB	ECB	TURB	Computed logECB	Computed ECB	Residual	Normal Quantiles	Censored Values
0										
1	2004-07-27	2.58	2.301	380	200	3.279	3774	-0.699	-1.41	--
2	2005-01-27	1.944	1.908	88	81	2.749	1115	-0.805	-1.78	--
3	2005-03-23	3.748	2.415	5600	260	3.433	5378	0.316	0.502	--
4	2005-05-10	3.833	2.217	6800	165	3.166	2911	0.666	1.17	--

5	2005-06-06	3.23	2.462	1700	290	3.497	6231	-0.266	-0.473	--
6	2005-06-09	4.041	2.58	11000	380	3.655	8974	0.386	0.792	--
7	2007-01-10	1.623	0.8388	42	6.9	1.306	40.16	0.318	0.532	--
8	2007-03-12	1.568	1.362	37	23	2.011	203.9	-0.443	-0.866	--
9	2007-03-21	2.447	1.415	280	26	2.083	240.5	0.364	0.657	--
10	2007-03-27	3.255	2.398	1800	250	3.41	5100	-0.154	-0.144	--
11	2007-04-02	3.839	2.58	6900	380	3.655	8974	0.184	0.387	--
12	2007-04-18	2.301	2.114	200	130	3.026	2110	-0.725	-1.49	--
13	2007-05-24	4.663	2.732	46000	540	3.861	14420	0.802	1.41	--
14	2007-05-25	3.462	2.319	2900	208.3	3.303	3988	0.16	0.332	--
15	2007-07-11	3.204	2.322	1600	210	3.307	4031	-0.103	-0.013	--
16	2007-08-16	1.826	1.412	67	25.8	2.079	238	-0.253	-0.416	--
17	2007-11-26	1.699	0.6435	50	4.4	1.042	21.88	0.657	1.07	--
18	2007-12-06	2.146	0.699	140	5	1.117	26	1.03	2.13	--
19	2007-12-13	3.38	2.406	2400	254.7	3.42	5229	-0.0402	0.0652	--
20	2008-03-06	3.176	2.779	1500	601.7	3.924	16680	-0.748	-1.57	--
21	2008-04-14	2.699	2.362	500	230	3.361	4558	-0.662	-1.28	--
22	2008-05-29	3.176	2.362	1500	230	3.361	4558	-0.185	-0.25	--
23	2008-06-30	3.204	2.324	1600	210.8	3.31	4053	-0.106	-0.0391	--
24	2008-08-05	1.929	1.477	85	30	2.167	291.8	-0.238	-0.359	--
25	2008-09-16	3.681	2.23	4800	170	3.184	3031	0.498	0.866	--
26	2009-04-06	1.903	1.724	80	53	2.501	628.9	-0.597	-1.23	--
27	2009-04-13	3.531	2.146	3400	140	3.07	2332	0.462	0.828	--
28	2009-04-28	4.23	2.447	17000	280	3.476	5943	0.754	1.23	--
29	2009-06-16	3.968	2.898	9300	790	4.084	24090	-0.115	-0.0913	--
30	2009-07-30	3.643	2.322	4400	210	3.307	4031	0.336	0.562	--
31	2009-09-09	4.079	2.322	12000	210	3.307	4031	0.772	1.28	--
32	2009-09-24	3.531	2.892	3400	780	4.076	23680	-0.545	-1.12	--
33	2009-11-03	2.643	2.146	440	140	3.07	2332	-0.426	-0.723	--
34	2009-11-19	1.672	0.8346	47	6.833	1.3	39.63	0.372	0.757	--
35	2009-12-01	1.146	0.6532	14	4.5	1.055	22.56	0.0909	0.197	--
36	2009-12-17	0.699	0.5185	5	3.3	0.8735	14.84	-0.174	-0.197	--
37	2010-01-06	0.9542	0.5185	9	3.3	0.8735	14.84	0.0808	0.17	--
38	2010-01-19	1.875	0.6532	75	4.5	1.055	22.56	0.82	1.49	--
39	2010-02-04	1.204	0.6402	16	4.367	1.038	21.66	0.167	0.359	--
40	2010-02-23	0.4771	1.041	3	11	1.579	75.35	-1.1	-2.13	--
41	2010-03-10	2.826	2.176	670	150	3.11	2560	-0.284	-0.562	--
42	2010-04-14	1.519	1.048	33	11.17	1.588	76.89	-0.0693	0.0391	--
43	2010-04-23	3.839	2.041	6900	110	2.928	1685	0.91	1.67	--
44	2010-05-13	4.431	2.663	27000	460	3.767	11610	0.664	1.12	--
45	2010-06-09	4.322	2.961	21000	915	4.17	29370	0.152	0.304	--
46	2010-06-10	3.38	2.204	2400	160	3.148	2793	0.232	0.416	--
47	2010-06-13	4.114	2.523	13000	333.3	3.578	7520	0.536	0.986	--
48	2010-06-14	3.826	2.431	6700	270	3.455	5659	0.371	0.723	--
49	2010-06-14	3.255	2.176	1800	150	3.11	2560	0.145	0.277	--
50	2010-06-15	3.176	2.398	1500	250	3.41	5100	-0.233	-0.332	--
51	2010-06-16	2.898	2.339	790	218.3	3.33	4248	-0.433	-0.757	--
52	2010-07-06	3.362	2.146	2300	140	3.07	2332	0.292	0.473	--
53	2010-08-19	2.643	1.559	440	36.25	2.278	376.7	0.366	0.689	--
54	2010-08-25	4.322	2.38	21000	240	3.386	4827	0.937	1.78	--
55	2010-11-16	3.431	2.146	2700	140	3.07	2332	0.362	0.593	--
56	2011-01-19	2.477	1.315	300	20.67	1.949	176.5	0.529	0.904	--

57	2011-03-07	1.491	1.146	31	14	1.72	104.3	-0.229	-0.304	--
58	2011-03-16	1.954	1.279	90	19	1.899	157.5	0.0549	0.118	--
59	2011-04-06	1.342	1.204	22	16	1.799	124.9	-0.456	-0.904	--
60	2011-04-18	1.568	1.279	37	19	1.899	157.5	-0.331	-0.625	--
61	2011-05-02	1.58	1.396	38	24.92	2.058	227.1	-0.478	-1.03	--
62	2011-05-16	1.74	1.362	55	23	2.011	203.9	-0.271	-0.532	--
63	2011-06-07	2.041	1.643	110	44	2.391	489.2	-0.35	-0.657	--
64	2011-06-22	2.771	2.124	590	133	3.04	2176	-0.269	-0.502	--
65	2011-08-15	2.672	2.443	470	277.5	3.471	5872	-0.799	-1.67	--
66	2011-09-22	3.041	2.041	1100	110	2.928	1685	0.113	0.223	--
67	2011-12-20	3.556	2.699	3600	499.6	3.815	12980	-0.259	-0.444	--
68	2012-02-06	2.94	2.13	870	134.9	3.048	2219	-0.109	-0.0652	--
69	2012-03-01	3.362	2.869	2300	740	4.046	22060	-0.684	-1.34	--
70	2012-04-07	3.613	2.114	4100	130	3.026	2110	0.586	1.03	--
71	2012-04-17	2.813	1.562	650	36.49	2.282	380	0.531	0.944	--
72	2012-05-09	2.23	1.703	170	50.5	2.472	589.1	-0.242	-0.387	--
73	2012-05-30	2.204	1.638	160	43.49	2.385	481.5	-0.18	-0.223	--
74	2012-06-12	2.602	1.748	400	56	2.533	677.4	0.0693	0.144	--
75	2012-06-18	2.672	2.176	470	150	3.11	2560	-0.438	-0.792	--
76	2012-06-19	2.663	2.079	460	120	2.979	1894	-0.317	-0.593	--
77	2012-07-12	1.38	1.704	24	50.59	2.473	590.6	-1.09	-1.93	--
78	2012-07-19	1.362	1.792	23	61.93	2.592	775.9	-1.23	-2.5	--
79	2012-09-11	1.813	1.653	65	45	2.405	504.3	-0.592	-1.17	--
80	2012-11-07	1.826	0.9564	67	9.044	1.464	57.85	0.362	0.625	--
81	2013-01-29	1.415	1.277	26	18.91	1.897	156.6	-0.482	-1.07	--
82	2013-03-13	1.519	1.301	33	20	1.929	168.8	-0.411	-0.689	--
83	2013-03-27	1.041	0.9696	11	9.324	1.482	60.28	-0.441	-0.828	--
84	2013-04-15	2.041	1.505	110	32	2.205	318.3	-0.163	-0.17	--
85	2013-04-24	3.681	2.021	4800	104.9	2.9	1580	0.781	1.34	--
86	2013-05-09	3.903	2.564	8000	366.8	3.634	8557	0.269	0.444	--
87	2013-05-21	3.94	2.079	8700	120	2.979	1894	0.96	1.93	--
88	2013-07-29	4.041	2.204	11000	160	3.148	2793	0.893	1.57	--
89	2013-08-07	2.898	1.932	790	85.5	2.781	1199	0.117	0.25	--
90	2014-04-09	1.38	1.041	24	11	1.579	75.35	-0.199	-0.277	--
91	2014-05-14	3.633	1.705	4300	50.66	2.474	591.8	1.16	2.5	--
92	2014-06-03	2.204	1.531	160	34	2.24	345.5	-0.0362	0.0913	--
93	2014-06-09	3.079	2.255	1200	180	3.217	3274	-0.138	-0.118	--
94	2014-07-15	2.114	1.509	130	32.28	2.21	322.1	-0.096	0.013	--
95	2014-08-04	1.653	1.439	45	27.49	2.116	259.3	-0.462	-0.944	--
96	2014-09-03	3.301	2.663	2000	460	3.767	11610	-0.466	-0.986	--

Definitions

ECB: Escherichia coli in cfu/100ml (90902)

TURB: Turbidity in FNU (63680)

Model Archive Summary for Fecal Coliform Bacteria at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the Fecal coliform bacteria (FCB) model developed to compute hourly FCB from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: December 26, 2014

Model calibration data period: July, 27 2004 to August 4, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in National Water Information System (NWIS) database. The regression model is based on 96 concurrent measurements of Fecal coliform bacteria, streamflow, and turbidity samples collected from July 27, 2004 through August 4, 2014. No samples were below laboratory reporting levels. Samples were collected throughout the range of continuously observed hydrologic and turbidity conditions. Summary statistics and complete model-calibration dataset are provided in the dataset. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. None of the studentized residuals for FCB samples were beyond ± 3 .

Sampling Details

Samples are collected either from the downstream side from the bridge or instream within 300 feet of the bridge. Samples are collected approximately quarterly and during selected runoff events. A weighted bottle sampler is used from the bridge; and hand dipped bottle for wading samples. Samples are analyzed for FCB at the USGS water quality laboratory in Wichita, Kansas.

Model Development

Regression analysis was done using R by examining turbidity and other continuously measured data as an explanatory variables for estimating fecal coliform bacteria. A variety of models that predict FCB and models that predict $\log_{10}(\text{FCB})$ were evaluated. The distribution of residuals was examined for normality and plots of residuals (the difference between the measured and predicted values) as compared to predicted FCB were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison of several models led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{FCB})$.

Turbidity was selected as the best predictor of $\log_{10}(\text{FCB})$ based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallow's C_p . Values for all of the aforementioned statistics and

metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for fecal coliform bacteria at site number 07144100.

Fecal coliform bacteria-based model:

$$\log_{10}(FCB) = 1.30 \times \log_{10}(TURB) + 0.356$$

where

FCB = Fecal coliform bacteria in colony forming units per 100 milliliters (cfu/100mL); and,

TURB = Turbidity, YSI model 6136, in formazin nephelometric units (FNU).

Turbidity makes physical and statistical sense as an explanatory variable for FCB. It makes physical sense because bacterial colonies become suspended in water in the same manner that light-scattering particles, which increase turbidity, become suspended. Turbidity makes statistical sense as an explanatory variable because it resulted in a model with low standard error, Mallows' C_p and PRESS values, and high R^2 values. The model selected was the simplest model (one explanatory variable) even though some of the other models were marginally better statistically.

The log-transformed model may be retransformed to the original units so that FCB can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 2.24. The retransformed model, accounting for BCF is:

$$FCB = 5.084 \times TURB^{1.30}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(FCB) = 1.19 \times \log_{10}(TURB) + 0.198$
1.1	2007	--	$\log_{10}(FCB) = 1.30 \times \log_{10}(TURB) + 0.356$

Fecal Coliform Bacteria Record

The FCB record is computed using this regression model in the National Real-Time Water Quality (NRTWQ) Web site from 2015 onward. Data are computed at hourly intervals. The complete water quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick

Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

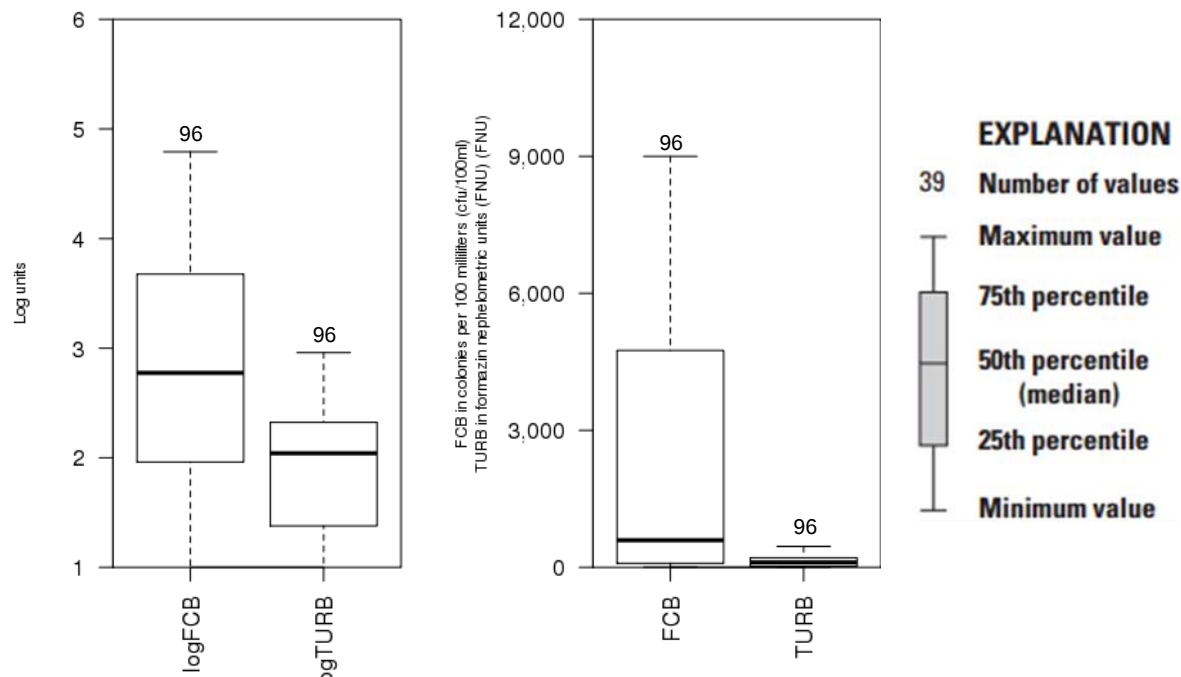
Model

$$\log FCB = + 1.3 * \log TURB + 0.356$$

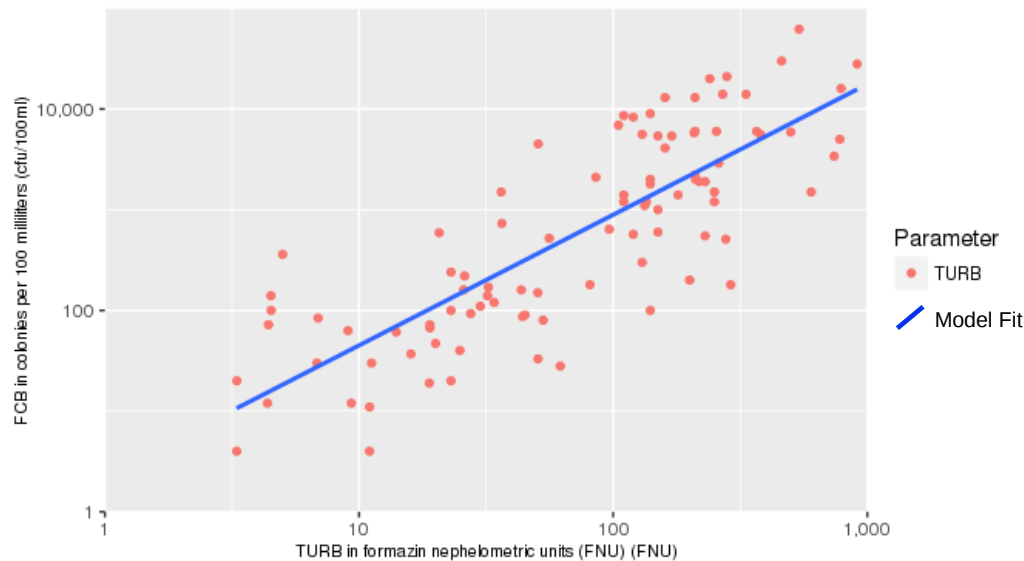
Variable Summary Statistics

	logFCB	logTURB	FCB	TURB
Minimum	0.602	0.519	4.0	3.3
1st Quartile	1.960	1.380	91.5	24.0
Median	2.770	2.040	595.0	110.0
Mean	2.750	1.850	3870.0	155.0
3rd Quartile	3.680	2.320	4750.0	210.0
Maximum	4.790	2.960	62000.0	915.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	96
Standard error (RMSE)	0.583
Upper Model standard percentage error (MSPE)	283
Lower Model standard percentage error (MSPE)	73.9
Coefficient of determination (R^2)	0.659
Adjusted Coefficient of Determination (Adj. R^2)	0.656
Bias Correction Factor (BCF)	2.24

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.356	0.1880	1.9	6.08e-02
logTURB	1.300	0.0962	13.5	1.06e-23

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.948
E.vars	-0.948	1.000

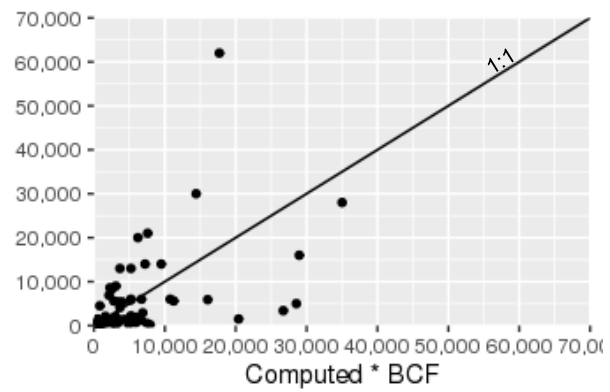
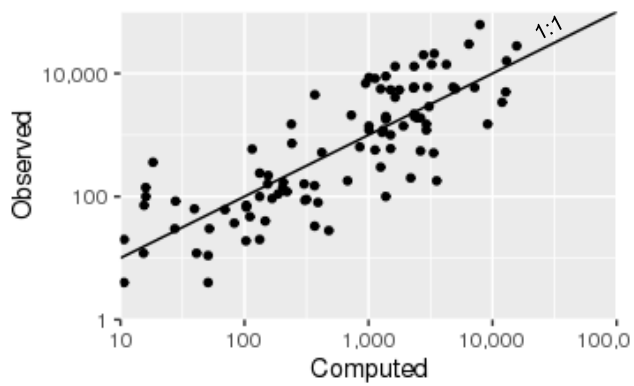
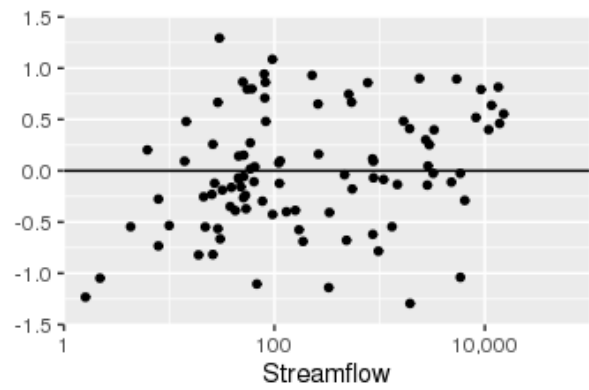
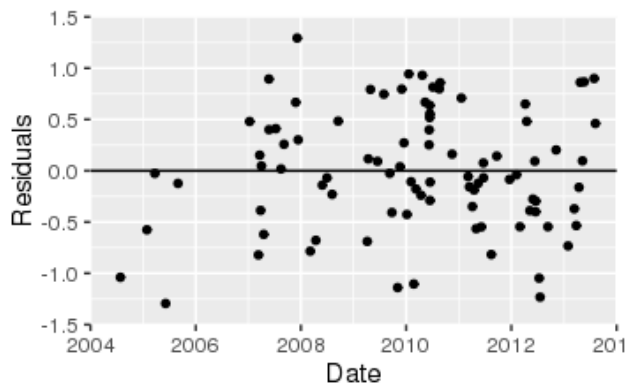
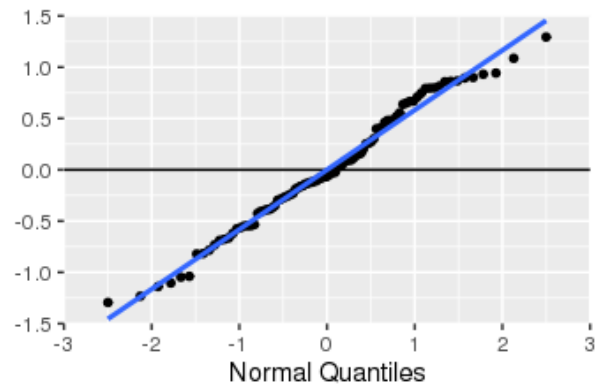
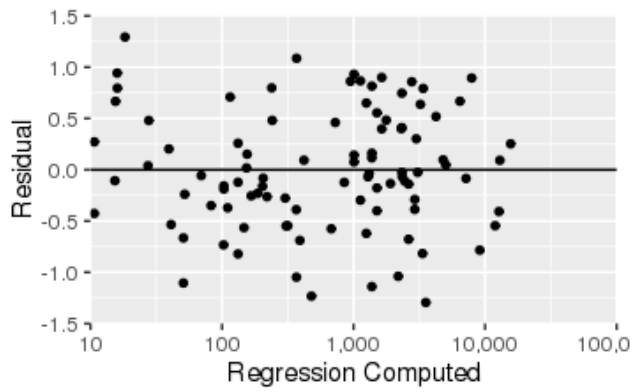
Outlier Test Criteria

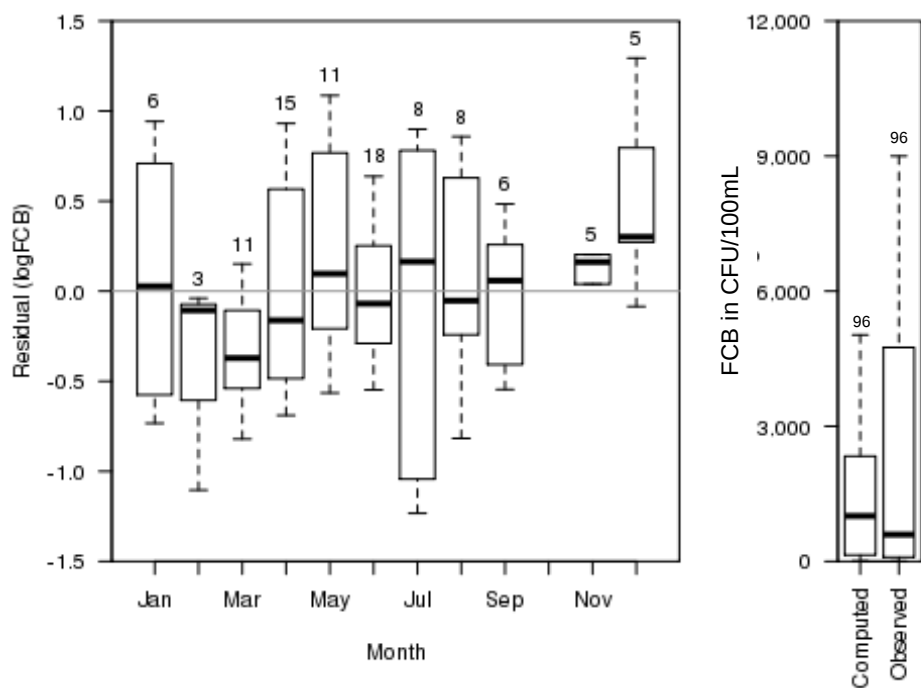
Leverage	Cook's D	DFFITS
0.0312500	0.1054775	0.2041241

Flagged Observations

	logFCB	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
7/27/2004 9:46	2.3010	3.340	-1.03900		-1.79500		-1.81700	0.01594	2.611e-02	-0.23130
6/6/2005 10:21	2.2550	3.549	-1.29400		-2.24100		-2.29100	0.02061	5.284e-02	-0.33230
1/10/2007 11:26	1.9240	1.444	0.48050		0.83970		0.83840	0.03818	1.399e-02	0.16700
5/24/2007 13:15	4.7920	3.898	0.89420		1.55700		1.56900	0.03152	3.947e-02	0.28320
11/26/2007 10:41	1.8570	1.190	0.66690		1.17300		1.17500	0.04995	3.615e-02	0.26940
12/6/2007 11:45	2.5560	1.262	1.29400		2.27100		2.32400	0.04639	1.255e-01	0.51250
3/6/2008 10:35	3.1760	3.960	-0.78390		-1.36700		-1.37300	0.03387	3.276e-02	-0.25720
6/16/2009 12:50	4.2040	4.112	0.09183		0.16070		0.15980	0.04017	5.401e-04	0.03270
9/24/2009 11:16	3.6990	4.106	-0.40700		-0.71200		-0.71010	0.03990	1.053e-02	-0.14470
11/3/2009 9:21	2.0000	3.139	-1.13900		-1.96500		-1.99600	0.01280	2.503e-02	-0.22730
11/19/2009 11:41	1.4770	1.438	0.03938		0.06884		0.06847	0.03844	9.472e-05	0.01369
12/1/2009 12:41	2.0000	1.204	0.79600		1.39900		1.40600	0.04926	5.072e-02	0.32010
12/17/2009 12:01	1.3010	1.029	0.27210		0.48060		0.47860	0.05853	7.180e-03	0.11930
1/6/2010 11:51	0.6021	1.028	-0.42630		-0.75310		-0.75140	0.05856	1.764e-02	-0.18740
1/19/2010 10:01	2.1460	1.203	0.94310		1.65800		1.67400	0.04931	7.127e-02	0.38110
2/4/2010 10:41	1.0790	1.186	-0.10650		-0.18730		-0.18630	0.05019	9.266e-04	-0.04283
2/23/2010 12:56	0.6021	1.706	-1.10400		-1.92000		-1.94900	0.02817	5.344e-02	-0.33170
6/9/2010 9:45	4.4470	4.195	0.25260		0.44280		0.44090	0.04389	4.501e-03	0.09447
3/1/2012 12:00	3.5310	4.077	-0.54540		-0.95340		-0.95290	0.03864	1.827e-02	-0.19100
7/19/2012 10:15	1.4470	2.680	-1.23300		-2.12400		-2.16500	0.01051	2.395e-02	-0.22310
11/7/2012 11:10	1.7990	1.596	0.20310		0.35390		0.35220	0.03210	2.077e-03	0.06415
3/27/2013 11:35	1.0790	1.613	-0.53420		-0.93030		-0.92970	0.03146	1.406e-02	-0.16760

Statistical Plots





Models Considered

	Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
	logFCB ~ logTURB	1	0.5834	65.93	65.57	16.58	33.42	<NA>	± 180
	logFCB ~ SC	1	0.654	57.2	56.74	44.42	41.9	<NA>	± 210
	logFCB ~ logSC	1	0.697	51.38	50.86	62.97	47.51	<NA>	± 240
	logFCB ~ logTURB + logQ	2	0.5437	70.72	70.09	3.303	29.23	1.82	± 160
	logFCB ~ logTURB + logSC	2	0.5603	68.91	68.25	9.075	30.93	2.207	± 170
	logFCB ~ Q + logTURB	2	0.5622	68.7	68.03	9.747	30.96	1.159	± 170
	logFCB ~ logTURB + logQ + sin4DY	3	0.5361	71.85	70.93	1.725	28.74	1.821	± 160
	logFCB ~ logTURB + logQ + sin2DY	3	0.5409	71.34	70.41	3.334	29.24	1.82	± 160
	logFCB ~ logTURB + logQ + cos4DY	3	0.5448	70.92	69.97	4.672	29.54	1.835	± 160
	logFCB ~ logTURB + logQ + sin2DY + sin4DY	4	0.5276	73.03	71.85	-0.05055	28.13	1.821	± 150
	logFCB ~ logTURB + logQ + SC + sin4DY	4	0.5372	72.04	70.81	3.105	29.06	3.104	± 160
	logFCB ~ logTURB + logQ + cos4DY + sin4DY	4	0.5379	71.97	70.73	3.345	29.15	1.837	± 160
	logFCB ~ logTURB + logQ + logSC + sin2DY + sin4DY	5	0.5302	73.06	71.57	1.85	28.61	2.286	± 150
	logFCB ~ logTURB + logQ + sin2DY + cos2DY + sin4DY	5	0.5303	73.05	71.55	1.891	28.68	2.27	± 150
	logFCB ~ logTURB + logQ + sin2DY + cos4DY + sin4DY	5	0.5305	73.04	71.54	1.938	28.71	1.842	± 150
	logFCB ~ logTURB + logQ + SC + logSC + sin2DY + sin4DY	6	0.5323	73.15	71.34	3.572	29.03	3.734	± 160
	logFCB ~ logTURB + logQ + logSC + sin2DY + cos2DY + sin4DY	6	0.5328	73.1	71.29	3.724	29.13	2.52	± 160
	logFCB ~ Q + logTURB + logQ + logSC + sin2DY + sin4DY	6	0.533	73.07	71.26	3.814	29.07	3.558	± 160

Model-Calibration Data Set

0	Date	logFCB	logTURB	FCB	TURB	Computed logFCB	Computed FCB	Residual	Normal Quantiles	Censored Values
1	2004-07-27	2.301	2.301	200	200	3.34	4894	-1.04	-1.57	--
2	2005-01-27	2.255	1.908	180	81	2.831	1516	-0.576	-1.03	--
3	2005-03-23	3.462	2.415	2900	260	3.488	6878	-0.0254	0.0652	--
4	2005-06-06	2.255	2.462	180	290	3.549	7924	-1.29	-2.5	--
5	2005-08-31	2.806	1.985	640	96.52	2.93	1902	-0.123	-0.197	--
6	2007-01-10	1.924	0.8388	84	6.9	1.444	62.16	0.48	0.689	--

7	2007-03-12	1.301	1.362	20	23	2.122	296.2	-0.821	-1.49	--
8	2007-03-21	2.342	1.415	220	26	2.191	347.2	0.151	0.359	--
9	2007-03-27	3.079	2.398	1200	250	3.466	6537	-0.387	-0.657	--
10	2007-04-02	3.748	2.58	5600	380	3.702	11250	0.0467	0.17	--
11	2007-04-18	2.477	2.114	300	130	3.097	2799	-0.62	-1.07	--
12	2007-05-24	4.792	2.731	62000	538.8	3.898	17700	0.894	1.57	--
13	2007-05-25	3.763	2.319	5800	208.3	3.363	5159	0.401	0.593	--
14	2007-07-11	3.778	2.322	6000	210	3.367	5214	0.411	0.625	--
15	2007-08-16	2.204	1.412	160	25.8	2.187	343.7	0.0176	0.118	--
16	2007-09-06	2.38	1.362	240	23	2.122	296.2	0.258	0.473	--
17	2007-11-26	1.857	0.6435	72	4.4	1.19	34.68	0.667	0.944	--
18	2007-12-06	2.556	0.699	360	5	1.262	40.93	1.29	2.5	--
19	2007-12-13	3.778	2.406	6000	255	3.477	6705	0.301	0.532	--
20	2008-03-06	3.176	2.779	1500	601.4	3.96	20400	-0.784	-1.34	--
21	2008-04-14	2.74	2.362	550	230	3.419	5867	-0.678	-1.17	--
22	2008-05-29	3.279	2.362	1900	230	3.419	5867	-0.14	-0.25	--
23	2008-06-30	3.301	2.324	2000	211	3.37	5245	-0.0691	-0.0391	--
24	2008-08-05	2.041	1.477	110	30	2.272	418	-0.23	-0.387	--
25	2008-09-16	3.732	2.23	5400	170	3.248	3964	0.484	0.757	--
26	2009-04-06	1.903	1.724	80	53	2.592	874.4	-0.689	-1.23	--
27	2009-04-13	3.255	2.146	1800	140	3.139	3082	0.116	0.304	--
28	2009-04-28	4.322	2.447	21000	280	3.53	7572	0.793	1.12	--
29	2009-06-16	4.204	2.897	16000	788	4.112	28970	0.0918	0.223	--
30	2009-07-30	4.114	2.322	13000	210	3.367	5214	0.746	1.07	--
31	2009-09-09	3.342	2.322	2200	210	3.367	5214	-0.0251	0.0913	--
32	2009-09-24	3.699	2.892	5000	779.3	4.106	28550	-0.407	-0.757	--
33	2009-11-03	2	2.146	100	140	3.139	3082	-1.14	-1.93	--
34	2009-11-19	1.477	0.8342	30	6.826	1.438	61.29	0.0394	0.144	--
35	2009-12-01	2	0.654	100	4.508	1.204	35.79	0.796	1.17	--
36	2009-12-17	1.301	0.5189	20	3.303	1.029	23.91	0.272	0.502	--
37	2010-01-06	0.6021	0.5185	4	3.3	1.028	23.88	-0.426	-0.792	--
38	2010-01-19	2.146	0.6532	140	4.5	1.203	35.71	0.943	1.93	--
39	2010-02-04	1.079	0.6398	12	4.363	1.186	34.3	-0.106	-0.118	--
40	2010-02-23	0.6021	1.041	4	11	1.706	113.8	-1.1	-1.78	--
41	2010-03-10	3	2.176	1000	150	3.178	3370	-0.178	-0.332	--
42	2010-04-14	1.477	1.049	30	11.19	1.716	116.4	-0.239	-0.416	--
43	2010-04-23	3.934	2.041	8600	110	3.003	2254	0.931	1.78	--
44	2010-05-13	4.477	2.663	30000	460	3.809	14410	0.668	0.986	--
45	2010-06-09	4.447	2.96	28000	911.9	4.195	35010	0.253	0.444	--
46	2010-06-10	3.613	2.204	4100	160	3.214	3664	0.398	0.562	--
47	2010-06-13	4.146	2.523	14000	333.2	3.627	9487	0.519	0.792	--
48	2010-06-14	4.146	2.431	14000	269.6	3.508	7210	0.638	0.866	--
49	2010-06-14	3.732	2.176	5400	150	3.178	3370	0.554	0.828	--
50	2010-06-15	3.176	2.398	1500	250	3.466	6537	-0.29	-0.532	--
51	2010-06-16	3.279	2.339	1900	218.3	3.389	5483	-0.111	-0.144	--
52	2010-07-06	3.954	2.146	9000	140	3.139	3082	0.815	1.28	--
53	2010-08-19	3.176	1.559	1500	36.23	2.378	533.9	0.798	1.23	--
54	2010-08-25	4.301	2.38	20000	240	3.443	6200	0.858	1.34	--
55	2010-11-16	3.301	2.146	2000	140	3.139	3082	0.162	0.387	--
56	2011-01-19	2.771	1.315	590	20.66	2.061	257.7	0.709	1.03	--
57	2011-03-07	1.785	1.146	61	14	1.842	155.6	-0.057	0.013	--
58	2011-03-16	1.857	1.279	72	19	2.014	231.2	-0.157	-0.277	--

59	2011-04-06	1.568	1.204	37	16	1.918	185	-0.349	-0.593	--
60	2011-04-18	1.826	1.279	67	19	2.014	231.2	-0.188	-0.359	--
61	2011-05-02	1.602	1.396	40	24.92	2.167	328.6	-0.565	-0.986	--
62	2011-05-16	2	1.362	100	23	2.122	296.2	-0.122	-0.17	--
63	2011-06-07	1.94	1.643	87	44	2.487	686.9	-0.548	-0.944	--
64	2011-06-21	3.079	2.041	1200	110	3.003	2254	0.0759	0.197	--
65	2011-06-22	3.041	2.124	1100	133	3.11	2883	-0.0688	-0.013	--
66	2011-08-15	2.708	2.443	510	277.5	3.524	7483	-0.817	-1.41	--
67	2011-09-22	3.146	2.041	1400	110	3.003	2254	0.143	0.332	--
68	2011-12-20	3.771	2.699	5900	499.6	3.856	16040	-0.0848	-0.0913	--
69	2012-02-06	3.079	2.13	1200	134.9	3.118	2937	-0.0391	0.0391	--
70	2012-03-01	3.531	2.869	3400	740	4.077	26700	-0.545	-0.866	--
71	2012-04-07	3.748	2.114	5600	130	3.097	2799	0.651	0.904	--
72	2012-04-17	2.863	1.562	730	36.49	2.382	538.9	0.481	0.723	--
73	2012-05-09	2.176	1.703	150	50.5	2.565	821.3	-0.389	-0.689	--
74	2012-05-30	2.204	1.638	160	43.49	2.481	676.5	-0.276	-0.502	--
75	2012-06-12	2.716	1.748	520	56	2.623	939.2	0.0929	0.25	--
76	2012-06-18	2.778	2.176	600	150	3.178	3370	-0.4	-0.723	--
77	2012-06-19	2.756	2.079	570	120	3.052	2523	-0.296	-0.562	--
78	2012-07-12	1.519	1.704	33	50.59	2.566	823.2	-1.05	-1.67	--
79	2012-07-19	1.447	1.792	28	61.93	2.68	1070	-1.23	-2.13	--
80	2012-09-11	1.954	1.653	90	45	2.5	707.3	-0.546	-0.904	--
81	2012-11-07	1.799	0.9564	63	9.044	1.596	88.28	0.203	0.416	--
82	2013-01-29	1.279	1.277	19	18.91	2.012	229.8	-0.733	-1.28	--
83	2013-03-13	1.672	1.301	47	20	2.043	247.1	-0.371	-0.625	--
84	2013-03-27	1.079	0.9696	12	9.324	1.613	91.84	-0.534	-0.828	--
85	2013-04-15	2.146	1.505	140	32	2.308	454.5	-0.162	-0.304	--
86	2013-04-24	3.839	2.021	6900	104.9	2.976	2119	0.862	1.41	--
87	2013-05-09	3.778	2.564	6000	366.8	3.682	10750	0.0965	0.277	--
88	2013-05-21	3.919	2.079	8300	120	3.052	2523	0.867	1.49	--
89	2013-07-29	4.114	2.204	13000	160	3.214	3664	0.9	1.67	--
90	2013-08-07	3.322	1.932	2100	85.5	2.861	1626	0.461	0.657	--
91	2014-04-09	1.041	1.041	11	11	1.706	113.8	-0.665	-1.12	--
92	2014-05-14	3.653	1.705	4500	50.66	2.567	824.8	1.09	2.13	--
93	2014-06-03	2.079	1.531	120	34	2.342	491.7	-0.263	-0.473	--
94	2014-06-09	3.146	2.255	1400	180	3.281	4269	-0.135	-0.223	--
95	2014-07-15	2.23	1.509	170	32.28	2.313	459.7	-0.0823	-0.0652	--
96	2014-08-04	1.968	1.439	93	27.49	2.222	373.2	-0.254	-0.444	--

Definitions

FCB: Fecal coliforms in cfu/100ml (31625)

TURB: Turbidity in FNU (63680)

Model Archive Summary for Arsenic Concentration at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the arsenic concentration (As) model developed to compute hourly As from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 11, 1998 to August 7, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 189 concurrent measurements of arsenic concentration, streamflow, and water temperature collected from May 11, 1998 through August 7, 2014. Samples were collected throughout the range of continuously observed hydrologic and specific conductance conditions. No samples were below laboratory reporting levels. Summary statistics and complete model-calibration dataset are provided below. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. A sample collected June 9, 2005 was deemed an outlier and was removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating arsenic concentration. A variety of models that predict As and models that predict $\log_{10}(\text{As})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted As were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the

range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(As)$.

Streamflow and water temperature were selected as the best predictors of As based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for arsenic concentration at site number 07144100.

Arsenic concentration-based model:

$$\log_{10}(As) = -0.183 \times \log_{10}(Q) + 0.014 \times TEMP + 0.880 ,$$

where

As = arsenic concentration, in milligrams per liter (mg/L); and

Q = streamflow in cubic feet per second (ft^3/s); and

TEMP = water temperature in degrees Celsius.

Streamflow is a good explanatory variable for modeling arsenic because it can be a good indicator of the source of the arsenic. When concentrations of arsenic are diluted by higher in-stream water volumes, there is potential that the source may be an underlying aquifer instead of being directly associated with rainfall and runoff. However, when higher streamflows increase the arsenic concentration, this potentially indicates that sources are directly related to rainfall and runoff. The physical significance of the correlation between water temperature and arsenic is less certain; however, the statistical correlation is strong once the variability for streamflow is accounted for. The model created using water temperature and streamflow had the highest R^2 value and the lowest values for standard error, Mallows' C_p , and $PRESS$.

The log-transformed model may be retransformed to the original units so that As can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.03. The retransformed model, accounting for BCF is:

$$As = \frac{7.81 \times 10^{0.014 \times TEMP}}{Q^{0.183}}.$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(As) = -0.25 \times \log_{10}(Q) + 1.30$
2.0	2007	--	$\log_{10}(As) = -0.183 \times \log_{10}(Q) + 0.014 \times TEMP + 0.880$

Arsenic Concentration Record

The As record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick
Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

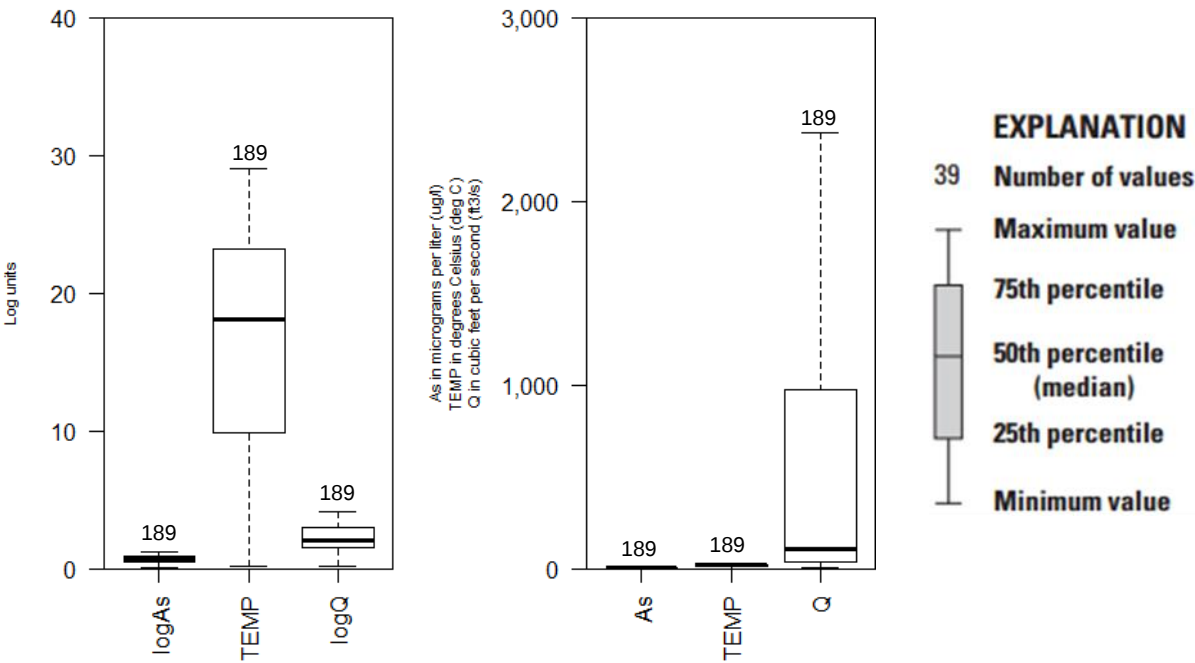
Model

$$\log As = + 0.014 * TEMP + -0.183 * \log Q + 0.88$$

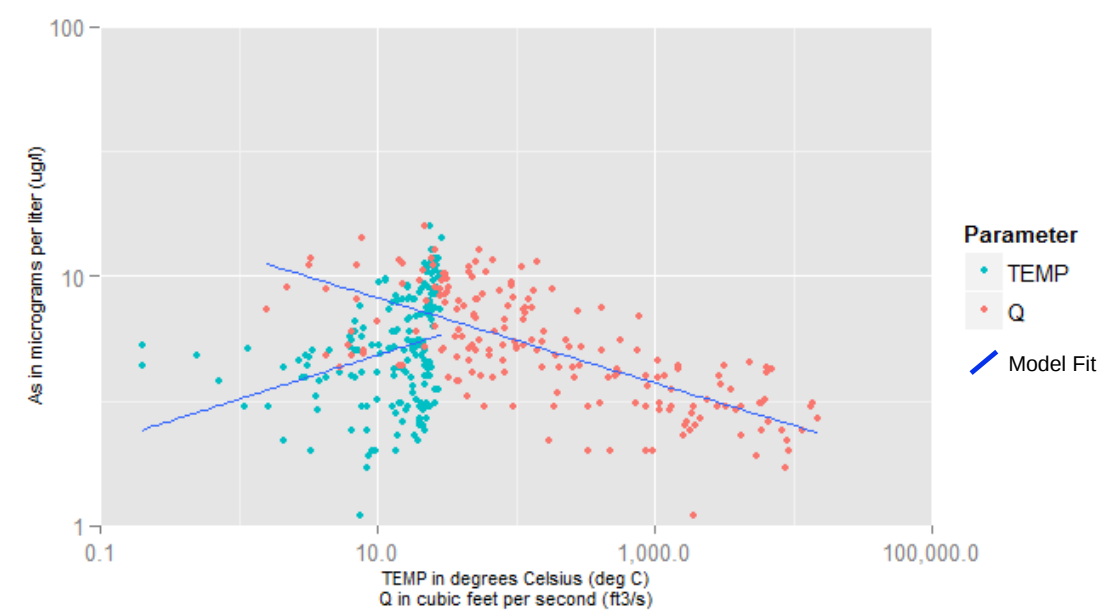
Variable Summary Statistics

	logAs	TEMP	logQ	As	Q
Minimum	0.0414	0.20	0.204	1.10	1.6
1st Quartile	0.5310	9.85	1.570	3.40	37.5
Median	0.6990	18.10	2.040	5.00	110.0
Mean	0.7040	16.50	2.230	5.75	1230.0
3rd Quartile	0.8920	23.20	2.990	7.80	978.0
Maximum	1.2000	29.00	4.180	15.90	15100.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	189
Standard error (RMSE)	0.114
Upper Model standard percentage error (MSPE)	30.1
Lower Model standard percentage error (MSPE)	23.1
Coefficient of determination (R ²)	0.741
Adjusted Coefficient of Determination (Adj. R ²)	0.738
Bias Correction Factor (BCF)	1.03
Variance Inflation Factors (VIF)	
TEMP	1.010864
logQ	1.010864

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.880	0.02660	33.1	8.65e-80
TEMP	0.014	0.00106	13.2	1.65e-28
logQ	-0.183	0.00905	-20.2	1.07e-48

Correlation Matrix

	Intercept	TEMP	logQ
Intercept	1.000	-0.579	-0.689
TEMP	-0.579	1.000	-0.104
logQ	-0.689	-0.104	1.000

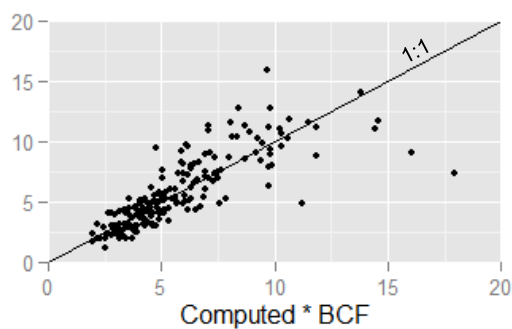
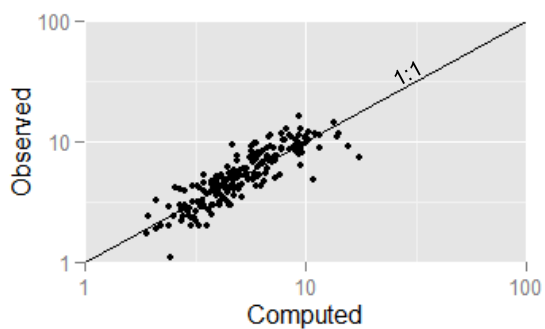
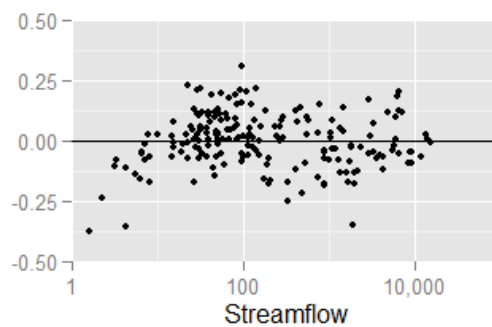
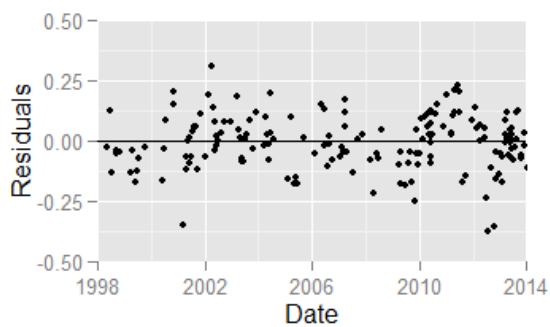
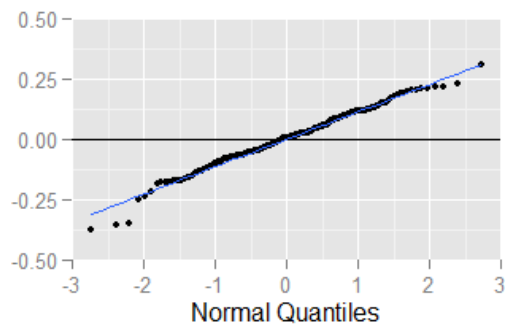
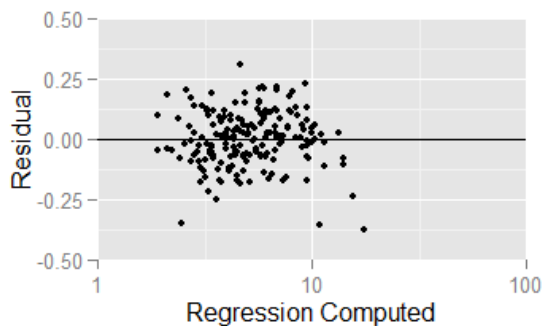
Outlier Test Criteria

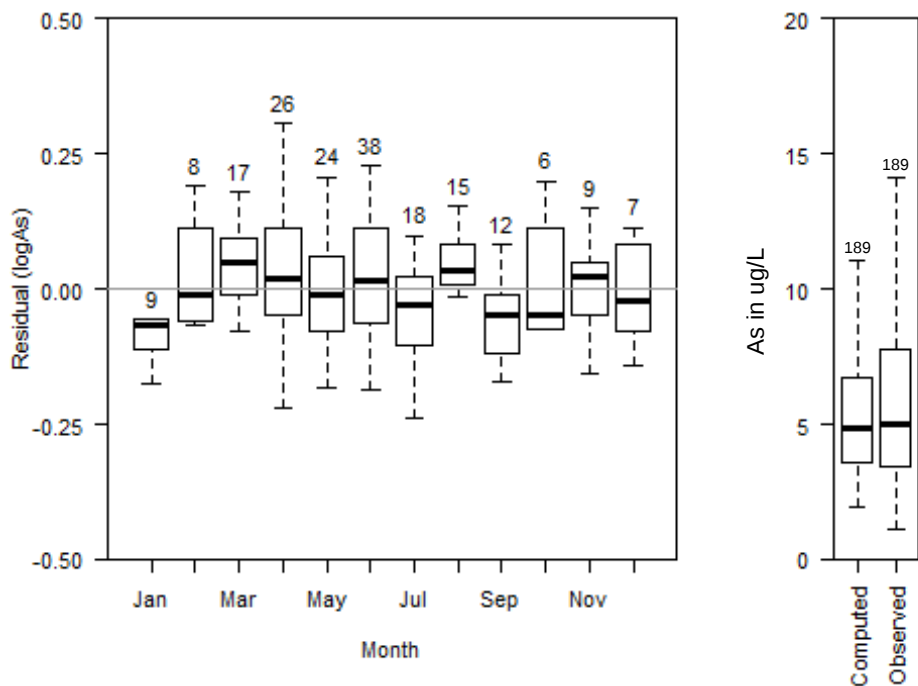
Leverage	Cook's D	DFFITS
0.03174603	0.19457636	0.20573780

Flagged Observations

	logAs	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFFITS
10/26/2000 11:36	0.61280	0.4124	0.200400		1.77400		1.78400	0.021040	2.254e-02	0.261500
3/14/2001 10:41	0.04139	0.3883	-0.346900		-3.06900		-3.14100	0.020450	6.554e-02	-0.453800
4/9/2002 10:06	0.97310	0.6657	0.307500		2.70400		2.75100	0.008704	2.140e-02	0.257800
3/20/2003 10:21	0.50510	0.3251	0.180000		1.59700		1.60400	0.026140	2.283e-02	0.262800
7/30/2003 12:21	1.14900	1.1260	0.023530		0.20950		0.20890	0.032840	4.965e-04	0.038490
1/27/2005 11:21	0.34240	0.5019	-0.159500		-1.41300		-1.41700	0.023180	1.579e-02	-0.218200
7/27/2006 11:16	1.04100	1.1450	-0.103800		-0.92450		-0.92420	0.033310	9.817e-03	-0.171500
2/5/2007 9:31	0.64350	0.6683	-0.024900		-0.22160		-0.22110	0.032560	5.509e-04	-0.040550
4/14/2008 12:11	0.30100	0.5193	-0.218300		-1.92300		-1.93700	0.011660	1.454e-02	-0.210400
11/3/2009 9:21	0.30100	0.5510	-0.250000		-2.20100		-2.22400	0.010610	1.731e-02	-0.230300
1/19/2011 11:41	0.72430	0.5349	0.189400		1.68200		1.69100	0.028060	2.724e-02	0.287300
6/7/2011 8:31	1.20100	0.9722	0.229200		2.02300		2.04100	0.016180	2.244e-02	0.261700
7/12/2012 10:16	0.95420	1.1920	-0.237600		-2.12300		-2.14300	0.039580	6.191e-02	-0.435100
7/19/2012 10:16	0.86330	1.2400	-0.376600		-3.37800		-3.47700	0.046800	1.867e-01	-0.770400
10/24/2012 9:30	0.68120	1.0360	-0.354300		-3.13800		-3.21600	0.022670	7.614e-02	-0.489800
12/12/2012 10:00	0.63350	0.7760	-0.142600		-1.27000		-1.27200	0.033950	1.889e-02	-0.238500
1/16/2013 9:30	0.68120	0.7377	-0.056420		-0.50330		-0.50230	0.036410	3.190e-03	-0.097630
1/29/2013 10:06	0.69020	0.8637	-0.173500		-1.53300		-1.53900	0.018290	1.460e-02	-0.210000
7/9/2013 9:31	1.06800	1.1500	-0.081900		-0.72960		-0.72870	0.033970	6.241e-03	-0.136700
8/7/2013 9:46	0.49140	0.4859	0.005414		0.04821		0.04808	0.033010	2.644e-05	0.008883
6/5/2014 10:40	1.05300	0.8367	0.216400		1.90500		1.91900	0.011510	1.409e-02	0.207100

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logAs ~ logQ	1	0.1585	49.8	49.53	251.4	4.796	1 ± 37	
logAs ~ logSC	1	0.1765	37.79	37.45	355.8	5.926	1 ± 42	
logAs ~ SC	1	0.185	31.61	31.24	409.5	6.53	1 ± 44	
logAs ~ TEMP + logSC	2	0.1123	74.96	74.69	34.7	2.411	1.082 ± 26	
logAs ~ TEMP + logQ	2	0.1142	74.08	73.8	42.3	2.514	1.011 ± 27	
logAs ~ logQ + cos(2piD/365)	2	0.1207	71.05	70.74	68.68	2.807	1.058 ± 28	
logAs ~ TEMP + logQ + logSC	3	0.1031	78.98	78.64	1.704	2.057	1.156 ± 24	
logAs ~ TEMP + logQ + SC	3	0.104	78.6	78.26	4.98	2.102	1.176 ± 24	
logAs ~ TEMP + logSC + cos(2piD/365)	3	0.1114	75.49	75.09	32.05	2.389	5.738 ± 26	
logAs ~ Q + TEMP + logQ + logSC	4	0.1028	79.22	78.76	1.677	2.048	2.424 ± 24	
logAs ~ TEMP + logQ + logSC + SC	4	0.103	79.15	78.69	2.278	2.068	1.179 ± 24	
logAs ~ TEMP + logQ + logSC + cos(4piD/365)	4	0.1031	79.11	78.65	2.628	2.066	1.264 ± 24	
logAs ~ Q + TEMP + logQ + logSC + cos(4piD/365)	5	0.1027	79.38	78.82	2.204	2.053	2.458 ± 24	
logAs ~ TEMP + logQ + logSC + SC + cos(4piD/365)	5	0.1028	79.33	78.76	2.698	2.071	1.308 ± 24	
logAs ~ Q + TEMP + logQ + logSC + SC	5	0.103	79.24	78.67	3.455	2.074	3.563 ± 24	
logAs ~ Q + TEMP + logQ + logTEMP + logSC + cos(4piD/365)	6	0.1027	79.48	78.8	3.398	2.061	2.47 ± 24	
logAs ~ Q + TEMP + logQ + logSC + SC + cos(4piD/365)	6	0.1029	79.43	78.75	3.809	2.075	3.565 ± 24	
logAs ~ TEMP + logQ + logTEMP + logSC + SC + cos(4piD/365)	6	0.1029	79.41	78.73	3.982	2.079	7.944 ± 24	

Model-Calibration Data Set

0	Date	logAs	TEMP	logQ	As	Q	Computed logAs	Computed As	Residual	Normal Quantiles	Censored Values
1	1998-05-11	0.7404	19.43	2.111	5.5	129	0.7677	6.054	-0.0273	-0.241	--
2	1998-06-24	0.8692	24.42	2.615	7.4	412.1	0.7456	5.754	0.124	1.15	--
3	1998-07-10	0.5441	26.13	3.125	3.5	1334	0.6764	4.907	-0.132	-1.2	--
4	1998-09-22	0.5563	18.17	2.947	3.6	884.6	0.5974	4.091	-0.0411	-0.338	--
5	1998-09-25	0.415	20.32	3.818	2.6	6575	0.4685	3.04	-0.0535	-0.482	--
6	1998-11-05	0.2304	8.4	3.938	1.7	8663	0.2792	1.966	-0.0488	-0.452	--
7	1999-04-07	0.3617	14.09	3.202	2.3	1594	0.4933	3.219	-0.132	-1.18	--

8	1999-04-16	0.2788	8.753	3.733	1.9	5405	0.3216	2.168	-0.0428	-0.366	--
9	1999-05-24	0.3979	19.92	3.219	2.5	1656	0.5722	3.86	-0.174	-1.59	--
10	1999-06-21	0.4314	20.4	3.334	2.7	2158	0.558	3.736	-0.127	-1.15	--
11	1999-07-20	0.5441	27.55	3.547	3.5	3528	0.6193	4.303	-0.0753	-0.737	--
12	1999-09-28	0.4472	13.6	3.264	2.8	1835	0.4753	3.088	-0.0281	-0.254	--
13	2000-05-31	0.6335	24.31	2.312	4.3	205.1	0.7994	6.513	-0.166	-1.42	--
14	2000-06-28	0.6021	22.62	3.067	4	1168	0.6377	4.489	-0.0357	-0.31	--
15	2000-07-20	0.9395	25.85	2.132	8.7	135.4	0.8539	7.384	0.0856	0.737	--
16	2000-10-26	0.6128	16.2	3.808	4.1	6430	0.4124	2.672	0.2	1.75	--
17	2000-11-08	0.7924	8.04	1.914	6.2	82	0.6437	4.551	0.149	1.32	--
18	2001-03-14	0.04139	7.605	3.279	1.1	1903	0.3883	2.527	-0.347	-2.2	--
19	2001-04-13	0.4914	14.7	2.602	3.1	400	0.6115	4.226	-0.12	-1.13	--
20	2001-04-26	0.716	19.19	2.001	5.2	100.3	0.7843	6.291	-0.0683	-0.686	--
21	2001-05-08	0.7324	18.07	2.186	5.4	153.3	0.7349	5.615	-0.00251	-0.0663	--
22	2001-06-04	0.5911	17.7	3.021	3.9	1049	0.5772	3.905	0.0138	0.106	--
23	2001-06-06	0.3424	19.82	3.952	2.2	8956	0.4369	2.827	-0.0944	-0.966	--
24	2001-06-23	0.4771	23.08	3.628	3	4250	0.5418	3.599	-0.0647	-0.605	--
25	2001-07-11	0.9956	27.7	1.69	9.9	49	0.9606	9.441	0.035	0.366	--
26	2001-08-02	1.072	27.52	1.394	11.8	24.76	1.012	10.63	0.0597	0.542	--
27	2001-08-28	1.009	24.5	1.491	10.2	31	0.952	9.255	0.0566	0.527	--
28	2001-09-20	0.3617	18.67	3.62	2.3	4166	0.4814	3.132	-0.12	-1.1	--
29	2001-10-31	0.9191	13.67	1.453	8.3	28.35	0.8069	6.628	0.112	0.925	--
30	2002-01-10	0.5798	3.777	1.574	3.8	37.52	0.6458	4.574	-0.0661	-0.637	--
31	2002-02-21	0.8808	7.485	1.623	7.6	42	0.689	5.051	0.192	1.64	--
32	2002-04-09	0.9731	10.35	1.971	9.4	93.59	0.6657	4.787	0.307	2.73	--
33	2002-04-22	0.6232	13.3	3.171	4.2	1481	0.4881	3.181	0.135	1.26	--
34	2002-05-13	0.699	15.82	2.621	5	417.9	0.6238	4.347	0.0752	0.621	--
35	2002-05-22	0.699	18.1	2.152	5	141.9	0.7415	5.701	-0.0425	-0.352	--
36	2002-06-06	0.716	18.1	2.387	5.2	243.9	0.6986	5.164	0.0174	0.16	--
37	2002-06-13	0.4914	22.7	3.758	3.1	5729	0.5128	3.366	-0.0214	-0.2	--
38	2002-07-09	1.009	28.52	1.477	10.2	30	1.011	10.6	-0.00244	-0.053	--
39	2002-08-15	0.699	22.1	2.875	5	750	0.6656	4.786	0.0334	0.338	--
40	2002-09-19	1.049	21.9	1.176	11.2	15	0.973	9.714	0.0762	0.637	--
41	2002-12-18	0.7559	6.42	1.613	5.7	41	0.6759	4.902	0.0799	0.653	--
42	2003-03-20	0.5051	9.865	3.799	3.2	6294	0.3251	2.185	0.18	1.54	--
43	2003-04-17	0.7782	13.65	1.843	6	69.73	0.7354	5.621	0.0428	0.394	--
44	2003-04-23	0.6435	14.5	2.464	4.4	290.9	0.634	4.45	0.00947	0.0663	--
45	2003-05-14	0.415	15.1	3.233	2.6	1710	0.502	3.284	-0.087	-0.885	--
46	2003-05-29	0.6812	21.01	2.286	4.8	193	0.7579	5.92	-0.0766	-0.791	--
47	2003-06-11	0.7324	21.6	1.987	5.4	97	0.8208	6.842	-0.0884	-0.904	--
48	2003-06-24	0.9294	25.88	1.756	8.5	57	0.923	8.658	0.00642	0.0398	--
49	2003-07-30	1.149	29.01	0.8865	14.1	7.7	1.126	13.81	0.0235	0.214	--
50	2003-09-03	0.7404	20.09	2.757	5.5	571.5	0.6589	4.713	0.0815	0.686	--
51	2003-10-14	0.4914	14.4	3.033	3.1	1079	0.5287	3.492	-0.0373	-0.324	--
52	2003-12-11	0.7076	1.155	1.658	5.1	45.48	0.5938	4.057	0.114	0.987	--
53	2004-03-09	0.3802	8.285	3.254	2.4	1794	0.4024	2.611	-0.0222	-0.214	--
54	2004-03-30	0.716	13.37	2.465	5.2	292	0.6178	4.288	0.0982	0.827	--
55	2004-04-26	0.8325	16.86	1.708	6.8	51	0.8052	6.601	0.0273	0.268	--
56	2004-05-13	0.4624	16.1	3.104	2.9	1270	0.5396	3.581	-0.0772	-0.809	--
57	2004-05-26	0.8451	20.57	1.699	7	50	0.8588	7.468	-0.0137	-0.133	--
58	2004-06-16	1.104	24.7	1.736	12.7	54.5	0.91	8.403	0.194	1.69	--
59	2004-06-22	0.6628	21.72	3.017	4.6	1040	0.6343	4.454	0.0285	0.31	--
60	2004-07-27	0.4914	20.95	3.767	3.1	5845	0.4867	3.17	0.00471	-0.0132	--
61	2005-01-27	0.3424	2.1	2.234	2.2	171.3	0.5019	3.283	-0.159	-1.39	--
62	2005-03-23	0.3802	6.466	3.766	2.4	5836	0.2834	1.985	0.0968	0.809	--
63	2005-05-10	0.5315	17.9	2.294	3.4	197	0.7126	5.334	-0.181	-1.75	--
64	2005-05-27	0.4914	20.6	2.862	3.1	727.9	0.6469	4.585	-0.156	-1.32	--

65	2005-06-06	0.3979	21.17	3.288	2.5	1943	0.577	3.903	-0.179	-1.64	--
66	2005-08-31	0.8633	24.61	2.047	7.3	111.5	0.8519	7.351	0.0114	0.0796	--
67	2006-02-09	0.5911	3	1.519	3.9	33	0.6451	4.566	-0.0541	-0.497	--
68	2006-05-02	0.9085	18.39	2.086	8.1	121.8	0.7576	5.916	0.151	1.35	--
69	2006-06-08	1.104	25.3	1.415	12.7	26	0.9771	9.807	0.127	1.2	--
70	2006-06-26	0.8261	24.31	2.049	6.7	111.9	0.8474	7.275	-0.0214	-0.187	--
71	2006-07-27	1.041	25.4	0.5021	11	3.177	1.145	14.44	-0.104	-1.03	--
72	2006-08-15	1.045	23.78	0.8451	11.1	7	1.06	11.86	-0.0145	-0.146	--
73	2006-08-23	1.064	26.85	1.163	11.6	14.56	1.045	11.46	0.0196	0.173	--
74	2006-09-27	0.9031	18.2	0.8451	8	7	0.9815	9.906	-0.0784	-0.827	--
75	2007-01-10	0.6435	3.1	1.159	4.4	14.42	0.7122	5.329	-0.0688	-0.703	--
76	2007-02-05	0.6435	0.2	1.176	4.4	15	0.6683	4.817	-0.0249	-0.227	--
77	2007-03-12	0.7782	12.7	1.279	6	19	0.8251	6.91	-0.0469	-0.409	--
78	2007-03-21	0.9031	15.3	1.708	8	51	0.7833	6.276	0.12	1.1	--
79	2007-03-27	0.7782	17	2.198	6	157.9	0.7176	5.395	0.0606	0.573	--
80	2007-04-02	0.6021	13.1	3.46	4	2882	0.4325	2.798	0.17	1.46	--
81	2007-04-18	0.4771	12.9	2.935	3	861	0.5255	3.466	-0.0483	-0.423	--
82	2007-07-11	0.4771	23.66	3.284	3	1924	0.6127	4.237	-0.136	-1.23	--
83	2007-09-06	0.9542	23.2	1.415	9	26	0.9476	9.163	0.00662	0.053	--
84	2007-11-26	0.699	4.5	1.462	5	29	0.6764	4.907	0.0225	0.2	--
85	2008-03-06	0.301	3.303	2.99	2	977.7	0.3807	2.484	-0.0796	-0.846	--
86	2008-04-14	0.301	9.21	2.685	2	484	0.5193	3.418	-0.218	-1.89	--
87	2008-05-29	0.4771	20.28	3.454	3	2846	0.5342	3.537	-0.0571	-0.542	--
88	2008-06-30	0.6021	23.83	2.942	4	874.4	0.6777	4.922	-0.0756	-0.773	--
89	2008-08-05	1.041	26.6	1.407	11	25.5	0.9969	10.26	0.0445	0.409	--
90	2009-04-06	0.4771	7.76	2.272	3	187	0.5744	3.88	-0.0973	-0.987	--
91	2009-04-13	0.301	9.7	2.933	2	856.8	0.4809	3.129	-0.18	-1.69	--
92	2009-04-28	0.301	13.58	3.963	2	9190	0.3472	2.3	-0.0462	-0.394	--
93	2009-06-16	0.4771	22.67	2.939	3	868.3	0.662	4.747	-0.185	-1.81	--
94	2009-07-30	0.6021	22.12	2.712	4	515.4	0.6956	5.129	-0.0935	-0.945	--
95	2009-09-09	0.4771	20.1	3.509	3	3227	0.5218	3.437	-0.0447	-0.38	--
96	2009-09-24	0.4771	16.41	2.522	3	333	0.65	4.618	-0.173	-1.46	--
97	2009-11-03	0.301	9.27	2.516	2	328	0.551	3.677	-0.25	-2.07	--
98	2009-11-19	0.699	7.273	1.813	5	65	0.6514	4.632	0.0476	0.438	--
99	2009-12-01	0.6021	6.473	1.74	4	55	0.6534	4.654	-0.0513	-0.467	--
100	2009-12-17	0.4771	1.61	1.771	3	59	0.5795	3.926	-0.102	-1.01	--
101	2010-01-06	0.4771	1.1	1.982	3	96	0.5338	3.533	-0.0567	-0.527	--
102	2010-01-19	0.6628	2.703	1.903	4.6	80	0.5707	3.847	0.092	0.773	--
103	2010-02-04	0.6812	3	1.806	4.8	64	0.5926	4.046	0.0886	0.755	--
104	2010-02-23	0.5911	2.847	1.833	3.9	68.13	0.5855	3.98	0.00558	0.0132	--
105	2010-03-10	0.6128	9.85	2.74	4.1	550	0.5182	3.409	0.0946	0.791	--
106	2010-04-14	0.9085	16.4	1.724	8.1	53	0.7957	6.458	0.113	0.945	--
107	2010-04-23	0.7404	16.41	2.357	5.5	227.7	0.6802	4.95	0.0602	0.558	--
108	2010-05-13	0.6232	15.25	2.733	4.2	541.2	0.5953	4.071	0.0279	0.296	--
109	2010-06-09	0.5682	21.75	3.471	3.7	2959	0.5518	3.683	0.0164	0.146	--
110	2010-06-10	0.6435	23.8	3.505	4.4	3200	0.5744	3.88	0.0691	0.605	--
111	2010-06-13	0.3802	21.9	3.915	2.4	8227	0.4728	3.071	-0.0926	-0.925	--
112	2010-06-14	0.3802	22.07	4.063	2.4	11570	0.4481	2.901	-0.0679	-0.67	--
113	2010-06-14	0.4314	22.9	4.178	2.7	15060	0.4389	2.84	-0.00754	-0.106	--
114	2010-06-15	0.6335	23	3.809	4.3	6438	0.5077	3.328	0.126	1.18	--
115	2010-06-16	0.6532	23.62	3.682	4.5	4808	0.5395	3.581	0.114	0.966	--
116	2010-07-06	0.4771	23.2	4.127	3	13400	0.4524	2.929	0.0247	0.227	--
117	2010-08-19	1.013	24.99	1.785	10.3	61	0.9051	8.308	0.108	0.904	--
118	2010-08-25	0.8388	23.7	2.887	6.9	770	0.6859	5.016	0.153	1.39	--
119	2010-11-16	0.5911	6.973	2.418	3.9	262	0.5366	3.557	0.0545	0.512	--
120	2011-01-19	0.7243	0.2	1.907	5.3	80.75	0.5349	3.542	0.189	1.59	--
121	2011-03-07	0.699	6.937	1.708	5	51	0.6659	4.79	0.0331	0.324	--

122	2011-03-16	0.7243	9.18	1.681	5.3	48	0.7022	5.207	0.0221	0.187	--
123	2011-04-06	0.8633	12	1.58	7.3	38	0.7603	5.953	0.103	0.865	--
124	2011-04-18	0.9542	16.7	1.509	9	32.3	0.8392	7.138	0.115	1.03	--
125	2011-05-02	0.9823	11.61	1.462	9.6	29	0.7763	6.176	0.206	1.89	--
126	2011-06-07	1.201	24	1.342	15.9	21.97	0.9722	9.696	0.229	2.39	--
127	2011-06-21	1.037	23.4	2.041	10.9	109.9	0.8362	7.089	0.201	1.81	--
128	2011-06-22	1.013	22.78	1.659	10.3	45.65	0.897	8.155	0.116	1.05	--
129	2011-08-15	0.7993	25.03	1.415	6.3	26	0.9733	9.722	-0.174	-1.54	--
130	2011-09-22	0.6628	16.7	1.66	4.6	45.68	0.8117	6.7	-0.149	-1.29	--
131	2011-12-20	0.4624	3.7	3.037	2.9	1090	0.3776	2.466	0.0848	0.72	--
132	2012-02-06	0.5911	4.3	2.667	3.9	464	0.4538	2.939	0.137	1.29	--
133	2012-03-01	0.4771	8.407	3.117	3	1310	0.4291	2.777	0.048	0.452	--
134	2012-04-07	0.6335	14.14	2.414	4.3	259.4	0.6381	4.492	-0.0046	-0.0796	--
135	2012-04-17	0.8261	16.41	1.917	6.7	82.69	0.7605	5.956	0.0656	0.589	--
136	2012-06-18	0.8751	26.09	2.114	7.5	130	0.8605	7.498	0.0145	0.12	--
137	2012-06-19	0.9395	25.2	1.886	8.7	76.95	0.8897	8.019	0.0498	0.467	--
138	2012-07-12	0.9542	26.65	0.3424	9	2.2	1.192	16.08	-0.238	-1.97	--
139	2012-07-19	0.8633	28.27	0.2041	7.3	1.6	1.24	17.96	-0.377	-2.73	--
140	2012-09-11	0.9445	21.01	0.6335	8.8	4.3	1.06	11.86	-0.115	-1.08	--
141	2012-10-24	0.6812	19.3	0.6335	4.8	4.3	1.036	11.22	-0.354	-2.39	--
142	2012-11-07	0.7243	10.36	0.7924	5.3	6.2	0.8811	7.862	-0.157	-1.35	--
143	2012-11-14	0.7782	6.833	0.8195	6	6.6	0.8266	6.934	-0.0484	-0.438	--
144	2012-12-12	0.6335	2.1	0.7324	4.3	5.4	0.776	6.172	-0.143	-1.26	--
145	2013-01-16	0.6812	0.5	0.8195	4.8	6.6	0.7377	5.65	-0.0564	-0.512	--
146	2013-01-29	0.6902	10.49	0.8976	4.9	7.9	0.8637	7.552	-0.173	-1.5	--
147	2013-02-13	0.699	3.4	0.8976	5	7.9	0.7641	6.005	-0.0652	-0.621	--
148	2013-03-12	0.716	6.4	1.342	5.2	22	0.725	5.488	-0.00901	-0.12	--
149	2013-03-13	0.7404	6.573	1.73	5.5	53.73	0.6566	4.689	0.0837	0.703	--
150	2013-03-27	0.8195	6.86	1	6.6	10	0.794	6.433	0.0255	0.241	--
151	2013-04-15	0.7853	13.8	1.591	6.1	39	0.7835	6.279	0.00182	-0.0398	--
152	2013-04-15	0.8976	13.8	1.591	7.9	39	0.7835	6.279	0.114	1.01	--
153	2013-04-24	0.6128	5.407	1.913	4.1	81.85	0.6069	4.181	0.0059	0.0265	--
154	2013-05-06	0.7076	12.6	2.004	5.1	101	0.6912	5.077	0.0164	0.133	--
155	2013-05-09	0.7243	20.1	2.054	5.3	113.3	0.7874	6.335	-0.0631	-0.589	--
156	2013-05-15	0.9345	20.25	1.505	8.6	32	0.8897	8.02	0.0448	0.423	--
157	2013-05-21	0.8388	18.9	1.699	6.9	49.97	0.8355	7.079	0.00332	-0.0265	--
158	2013-05-28	0.9685	22.15	1.181	9.3	15.16	0.9757	9.774	-0.00717	-0.0929	--
159	2013-06-05	0.8751	22.9	2.064	7.5	116	0.8248	6.906	0.0502	0.482	--
160	2013-06-05	0.8513	22.9	2.063	7.1	115.7	0.825	6.91	0.0262	0.254	--
161	2013-06-13	0.9243	24.77	1.487	8.4	30.66	0.9565	9.353	-0.0323	-0.296	--
162	2013-06-24	0.8976	24.23	1.355	7.9	22.66	0.973	9.715	-0.0754	-0.755	--
163	2013-07-09	1.068	25.96	0.5185	11.7	3.3	1.15	14.61	-0.0819	-0.865	--
164	2013-07-29	0.5051	19.23	3.375	3.2	2370	0.5341	3.536	-0.0289	-0.282	--
165	2013-08-07	0.4914	25.75	4.14	3.1	13790	0.4859	3.165	0.00541	0	--
166	2013-08-15	0.6232	23.5	3.849	4.2	7070	0.5073	3.325	0.116	1.08	--
167	2013-08-29	0.9494	25.6	2.262	8.9	183	0.8266	6.934	0.123	1.13	--
168	2013-10-24	0.7076	12.07	1.477	5.1	30	0.78	6.229	-0.0724	-0.72	--
169	2013-10-30	0.6335	15.14	2.19	4.3	154.8	0.6929	5.097	-0.0595	-0.558	--
170	2013-11-25	0.6721	3.2	1.572	4.7	37.33	0.6382	4.494	0.0339	0.352	--
171	2013-12-11	0.5798	0.7167	1.591	3.8	39	0.5998	4.114	-0.02	-0.173	--
172	2014-01-14	0.5185	3.6	1.653	3.3	45	0.629	4.399	-0.11	-1.05	--
173	2014-02-20	0.6128	7.683	1.69	4.1	49	0.6795	4.943	-0.0667	-0.653	--
174	2014-03-17	0.7559	7.7	1.568	5.7	37	0.702	5.205	0.0538	0.497	--
175	2014-04-09	0.8921	12.66	1.484	7.8	30.51	0.7869	6.329	0.105	0.885	--
176	2014-04-14	0.9868	11.47	1.496	9.7	31.33	0.7681	6.061	0.219	2.2	--
177	2014-05-14	0.9138	16.88	1.98	8.2	95.58	0.7556	5.889	0.158	1.42	--
178	2014-05-15	0.9638	16.65	1.961	9.2	91.5	0.7559	5.893	0.208	1.97	--

179	2014-05-29	1.064	24.67	1.837	11.6	68.67	0.8912	8.047	0.173	1.5	--
180	2014-06-03	1.053	25.24	1.706	11.3	50.82	0.9231	8.66	0.13	1.23	--
181	2014-06-05	1.053	24.83	2.148	11.3	140.6	0.8367	7.098	0.216	2.07	--
182	2014-06-09	0.6435	21.65	3.168	4.4	1474	0.6057	4.17	0.0378	0.38	--
183	2014-06-12	0.4624	21.3	3.589	2.9	3880	0.524	3.455	-0.0616	-0.573	--
184	2014-06-24	0.8573	24.4	2.444	7.2	278	0.7766	6.18	0.0808	0.67	--
185	2014-07-10	0.8808	24.4	1.946	7.6	88.33	0.8675	7.619	0.0133	0.0929	--
186	2014-07-15	1.033	25.48	1.663	10.8	46	0.9344	8.888	0.0991	0.846	--
187	2014-07-24	0.9494	25.78	1.447	8.9	28	0.978	9.827	-0.0286	-0.268	--
188	2014-08-04	1.025	25.67	1.329	10.6	21.33	0.998	10.29	0.0273	0.282	--
189	2014-08-07	0.9823	25.33	1.301	9.6	20	0.9984	10.3	-0.0161	-0.16	--

Definitions

As: Arsenic in ug/l (01000)

TEMP: Temperature, water in deg C (00010)

Q: Stream flow, mean. daily in ft3/s (00060)

Model Archive Summary for Atrazine Concentration at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the atrazine concentration (ATR) model developed to compute hourly ATR from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: May 12, 1998 to September 3, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 261 concurrent measurements of atrazine concentration, streamflow, and specific conductance collected from May 12, 1998 through September 3, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. Three samples were below a laboratory detection limit of 0.025 µg/L. Summary statistics and the complete model-calibration dataset are provided below. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. No ATR samples were deemed outliers.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating atrazine concentration. A variety of models that predict ATR and models that predict $\log_{10}(\text{ATR})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted ATR were examined for homoscedasticity (meaning that their departures from zero did not change substantially over

the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{ATR})$.

Specific conductance and the day of the year were selected as the best predictors of ATR based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows's C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for atrazine concentration at site number 07144100.

Atrazine concentration-based model:

$$\log_{10}(\text{ATR}) = -0.67 \times \log_{10}(\text{SC}) + 0.39 \times \sin\left(\frac{2\pi D}{365}\right) - 0.393 \times \cos\left(\frac{2\pi D}{365}\right) - 0.363 \times \sin\left(\frac{4\pi D}{365}\right) + 0.13 \times \cos\left(\frac{4\pi D}{365}\right) + 1.68$$

where

ATR = atrazine in micrograms per liter ($\mu\text{g/L}$);

SC = specific conductance in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{g/cm}$); and,

D = day of the year.

Specific conductance and the day of the year make physical and statistical sense as explanatory variables for atrazine. The inverse relation with SC makes sense physically because SC is an indicator of the amount of streamflow that is from groundwater sources. Atrazine concentrations are lowest when groundwater is the greatest source of streamflow. Day of the year makes statistical sense as atrazine concentrations vary seasonally. The relation between turbidity, day, and ATR makes statistical sense as the resulting model has the lowest standard error, Mallows's C_p and $PRESS$ values, and highest R^2 values.

The log-transformed model may be retransformed to the original units so that ATR can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.63. The retransformed model, accounting for BCF is:

$$\text{ATR} = \frac{78.02 \times 10^{0.39 \times \sin\left(\frac{2\pi D}{365}\right) + 0.13 \times \cos\left(\frac{4\pi D}{365}\right)}}{\text{SC}^{0.67} \times 10^{0.393 \times \cos\left(\frac{2\pi D}{365}\right) + 0.363 \times \sin\left(\frac{4\pi D}{365}\right)}}$$

Previous Models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(\text{ATR}) = -0.000647 \times \log_{10}(\text{SC}) + 0.5043 \times \sin\left(\frac{2\pi D}{365}\right) - 0.7452 \times \cos\left(\frac{2\pi D}{365}\right) + 0.237$
2.0	2007	--	$\log_{10}(\text{ATR}) = -0.67 \times \log_{10}(\text{SC}) + 0.39 \times \sin\left(\frac{2\pi D}{365}\right) - 0.393 \times \cos\left(\frac{2\pi D}{365}\right) - 0.363 \times \sin\left(\frac{4\pi D}{365}\right) + 0.13 \times \cos\left(\frac{4\pi D}{365}\right) + 1.68$

Atrazine Concentration Record

The ATR record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick

Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

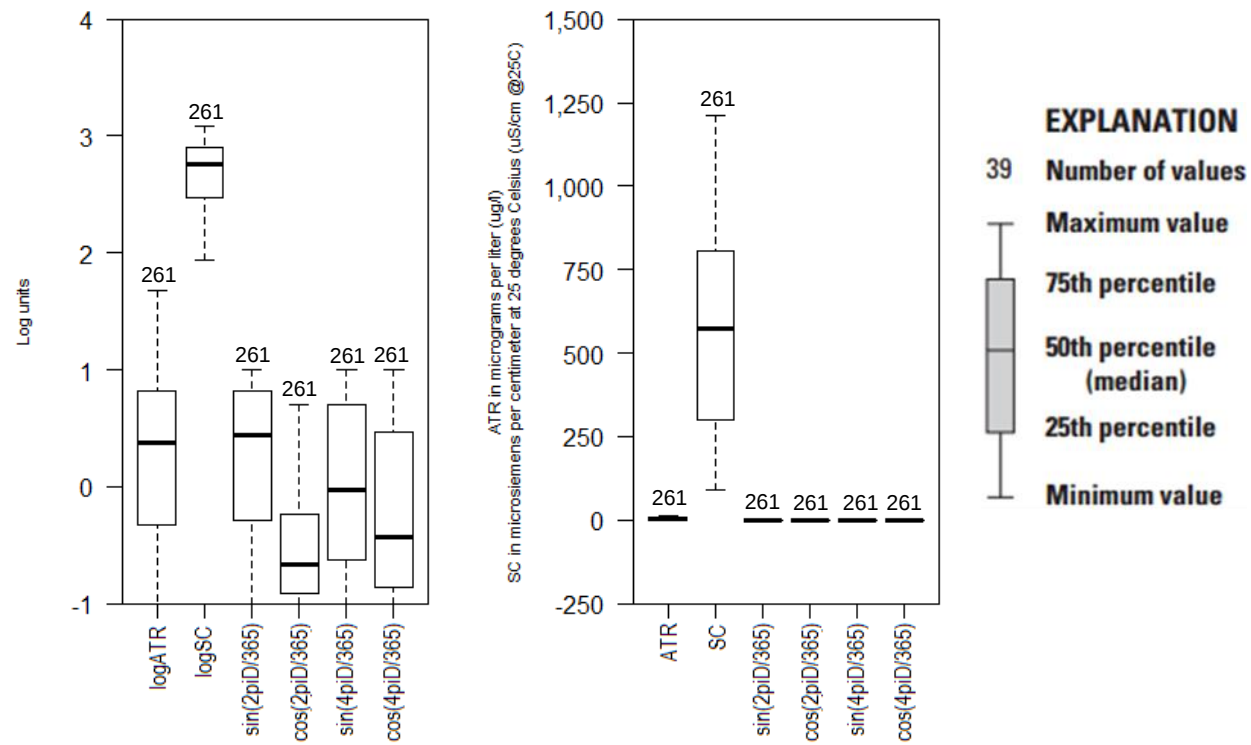
Model

$\log\text{ATR} = + -0.67 * \log\text{SC} + 0.39 * \sin(2\pi\text{ID}/365) + -0.393 * \cos(2\pi\text{ID}/365) + 0.13 * \cos(4\pi\text{ID}/365) + -0.363 * \sin(4\pi\text{ID}/365) + 1.68$

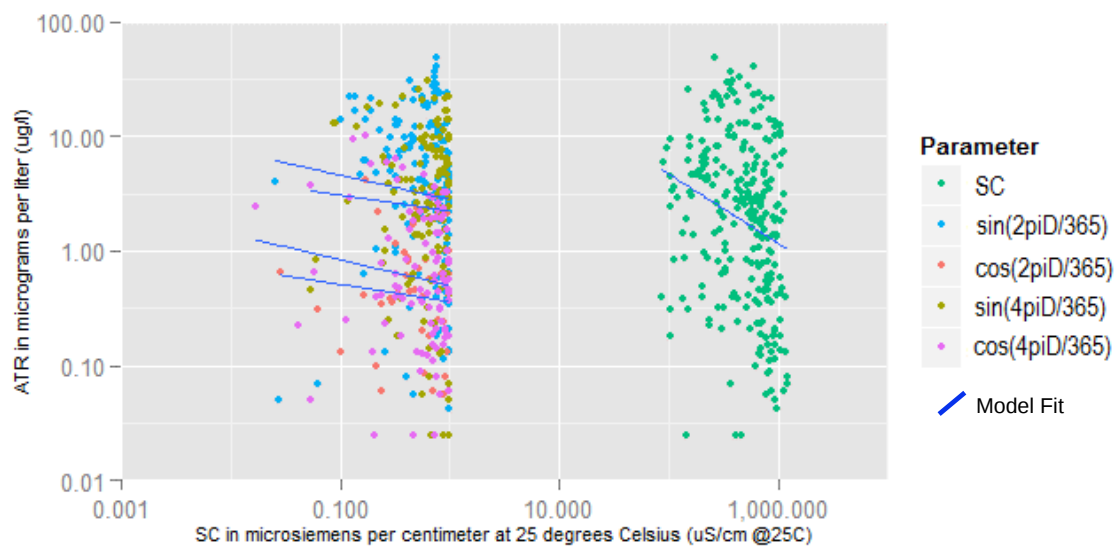
Variable Summary Statistics

	logATR	logSC	sin(2piD/365)	cos(2piD/365)	cos(4piD/365)	sin(4piD/365)	ATR	SC
Minimum	-1.6	1.95	-1	-1	-1	-1	0.0125	88.2
1st Quartile	-0.328	2.48	-0.294	-0.914	-0.632	-0.859	0.47	301
Median	0.378	2.76	0.448	-0.663	-0.0315	-0.436	2.39	572
Mean	0.265	2.68	0.254	-0.497	0.0346	-0.214	5.42	567
3rd Quartile	0.813	2.91	0.813	-0.242	0.699	0.466	6.5	805
Maximum	1.68	3.08	1	1	1	1	48	1210
Censored [< 0.025]	3	--	--	--	--	--	3	--

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	261			
Standard error (RMSE)	0.502			
Upper Model standard percentage error (MSPE)	218			
Lower Model standard percentage error (MSPE)	68.5			
Coefficient of determination (R ²)	0.541			
Adjusted Coefficient of Determination (Adj. R ²)	0.532			
Bias Correction Factor (BCF)	1.63			
Variance Inflation Factors (VIF)				
logSC	sin(2piD/365)	cos(2piD/365)	cos(4piD/365)	sin(4piD/365)
1.094039	1.506875	1.504234	1.476458	1.453265

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	1.680	0.3140	5.36	1.91e-07
logSC	-0.670	0.1150	-5.83	1.66e-08
sin(2piD/365)	0.390	0.0590	6.61	2.17e-10
cos(2piD/365)	-0.393	0.0733	-5.36	1.84e-07
cos(4piD/365)	0.130	0.0551	2.35	1.95e-02
sin(4piD/365)	-0.363	0.0539	-6.74	1.08e-10

Correlation Matrix

	Intercept	logSC	sin(2piD/365)	cos(2piD/365)	cos(4piD/365)	sin(4piD/365)
Intercept	1.0000	-0.9880	0.1440	0.2490	0.0191	-0.0036
logSC	-0.9880	1.0000	-0.1800	-0.1460	0.0264	-0.0089
sin(2piD/365)	0.1440	-0.1800	1.0000	-0.0236	0.1600	0.5170
cos(2piD/365)	0.2490	-0.1460	-0.0236	1.0000	0.5220	-0.2120
cos(4piD/365)	0.0191	0.0264	0.1600	0.5220	1.0000	-0.0486
sin(4piD/365)	-0.0036	-0.0089	0.5170	-0.2120	-0.0486	1.0000

Outlier Test Criteria

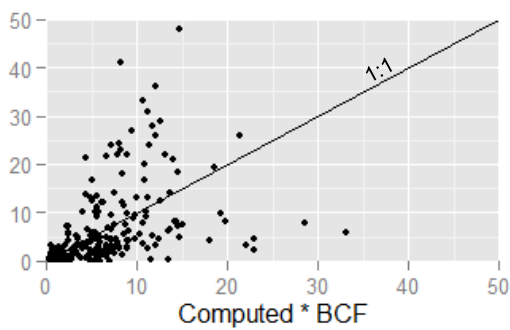
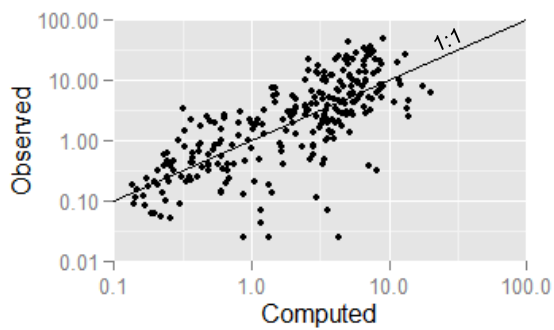
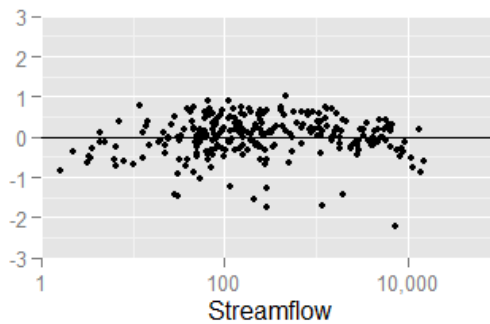
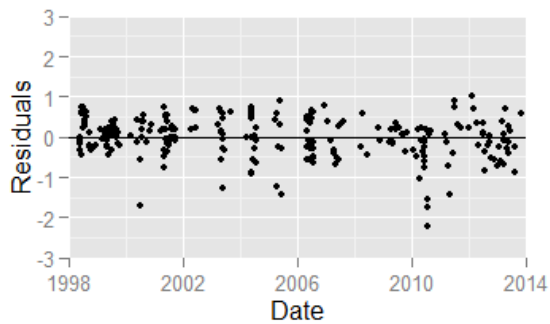
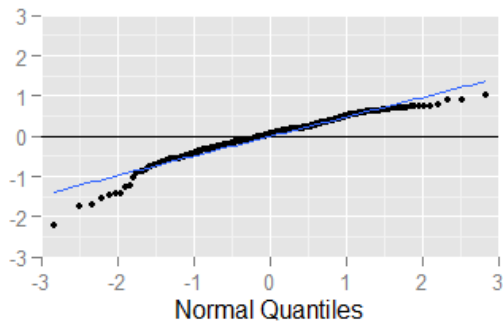
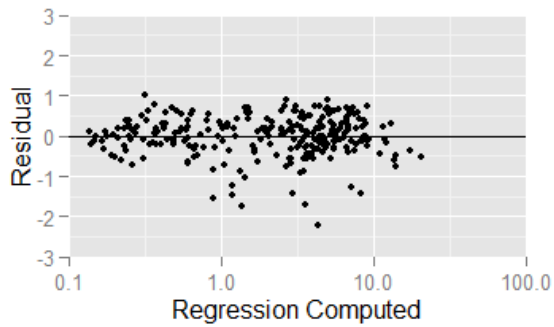
Leverage	Cook's D	DFFITS
0.05747126	0.36607825	0.27681827

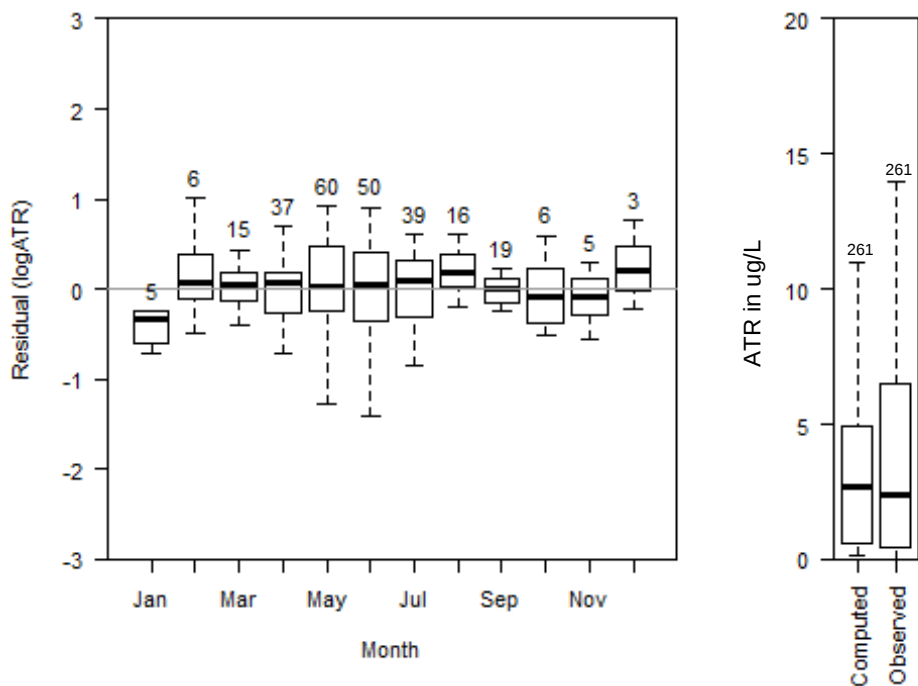
Flagged Observations

	logATR	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
10/5/1998 10:20	-0.508600	-0.17440	-0.3342	-0.6857	-0.6850	0.05823	0.0048450	-0.17030
11/5/1998 13:42	-0.408900	-0.11990	-0.2890	-0.5965	-0.5957	0.06927	0.0044130	-0.16250
12/4/1998 10:40	-0.619800	-0.39440	-0.2254	-0.4688	-0.4681	0.08356	0.0033390	-0.14130
2/1/1999 11:00	-0.193800	-0.37990	0.1861	0.3839	0.3833	0.06811	0.0017950	0.10360
6/28/2000 10:07	-1.155000	0.55410	-1.7090	-3.4230	-3.4980	0.01172	0.0231600	-0.38090
10/26/2000 11:38	-0.060480	-0.22800	0.1676	0.3439	0.3433	0.05886	0.0012330	0.08586
11/8/2000 9:37	-0.070580	-0.36920	0.2987	0.6149	0.6141	0.06474	0.0043620	0.16160
4/12/2005 14:00	-1.155000	0.07330	-1.2280	-2.4700	-2.4950	0.01953	0.0202500	-0.35220
6/6/2005 10:15	-0.494900	0.91810	-1.4130	-2.8290	-2.8690	0.01136	0.0153300	-0.30750
12/12/2006 13:35	0.326300	-0.43470	0.7610	1.5860	1.5900	0.08667	0.0397600	0.48990
1/10/2007 11:25	-0.207600	-0.60750	0.3999	0.8304	0.8299	0.08039	0.0100500	0.24540
10/31/2008 12:30	-0.337200	-0.55840	0.2211	0.4544	0.4537	0.06122	0.0022440	0.11590
11/24/2008 10:20	-0.602100	-0.51030	-0.0918	-0.1908	-0.1904	0.08216	0.0005430	-0.05697
11/3/2009 9:20	-0.161800	-0.27220	0.1104	0.2269	0.2265	0.06173	0.0005645	0.05809
1/25/2010 11:32	-1.097000	-0.76820	-0.3287	-0.6793	-0.6786	0.07183	0.0059520	-0.18880
7/8/2010 13:40	-1.602000	0.63130	-2.2330	-4.4970	-4.6770	0.02200	0.0758000	-0.70140
7/16/2010 11:30	-1.602000	0.13030	-1.7320	-3.4740	-3.5530	0.01435	0.0292800	-0.42860

7/26/2010 14:30	-1.602000	-0.05361	-1.5480	-3.1080	-3.1620	0.01581	0.0258500	-0.40070
5/2/2011 9:05	-0.950800	0.46970	-1.4200	-2.8470	-2.8880	0.01314	0.0179900	-0.33330
12/20/2011 11:15	-0.007446	-0.21630	0.2088	0.4356	0.4349	0.08903	0.0030910	0.13600
2/6/2012 10:15	0.513200	-0.49790	1.0110	2.0760	2.0890	0.05916	0.0451400	0.52390
3/1/2012 12:00	0.378400	-0.32680	0.7052	1.4330	1.4360	0.03958	0.0141000	0.29140
11/7/2012 11:10	-1.071000	-0.51280	-0.5577	-1.1500	-1.1500	0.06684	0.0157800	-0.30790
1/2/2013 14:10	-1.301000	-0.58700	-0.7140	-1.4870	-1.4900	0.08533	0.0343600	-0.45510
1/16/2013 9:45	-0.886100	-0.64080	-0.2453	-0.5082	-0.5075	0.07634	0.0035570	-0.14590
1/29/2013 10:05	-1.260000	-0.65310	-0.6066	-1.2490	-1.2500	0.06506	0.0180900	-0.32990
8/7/2013 9:45	-0.749600	0.12400	-0.8736	-1.7700	-1.7770	0.03418	0.0184800	-0.33440
10/30/2013 10:20	0.227900	-0.36280	0.5907	1.2110	1.2130	0.05732	0.0148700	0.29900
4/9/2014 12:30	-1.377000	0.07358	-1.4500	-2.9140	-2.9580	0.01815	0.0261600	-0.40220

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logATR ~ sin(4piD/365)	1	0.617	29.63	29.36	187.8	100	1 ± 190	
logATR ~ cos(2piD/365)	1	0.6636	18.61	18.29	257.5	115.6	1 ± 220	
logATR ~ sin(2piD/365)	1	0.6661	17.99	17.67	261.4	116.5	1 ± 220	
logATR ~ cos(2piD/365) + sin(4piD/365)	2	0.5624	41.76	41.31	113.1	83.57	1.027 ± 170	
logATR ~ SC + sin(4piD/365)	2	0.5704	40.09	39.63	123.7	85.84	1.005 ± 170	
logATR ~ sin(2piD/365) + cos(2piD/365)	2	0.5764	38.83	38.35	131.7	87.78	1.003 ± 180	
logATR ~ logQ + cos(2piD/365) + sin(4piD/365)	3	0.5309	48.31	47.71	73.74	74.76	1.034 ± 160	
logATR ~ SC + cos(2piD/365) + sin(4piD/365)	3	0.5331	47.87	47.27	76.5	75.42	1.066 ± 160	
logATR ~ SC + sin(2piD/365) + cos(2piD/365)	3	0.5336	47.78	47.17	77.07	75.44	1.106 ± 160	
logATR ~ SC + sin(2piD/365) + cos(2piD/365) + sin(4piD/365)	4	0.493	55.59	54.9	29.71	64.42	1.106 ± 140	
logATR ~ logSC + sin(2piD/365) + cos(2piD/365) + sin(4piD/365)	4	0.5067	53.1	52.37	45.47	68.04	1.093 ± 140	
logATR ~ logQ + sin(2piD/365) + cos(2piD/365) + sin(4piD/365)	4	0.508	52.84	52.11	47.09	68.42	1.037 ± 150	

Model-Calibration Data Set

	Date	logATR	logSC	sin(2piD/365)	cos(2piD/365)	cos(4piD/365)	sin(4piD/365)	ATR	SC	Computed logATR	Computed ATR	Residual	Normal Quantiles	Censored Values
0														
1	1998-05-12	0.3404	3.061	0.769	-0.6393	-0.1826	-0.9832	2.19	1150	0.5147	5.348	-0.174	-0.489	--
2	1998-05-15	0.9149	2.453	0.7349	-0.6781	-0.08025	-0.9968	8.22	284	0.9419	14.3	-0.027	-0.174	--
3	1998-05-26	0.5944	2.888	0.6011	-0.7992	0.2775	-0.9607	3.93	772	0.6795	7.815	-0.0851	-0.252	--
4	1998-05-29	0.2989	2.952	0.559	-0.8292	0.375	-0.927	1.99	895	0.6322	7.01	-0.333	-0.864	--
5	1998-06-02	0.1335	2.99	0.4929	-0.8701	0.514	-0.8578	1.36	978	0.5896	6.354	-0.456	-1.05	--
6	1998-06-04	0.1239	2.998	0.4705	-0.8824	0.5572	-0.8304	1.33	996	0.576	6.159	-0.452	-1.03	--
7	1998-06-10	1.332	2.87	0.3691	-0.9294	0.7276	-0.686	21.5	741	0.6106	6.67	0.722	1.84	--
8	1998-06-12	1.13	2.969	0.3449	-0.9386	0.762	-0.6475	13.5	931	0.5289	5.526	0.601	1.25	--
9	1998-06-13	1.093	3.017	0.3287	-0.9444	0.7839	-0.6209	12.4	1040	0.4858	5.004	0.608	1.36	--
10	1998-06-13	1.104	3.009	0.3206	-0.9472	0.7945	-0.6073	12.7	1020	0.4858	5.004	0.618	1.39	--
11	1998-06-24	1.22	2.779	0.1386	-0.9903	0.9616	-0.2746	16.6	600.7	0.4867	5.014	0.733	2.02	--
12	1998-07-07	1	2.549	-0.08668	-0.9962	0.985	0.1727	10	354	0.3956	4.065	0.604	1.27	--
13	1998-07-08	0.7574	2.35	-0.09525	-0.9955	0.9819	0.1896	5.72	224	0.5186	5.396	0.239	0.522	--
14	1998-07-10	0.7709	2.316	-0.1357	-0.9907	0.9632	0.2689	5.9	207.1	0.4926	5.083	0.278	0.566	--
15	1998-07-12	0.8102	2.336	-0.1635	-0.9865	0.9465	0.3226	6.46	217	0.4448	4.553	0.365	0.745	--
16	1998-07-13	0.7243	2.5	-0.189	-0.982	0.9286	0.3712	5.3	316	0.3038	3.29	0.42	0.878	--
17	1998-07-25	0.4639	2.712	-0.3784	-0.9257	0.7137	0.7005	2.91	515	-0.08179	1.354	0.546	1.1	--
18	1998-07-29	0.3522	2.76	-0.4412	-0.8974	0.6108	0.7918	2.25	576	-0.1965	1.04	0.549	1.13	--
19	1998-08-02	0.3139	2.773	-0.5093	-0.8606	0.4813	0.8766	2.06	593	-0.2935	0.8317	0.607	1.34	--
20	1998-08-09	-0.004365	2.928	-0.609	-0.7931	0.2581	0.9661	0.99	847	-0.5241	0.489	0.52	1.03	--
21	1998-09-15	-1.046	2.933	-0.9605	-0.2783	-0.8451	0.5346	0.09	857.8	-0.8537	0.229	-0.192	-0.511	--

22	1998-09-21	-0.7447	2.96	-0.9831	-0.1833	-0.9328	0.3604	0.18	911	-0.8655	0.2228	0.121	0.115	--
23	1998-09-22	-0.3036	2.307	-0.987	-0.1605	-0.9485	0.3169	0.497	203	-0.4253	0.614	0.122	0.125	--
24	1998-09-25	-0.4101	1.945	-0.994	-0.1094	-0.9761	0.2175	0.389	88.17	-0.173	1.098	-0.237	-0.624	--
25	1998-10-05	-0.5086	2.027	-0.998	0.0626	-0.9922	-0.125	0.31	106.3	-0.1744	1.094	-0.334	-0.878	--
26	1998-11-05	-0.4089	2.31	-0.8257	0.5642	-0.3635	-0.9316	0.39	204.2	-0.1199	1.24	-0.289	-0.758	--
27	1998-12-04	-0.6198	2.862	-0.4568	0.8896	0.5827	-0.8127	0.24	728.3	-0.3944	0.6593	-0.225	-0.6	--
28	1999-02-01	-0.1938	2.486	0.5154	0.8569	0.4686	0.8834	0.64	306	-0.3799	0.6816	0.186	0.363	--
29	1999-02-19	-0.7447	3.017	0.7528	0.6582	-0.1335	0.9911	0.18	1040	-0.6823	0.3398	-0.0624	-0.223	--
30	1999-04-06	0.4116	2.435	0.9973	-0.07381	-0.9891	-0.1472	2.58	272	0.3933	4.044	0.0183	-0.0672	--
31	1999-04-07	0.4425	2.625	0.9959	-0.09091	-0.9835	-0.1811	2.77	421.4	0.2851	3.152	0.157	0.232	--
32	1999-04-08	0.4548	2.659	0.995	-0.09955	-0.9802	-0.1981	2.85	456.1	0.2717	3.056	0.183	0.312	--
33	1999-04-11	0.3404	2.803	0.9886	-0.1508	-0.9545	-0.2981	2.19	635	0.2327	2.793	0.108	0.0865	--
34	1999-04-15	0.4533	2.797	0.9759	-0.2184	-0.9046	-0.4263	2.84	626	0.3114	3.349	0.142	0.174	--
35	1999-04-16	0.6464	2.302	0.9704	-0.2416	-0.8832	-0.4689	4.43	200.5	0.668	7.611	-0.0216	-0.144	--
36	1999-04-17	0.6474	2.362	0.9678	-0.2519	-0.8731	-0.4875	4.44	230	0.6391	7.122	0.00829	-0.0768	--
37	1999-04-21	0.5944	2.757	0.9481	-0.3179	-0.7979	-0.6028	3.93	571	0.4443	4.548	0.15	0.203	--
38	1999-04-22	0.4829	2.819	0.9425	-0.3341	-0.7767	-0.6299	3.04	659	0.4194	4.294	0.0635	0.0096	--
39	1999-04-23	0.4698	2.863	0.9366	-0.3503	-0.7546	-0.6562	2.95	730	0.4061	4.165	0.0637	0.0192	--
40	1999-04-25	0.5478	2.932	0.924	-0.3824	-0.7076	-0.7066	3.53	856	0.3918	4.03	0.156	0.223	--
41	1999-04-27	0.4786	2.524	0.9103	-0.4139	-0.6573	-0.7536	3.01	334.1	0.6962	8.123	-0.218	-0.555	--
42	1999-04-28	0.6684	2.441	0.8994	-0.4372	-0.6177	-0.7864	4.66	275.9	0.7739	9.713	-0.105	-0.342	--
43	1999-05-05	0.3284	2.889	0.8449	-0.535	-0.4276	-0.904	2.13	775	0.5577	5.905	-0.229	-0.612	--
44	1999-05-10	0.1399	2.961	0.7905	-0.6125	-0.2498	-0.9683	1.38	914	0.5653	6.009	-0.425	-0.997	--
45	1999-05-22	1.09	2.573	0.6546	-0.756	0.143	-0.9897	12.3	374	0.8874	12.61	0.203	0.425	--
46	1999-05-24	1.288	2.324	0.622	-0.783	0.2262	-0.9741	19.4	211	1.057	18.64	0.231	0.511	--
47	1999-06-05	0.9996	2.604	0.4476	-0.8942	0.5993	-0.8005	9.99	402	0.8303	11.06	0.169	0.272	--
48	1999-06-21	1.223	2.344	0.1878	-0.9822	0.9295	-0.3688	16.7	220.7	0.8241	10.9	0.399	0.81	--
49	1999-07-01	0.5988	2.628	0.0251	-0.9997	0.9987	-0.05019	3.97	425	0.4701	4.826	0.129	0.154	--
50	1999-07-04	0.5786	2.412	-0.02654	-0.9996	0.9986	0.05305	3.79	258	0.5577	5.904	0.021	-0.0576	--
51	1999-07-09	-0.1024	2.757	-0.1209	-0.9927	0.9708	0.2401	0.79	572	0.2149	2.682	-0.317	-0.797	--
52	1999-07-20	0.6712	2.247	-0.3034	-0.9529	0.8159	0.5782	4.69	176.7	0.327	3.471	0.344	0.695	--
53	1999-07-27	0.2878	2.508	-0.4189	-0.908	0.649	0.7608	1.94	322.3	0.001572	1.641	0.286	0.589	--
54	1999-08-02	0.5051	2.193	-0.508	-0.8614	0.484	0.8751	3.2	155.8	0.09711	2.045	0.408	0.85	--
55	1999-08-31	-0.8239	2.977	-0.8547	-0.5191	-0.461	0.8874	0.15	949	-0.8254	0.2444	0.00152	-0.106	--
56	1999-09-02	-0.6198	2.635	-0.8721	-0.4894	-0.521	0.8536	0.24	432	-0.6104	0.401	-0.00941	-0.135	--
57	1999-09-04	-0.4949	2.721	-0.8884	-0.4591	-0.5785	0.8157	0.32	526	-0.6797	0.3418	0.185	0.342	--
58	1999-09-24	-0.6383	2.812	-0.9912	-0.1323	-0.965	0.2623	0.23	648	-0.7582	0.2853	0.12	0.106	--
59	1999-09-28	-0.6038	2.374	-0.9983	-0.05747	-0.9934	0.1147	0.249	236.7	-0.4475	0.5835	-0.156	-0.468	--
60	1999-09-30	-0.6576	2.369	-0.9998	-0.0208	-0.9991	0.04159	0.22	234	-0.4333	0.6029	-0.224	-0.578	--
61	2000-03-07	-0.08619	2.458	0.9088	0.4172	-0.6519	0.7583	0.82	287.3	-0.1351	1.198	0.0489	-0.0192	--
62	2000-05-09	0.4065	3.004	0.7942	-0.6076	-0.2616	-0.9652	2.55	1010	0.5332	5.58	-0.127	-0.404	--
63	2000-05-28	1.344	2.542	0.5577	-0.83	0.3779	-0.9258	22.1	348.2	0.9067	13.19	0.438	0.907	--
64	2000-06-19	0.01284	2.774	0.2122	-0.9772	0.9099	-0.4148	1.03	594	0.5577	5.905	-0.545	-1.21	--
65	2000-06-28	-1.155	2.562	0.06211	-0.9981	0.9923	-0.124	0.07	365	0.5541	5.856	-1.71	-2.33	--
66	2000-07-20	0.2833	2.86	-0.3107	-0.9505	0.8069	0.5906	1.92	725	-0.09316	1.319	0.376	0.77	--
67	2000-07-22	0.4757	2.22	-0.3454	-0.9385	0.7614	0.6483	2.99	166	0.2907	3.193	0.185	0.353	--
68	2000-07-23	0.281	2.164	-0.3614	-0.9324	0.7387	0.674	1.91	146	0.3071	3.316	-0.0261	-0.164	--
69	2000-07-31	0.2742	2.767	-0.4857	-0.8741	0.5282	0.8491	1.88	585	-0.259	0.9005	0.533	1.05	--
70	2000-08-09	-0.1135	2.863	-0.6144	-0.789	0.245	0.9695	0.77	730	-0.4876	0.532	0.374	0.758	--
71	2000-09-08	-0.9586	2.927	-0.9222	-0.3868	-0.7008	0.7133	0.11	846	-0.8383	0.2373	-0.12	-0.383	--
72	2000-10-26	-0.06048	2.358	-0.9097	0.4152	-0.6552	-0.7555	0.87	228	-0.228	0.967	0.168	0.262	--
73	2000-11-08	-0.07058	2.711	-0.7957	0.6057	-0.2663	-0.9639	0.85	514.6	-0.3692	0.6986	0.299	0.6	--
74	2001-03-14	0.0607	2.525	0.9481	0.3181	-0.7977	0.6031	1.15	335.3	-0.08828	1.334	0.149	0.193	--
75	2001-04-16	0.5705	2.714	0.9699	-0.2435	-0.8814	-0.4724	3.72	518	0.3938	4.049	0.177	0.292	--
76	2001-04-25	-0.1192	2.982	0.9208	-0.3901	-0.6957	-0.7183	0.76	958.3	0.3665	3.802	-0.486	-1.08	--
77	2001-05-02	-0.3279	3.041	0.8671	-0.4981	-0.5037	-0.8639	0.47	1100	0.4257	4.357	-0.754	-1.56	--
78	2001-05-07	0.2788	2.844	0.826	-0.5637	-0.3644	-0.9312	1.9	699	0.6098	6.657	-0.331	-0.85	--
79	2001-05-08	1.38	2.821	0.8129	-0.5825	-0.3215	-0.9469	24	662.6	0.6388	7.117	0.741	2.11	--
80	2001-05-11	1.041	3.021	0.7852	-0.6192	-0.2331	-0.9725	11	1050	0.5292	5.53	0.512	1.01	--
81	2001-05-16	0.4983	3.057	0.7291	-0.6844	-0.06308	-0.998	3.15	1140	0.5403	5.673	-0.042	-0.193	--
82	2001-05-23	1.255	2.84	0.6415	-0.7671	0.1769	-0.9842	18	692	0.71	8.384	0.545	1.08	--
83	2001-05-25	0.8261	2.971	0.6147	-0.7887	0.2442	-0.9697	6.7	935	0.6239	6.877	0.202	0.404	--
84	2001-05-31	0.617	2.787	0.5228	-0.8525	0.4534	-0.8913	4.14	613	0.7346	8.872	-0.118	-0.373	--
85	2001-06-03	1.415	2.569	0.4856	-0.8742	0.5283	-0.8491	26	371	0.8691	12.09	0.546	1.11	--
86	2001-06-04	1.32	2.465	0.4655	-0.8851	0.5667	-0.8239	20.9	292	0.931	13.95	0.389	0.797	--
87	2001-06-06	0.8965	1.982	0.4346	-0.9006	0.6222	-0.7828	7.88	95.83	1.242	28.51	-0.345	-0.892	--
88	2001-06-08	0.9074	2.192	0.4007	-0.9162	0.6788	-0.7343	8.08	155.7	1.083	19.79	-0.176	-0.5	--
89	2001-06-11	0.8639	2.346	0.3526	-0.9358	0.7514	-0.6598	7.31	222	0.951	14.6	-0.0871	-0.262	--
90	2001-06-22	0.7839	2.186	0.1707	-0.9853	0.9417	-0.3364	6.08	153.3	0.9144	13.43	-0.131	-0.425	--
91	2001-06-23	0.6721	2.219	0.1555	-0.9878	0.9516	-0.3072	4.7	165.6	0.8778	12.34	-0.206	-0.544	--
92	2001-07-10	0.1004	2.908	-0.138	-0.9904	0.9619	0.2733	1.26	809	0.09329	2.027	0.00708	-0.0865	--
93	2001-07-26	-0.2676	2.888	-0.3942	-0.919	0.6891	0.7246	0.54	772	-0.2203	0.9843	-0.0473	-0.203	--
94	2001-08-15	-0.3468	2.907	-0.6876	-0.7261	0.05448	0.9985	0.45	807	-0.6052	0.4058	0.258	0.555	--
95	2001-08-17	-0.4318	2.907	-0.7122	-0.702	-0.01434	0.9999	0.37	807	-0.6337	0.38	0.202	0.394	--
96	2001-08-28	-0.757	2.897	-0.8302	-0.5575	-0.3784	0.9257	0.175	789	-0.7502	0.2906	-0.00674	-0.125	--
97	2001-09-08	-0.8239	2.905	-0.9213	-0.3889	-0.6974	0.7166	0.15	804	-0.823	0.2457	-0.000898	-0.115	--
98	2001-09-19	-0.07572	2.052	-0.9783	-0.2071	-0.9142	0.4053	0.84	112.6	-0.2599	0.8986	0.184	0.322	--
99	2001-09-20	-0.4123	2.136	-0.9809	-0.1943	-0.9245	0.3812	0.387	136.6	-0.3148	0.792	-0.0975	-0.302	--
100	2002-04-09	0.2648	2.983	0.9925	-0.1224	-0.97	-0.243	1.84	960.7	0.08053	1.968	0.184	0.332	--
101	2002-04-22	1.384	2.423	0.9403	-0.3402	-0.7685	-0.6							

104	2002-06-13	1.146	2.36	0.3236	-0.9462	0.7905	-0.6124	14	229.2	0.9224	13.67	0.224	0.489	--
105	2003-03-20	0.3424	2.479	0.9757	-0.2189	-0.9042	0.4272	2.2	301	0.04291	1.805	0.3	0.624	--
106	2003-04-17	0.8591	3.061	0.9662	-0.2576	-0.8673	-0.4979	7.23	1150	0.1769	2.457	0.682	1.59	--
107	2003-04-21	1.114	2.704	0.9481	-0.3179	-0.7979	-0.6028	13	506	0.4795	4.931	0.634	1.44	--
108	2003-04-23	-0.1135	2.808	0.9346	-0.3556	-0.7471	-0.6647	0.77	642	0.4489	4.596	-0.562	-1.27	--
109	2003-04-26	0.9624	2.318	0.9138	-0.4061	-0.6702	-0.7422	9.17	208	0.8266	10.97	0.136	0.164	--
110	2003-05-04	0.6911	2.872	0.8494	-0.5277	-0.4431	-0.8965	4.91	744	0.5638	5.988	0.127	0.144	--
111	2003-05-11	0.2718	2.99	0.7852	-0.6192	-0.2331	-0.9725	1.87	977	0.5502	5.803	-0.278	-0.745	--
112	2003-05-12	1	3.021	0.7689	-0.6393	-0.1825	-0.9832	10	1050	0.5412	5.685	0.459	0.921	--
113	2003-05-14	1.447	2.567	0.7484	-0.6632	-0.1202	-0.9927	28	369	0.8585	11.8	0.589	1.21	--
114	2003-05-26	0.7482	2.708	0.5941	-0.8044	0.294	-0.9558	5.6	511	0.7992	10.3	-0.051	-0.213	--
115	2003-05-28	-0.4202	2.628	0.5661	-0.8243	0.359	-0.9333	0.38	425	0.85	11.57	-1.27	-1.89	--
116	2003-05-29	0.9009	2.68	0.5542	-0.8324	0.3857	-0.9226	7.96	479.1	0.8132	10.63	0.0877	0.0672	--
117	2003-06-09	0.4082	2.702	0.3929	-0.9196	0.6912	-0.7227	2.56	504	0.7368	8.918	-0.329	-0.823	--
118	2003-09-03	0.1553	2.425	-0.8832	-0.469	-0.5601	0.8284	1.43	265.8	-0.4774	0.5446	0.633	1.41	--
119	2004-03-09	-0.01773	2.328	0.9225	0.3861	-0.7019	0.7123	0.96	212.9	-0.01999	1.561	0.00226	-0.0961	--
120	2004-05-12	-0.4089	3.064	0.7619	-0.6477	-0.161	-0.987	0.39	1160	0.5169	5.376	-0.926	-1.74	--
121	2004-05-13	-0.3279	3.041	0.7563	-0.6542	-0.144	-0.9896	0.47	1100	0.5359	5.616	-0.864	-1.66	--
122	2004-05-13	1.681	2.421	0.7513	-0.66	-0.1289	-0.9917	48	263.7	0.9546	14.73	0.727	1.96	--
123	2004-05-13	0.9138	2.446	0.7507	-0.6607	-0.127	-0.9919	8.2	279	0.9385	14.19	-0.0247	-0.154	--
124	2004-05-14	1.301	2.627	0.745	-0.6671	-0.1099	-0.9939	20	424	0.82	10.8	0.481	0.951	--
125	2004-05-14	1.38	2.602	0.7392	-0.6735	-0.09285	-0.9957	24	400	0.84	11.31	0.54	1.06	--
126	2004-05-15	1.462	2.534	0.7334	-0.6798	-0.07575	-0.9971	29	342	0.8886	12.65	0.574	1.17	--
127	2004-05-15	1.556	2.571	0.7275	-0.6861	-0.05862	-0.9983	36	372	0.8669	12.03	0.689	1.63	--
128	2004-05-16	1.519	2.647	0.7216	-0.6923	-0.04148	-0.9991	33	444	0.8181	10.75	0.7	1.7	--
129	2004-05-16	1.431	2.732	0.7157	-0.6985	-0.02432	-0.9997	27	540	0.7637	9.487	0.668	1.56	--
130	2004-06-12	-0.01773	2.936	0.3279	-0.9447	0.785	-0.6195	0.96	862	0.5398	5.667	-0.558	-1.23	--
131	2004-06-22	0.781	2.432	0.165	-0.9863	0.9455	-0.3256	6.04	270.6	0.7439	9.066	0.0371	-0.0384	--
132	2004-07-05	0.4683	2.09	-0.06076	-0.9982	0.9926	0.1213	2.94	123	0.7337	8.856	-0.265	-0.707	--
133	2004-07-09	-0.3872	2.729	-0.1206	-0.9927	0.9709	0.2394	0.41	536	0.2342	2.804	-0.621	-1.39	--
134	2004-07-26	0.5575	2.049	-0.4051	-0.9143	0.6717	0.7408	3.61	112	0.3272	3.473	0.23	0.5	--
135	2004-07-27	0.1523	2.126	-0.4218	-0.9067	0.6442	0.7649	1.42	133.7	0.2537	2.932	-0.101	-0.322	--
136	2005-03-23	0.616	2.355	0.9857	0.1682	-0.9434	0.3317	4.13	226.4	0.1793	2.47	0.437	0.892	--
137	2005-04-12	-1.155	3.083	0.9843	-0.1762	-0.9379	-0.347	0.07	1210	0.0733	1.935	-1.23	-1.84	--
138	2005-04-15	0.7404	3.025	0.9739	-0.2268	-0.8971	-0.4418	5.5	1060	0.1673	2.403	0.573	1.15	--
139	2005-05-08	0.2553	3.025	0.8111	-0.5849	-0.3158	-0.9488	1.8	1060	0.5038	5.215	-0.249	-0.647	--
140	2005-05-12	1.613	2.785	0.769	-0.6393	-0.1826	-0.9832	41	609	0.6997	8.189	0.913	2.5	--
141	2005-05-14	1.415	2.185	0.7484	-0.6632	-0.1202	-0.9927	26	153	1.115	21.29	0.3	0.635	--
142	2005-05-20	1.114	2.716	0.6739	-0.7388	0.09168	-0.9958	13	520	0.7878	10.03	0.326	0.659	--
143	2005-05-27	1.265	2.484	0.5827	-0.8127	0.3208	-0.9471	18.4	305	0.9485	14.52	0.316	0.647	--
144	2005-06-04	0.5403	2.632	0.4629	-0.8864	0.5714	-0.8207	3.47	429	0.818	10.75	-0.278	-0.732	--
145	2005-06-06	-0.4949	2.464	0.4346	-0.9006	0.6223	-0.7828	0.32	291.2	0.9181	13.54	-1.41	-1.96	--
146	2006-04-28	-0.09151	2.918	0.9007	-0.4344	-0.6226	-0.7825	0.81	827.4	0.4516	4.625	-0.543	-1.19	--
147	2006-04-29	0.3284	2.733	0.8915	-0.4531	-0.5894	-0.8078	2.13	541.2	0.5924	6.395	-0.264	-0.695	--
148	2006-05-01	0.6702	2.873	0.8753	-0.4837	-0.5321	-0.8467	4.68	745.8	0.5262	5.492	0.144	0.183	--
149	2006-05-04	1.079	2.836	0.8511	-0.525	-0.4487	-0.8937	12	685.3	0.5856	6.296	0.494	0.982	--
150	2006-05-05	0.9571	2.922	0.8414	-0.5404	-0.4159	-0.9094	9.06	836	0.54	5.668	0.417	0.864	--
151	2006-05-06	1	2.973	0.8319	-0.555	-0.384	-0.9233	10	939.5	0.5172	5.378	0.483	0.966	--
152	2006-05-09	0.5159	2.883	0.8008	-0.5989	-0.2826	-0.9592	3.28	763.3	0.6089	6.644	-0.093	-0.282	--
153	2006-05-10	0.4393	2.813	0.7914	-0.6113	-0.2527	-0.9675	2.75	649.9	0.6638	7.538	-0.224	-0.589	--
154	2006-05-13	1.079	2.982	0.7579	-0.6524	-0.1489	-0.9889	12	958.8	0.5749	6.143	0.504	0.997	--
155	2006-06-01	0.1367	2.812	0.5086	-0.861	0.4827	-0.8758	1.37	648	0.7144	8.47	-0.578	-1.32	--
156	2006-06-02	0.415	2.842	0.4941	-0.8694	0.5118	-0.8591	2.6	694.5	0.6896	7.999	-0.275	-0.72	--
157	2006-06-03	1.079	2.796	0.4778	-0.8785	0.5434	-0.8395	12	625.5	0.7142	8.466	0.365	0.732	--
158	2006-06-24	1.342	2.407	0.1389	-0.9903	0.9614	-0.2752	22	255	0.7363	8.908	0.606	1.32	--
159	2006-06-25	1.342	2.462	0.1213	-0.9926	0.9706	-0.2409	22	289.6	0.6821	7.863	0.66	1.53	--
160	2006-06-26	1.146	2.458	0.103	-0.9947	0.9788	-0.2049	14	287	0.6663	7.583	0.48	0.936	--
161	2006-07-17	-0.1367	2.823	-0.254	-0.9672	0.871	0.4913	0.73	666	0.004608	1.652	-0.141	-0.436	--
162	2006-07-19	-0.3372	2.835	-0.2887	-0.9574	0.8333	0.5528	0.46	683.7	-0.04765	1.465	-0.29	-0.77	--
163	2006-07-24	-0.6383	2.843	-0.3695	-0.9292	0.7269	0.6867	0.23	696.3	-0.158	1.136	-0.48	-1.06	--
164	2006-07-25	-0.7212	2.845	-0.3854	-0.9227	0.7029	0.7113	0.19	700	-0.1803	1.079	-0.541	-1.17	--
165	2006-07-27	-0.8539	2.841	-0.4161	-0.9093	0.6538	0.7567	0.14	692.7	-0.2173	0.9912	-0.637	-1.41	--
166	2006-07-28	0.4166	2.769	-0.4315	-0.9021	0.6276	0.7786	2.61	586.9	-0.1893	1.057	0.606	1.29	--
167	2006-12-12	0.3263	2.9	-0.3283	0.9446	0.7844	-0.6203	2.12	794	-0.4347	0.6009	0.761	2.2	--
168	2007-01-10	-0.2076	2.941	0.1624	0.9867	0.9473	0.3205	0.62	873	-0.6075	0.4036	0.4	0.823	--
169	2007-02-26	-0.699	2.982	0.8269	0.5624	-0.3674	0.9301	0.2	960.1	-0.6006	0.4101	-0.0983	-0.312	--
170	2007-03-31	-0.1871	2.529	0.9996	0.02857	-0.9984	0.05711	0.65	338	0.2154	2.685	-0.402	-0.966	--
171	2007-04-02	0.1367	2.223	1	-0.0034	-1	-0.006933	1.37	167	0.4563	4.676	-0.32	-0.81	--
172	2007-05-04	-0.2366	3.029	0.8509	-0.5253	-0.448	-0.894	0.58	1070	0.4562	4.674	-0.693	-1.47	--
173	2007-05-25	0.7767	1.953	0.6084	-0.7936	0.2597	-0.9657	5.98	89.81	1.306	33.05	-0.529	-1.15	--
174	2007-06-13	0.02938	2.831	0.3212	-0.947	0.7936	-0.6084	1.07	678.2	0.605	6.584	-0.576	-1.29	--
175	2007-06-15	0.9939	2.598	0.2896	-0.9572	0.8323	-0.5543	9.86	396.1	0.7385	8.954	0.255	0.544	--
176	2007-07-19	0.3444	2.776	-0.2889	-0.9573	0.833	0.5532	2.21	597.3	-0.008664	1.603	0.353	0.72	--
177	2007-08-09	0.1875	2.47	-0.6086	-0.7935	0.2593	0.9658	1.54	295.5	-0.2171	0.9918	0.405	0.837	--
178	2008-03-18	-0.4685	2.824	0.9717	0.2361	-0.8885	0.4588	0.34	666.2	-0.206	1.017	-0.263	-0.671	--
179	2008-04-11	0.7627	2.9	0.9858	-0.1681	-0.9435	-0.3314	5.79	794.7	0.1866	2.512	0.576	1.19	--
180	2008-05-29	0.6149	2.336	0.5447	-0.8387	0.4067	-0.9136	4.12	216.7	1.042	18.02	-0.427	-1.01	--
181	2008-10-31	-0.3372	2.911	-0.8705	0.4922	-0.5154	-0.8569	0.46	814	-0.5584	0.452	0.221	0.478	--
182	2008-11-24	-0.6021	3.025	-0.6012	0.7991	0.2772	-0.9608	0.25	1060	-0.5103	0.5049	-0.0918	-0.272	--
183	2009-03-23	-0.3872	2.986	0.986	0.1666	-0.9445	0.3285	0.41	969	-0.2421	0.9362			

186	2009-05-04	0.4713	2.755	0.8502	-0.5264	-0.4458	-0.8951	2.96	568.5	0.6411	7.154	-0.17	-0.478	--
187	2009-06-03	0.9754	2.897	0.4782	-0.8783	0.5427	-0.8399	9.45	789	0.6468	7.248	0.329	0.671	--
188	2009-06-11	0.8182	2.813	0.3532	-0.9355	0.7505	-0.6609	6.58	650.7	0.6385	7.112	0.18	0.302	--
189	2009-06-16	0.8785	2.684	0.2721	-0.9623	0.852	-0.5236	7.56	483.3	0.6672	7.598	0.211	0.446	--
190	2009-07-16	0.2553	2.801	-0.2401	-0.9707	0.8847	0.4662	1.8	632	0.03752	1.782	0.218	0.468	--
191	2009-08-18	-0.3768	2.594	-0.7239	-0.6899	-0.04804	0.9988	0.42	393	-0.4376	0.5968	0.0609	0	--
192	2009-09-11	-0.4949	2.503	-0.9392	-0.3433	-0.7643	0.6449	0.32	318.3	-0.5609	0.4493	0.0661	0.0384	--
193	2009-10-14	-1	2.794	-0.9764	0.2159	-0.9068	-0.4215	0.1	622.3	-0.6217	0.3906	-0.378	-0.921	--
194	2009-11-03	-0.1618	2.514	-0.8463	0.5328	-0.4323	-0.9017	0.689	326.7	-0.2722	0.8736	0.11	0.0961	--
195	2010-01-25	-1.097	3.083	0.4091	0.9125	0.6654	0.7465	0.08	1210	-0.7682	0.2788	-0.329	-0.837	--
196	2010-02-16	-1.222	3.053	0.7182	0.6959	-0.03148	0.9995	0.06	1130	-0.7246	0.3082	-0.497	-1.11	--
197	2010-03-09	-0.2218	2.917	0.9178	0.397	-0.6848	0.7287	0.6	825.9	-0.4244	0.6154	0.203	0.415	--
198	2010-04-14	-0.8729	3.017	0.9784	-0.2066	-0.9147	-0.4042	0.134	1040	0.1508	2.313	-1.02	-1.79	--
199	2010-04-23	0.711	2.779	0.9346	-0.3557	-0.747	-0.6649	5.14	601	0.4681	4.804	0.243	0.533	--
200	2010-05-03	0.3802	2.985	0.8595	-0.5112	-0.4774	-0.8787	2.4	965	0.4746	4.876	-0.0944	-0.292	--
201	2010-05-13	0.5051	2.543	0.7596	-0.6504	-0.1539	-0.9881	3.2	349	0.8679	12.06	-0.363	-0.907	--
202	2010-05-28	0.6128	2.939	0.5679	-0.8231	0.355	-0.9349	4.1	868	0.6425	7.177	-0.0297	-0.183	--
203	2010-06-09	0.9965	2.2	0.3878	-0.9217	0.6992	-0.7149	9.92	158.6	1.07	19.22	-0.0738	-0.232	--
204	2010-06-13	0.6532	2.022	0.3197	-0.9475	0.7956	-0.6058	4.5	105.3	1.146	22.88	-0.493	-1.1	--
205	2010-06-14	0.3802	2.019	0.3169	-0.9484	0.7991	-0.6012	2.4	104.4	1.147	22.91	-0.766	-1.59	--
206	2010-06-14	0.5211	2.035	0.3072	-0.9516	0.8113	-0.5847	3.32	108.3	1.129	21.99	-0.608	-1.36	--
207	2010-06-15	0.6937	2.281	0.291	-0.9567	0.8306	-0.5568	4.94	191	0.9519	14.63	-0.258	-0.659	--
208	2010-06-16	0.8129	2.309	0.2746	-0.9616	0.8492	-0.5281	6.5	203.5	0.9209	13.63	-0.108	-0.353	--
209	2010-07-06	0.9708	2.017	-0.06594	-0.9978	0.9913	0.1316	9.35	104	0.7765	9.772	0.194	0.383	--
210	2010-07-08	-1.602	2.167	-0.1036	-0.9946	0.9785	0.206	0.025	146.9	0.6313	6.995	-2.23	-2.83	< 0.025
211	2010-07-16	-1.602	2.667	-0.2376	-0.9714	0.8871	0.4616	0.025	464.5	0.1303	2.207	-1.73	-2.5	< 0.025
212	2010-07-26	-1.602	2.623	-0.4025	-0.9154	0.676	0.7369	0.025	419.5	-0.05361	1.445	-1.55	-2.2	< 0.025
213	2010-08-03	-0.2518	2.768	-0.5236	-0.852	0.4518	0.8921	0.56	586.5	-0.3088	0.803	0.0569	-0.0096	--
214	2010-08-19	-0.4318	2.802	-0.7351	-0.6779	-0.08084	0.9967	0.37	633.7	-0.5892	0.421	0.157	0.242	--
215	2011-03-07	-0.3625	2.88	0.9033	0.4291	-0.6317	0.7752	0.434	759	-0.4281	0.6101	0.0656	0.0288	--
216	2011-03-16	-0.4237	2.906	0.9579	0.2871	-0.8352	0.5499	0.377	805.2	-0.3127	0.7957	-0.111	-0.363	--
217	2011-04-06	-0.6819	2.981	0.9975	-0.07059	-0.99	-0.1408	0.208	957	0.02362	1.726	-0.706	-1.5	--
218	2011-05-02	-0.9508	2.972	0.8689	-0.4951	-0.5098	-0.8603	0.112	936.9	0.4697	4.821	-1.42	-2.02	--
219	2011-06-07	0.238	2.839	0.4201	-0.9075	0.647	-0.7625	1.73	691	0.6596	7.465	-0.422	-0.982	--
220	2011-06-21	1.328	2.949	0.1903	-0.9817	0.9275	-0.3737	21.3	890	0.4207	4.307	0.908	2.33	--
221	2011-06-22	1.143	2.93	0.1732	-0.9849	0.94	-0.3411	13.9	850.7	0.4181	4.282	0.725	1.89	--
222	2011-08-15	-0.08355	2.578	-0.6859	-0.7277	0.05914	0.9982	0.825	378.2	-0.3827	0.6773	0.299	0.612	--
223	2011-09-22	-0.3979	2.591	-0.987	-0.1609	-0.9482	0.3175	0.4	390.2	-0.6156	0.3962	0.218	0.457	--
224	2011-12-20	-0.007446	2.529	-0.1972	0.9804	0.9222	-0.3867	0.983	338.4	-0.2163	0.9936	0.209	0.436	--
225	2012-02-06	0.5132	2.664	0.5854	0.8108	0.3147	0.9492	3.26	461.5	-0.4979	0.5195	1.01	2.83	--
226	2012-03-01	0.3784	2.633	0.8617	0.5074	-0.4851	0.8745	2.39	430	-0.3268	0.7704	0.705	1.79	--
227	2012-04-07	0.6776	2.576	0.9949	-0.101	-0.9796	-0.2009	4.76	376.7	0.329	3.487	0.349	0.707	--
228	2012-04-17	0.1038	2.86	0.9629	-0.2697	-0.9545	-0.5194	1.27	725	0.3241	3.448	-0.22	-0.566	--
229	2012-06-18	1.057	2.559	0.2302	-0.9731	0.894	-0.4481	11.4	362.2	0.7171	8.522	0.34	0.683	--
230	2012-06-19	0.6767	2.71	0.2157	-0.9765	0.9069	-0.4213	4.75	513	0.6034	6.56	0.0733	0.0576	--
231	2012-07-02	0.3802	2.843	-0.00846	-1	0.9999	0.01693	2.4	696.8	0.289	3.18	0.0912	0.0768	--
232	2012-07-12	-0.3279	2.894	-0.1774	-0.9841	0.9371	0.3492	0.47	782.7	0.05431	1.853	-0.382	-0.936	--
233	2012-07-19	-0.9031	2.836	-0.294	-0.9558	0.8271	0.5621	0.125	685	-0.05511	1.44	-0.848	-1.63	--
234	2012-08-27	-0.6778	2.49	-0.8248	-0.5654	-0.3607	0.9327	0.21	308.8	-0.4723	0.551	-0.205	-0.533	--
235	2012-09-06	-0.6778	2.742	-0.9094	-0.416	-0.654	0.7565	0.21	552.4	-0.7074	0.3207	0.0296	-0.048	--
236	2012-09-11	-0.9136	2.837	-0.941	-0.3385	-0.7709	0.637	0.122	687.5	-0.7856	0.2679	-0.128	-0.415	--
237	2012-10-15	-1.222	2.934	-0.971	0.2392	-0.8856	-0.4645	0.06	860	-0.7046	0.3228	-0.517	-1.13	--
238	2012-11-07	-1.071	2.917	-0.8053	0.5928	-0.2971	-0.9549	0.085	825.8	-0.5128	0.5019	-0.558	-1.25	--
239	2013-01-02	-1.301	2.978	0.02737	0.9996	0.9985	0.05472	0.05	950.5	-0.587	0.4231	-0.714	-1.53	--
240	2013-01-16	-0.8861	2.945	0.2621	0.965	0.8626	0.5059	0.13	880.2	-0.6408	0.3739	-0.245	-0.635	--
241	2013-01-29	-1.26	2.898	0.4699	0.8827	0.5583	0.8296	0.055	791	-0.6531	0.3634	-0.607	-1.34	--
242	2013-02-19	-0.2441	2.937	0.7516	0.6596	-0.1299	0.9915	0.57	864	-0.629	0.3841	0.385	0.783	--
243	2013-03-13	-0.3686	3.018	0.9419	0.336	-0.7742	0.6329	0.428	1042	-0.4356	0.5996	0.0671	0.048	--
244	2013-03-15	-0.4559	2.945	0.9538	0.3004	-0.8196	0.573	0.35	882	-0.3524	0.7262	-0.104	-0.332	--
245	2013-03-27	-0.8861	3.064	0.995	0.09983	-0.9801	0.1987	0.13	1160	-0.2222	0.9801	-0.664	-1.44	--
246	2013-04-15	0.8513	3.045	0.9747	-0.2235	-0.9001	-0.4356	7.1	1108	0.1508	2.314	0.7	1.74	--
247	2013-04-24	0.2041	2.764	0.9285	-0.3714	-0.7241	-0.6897	1.6	581	0.4937	5.096	-0.29	-0.783	--
248	2013-05-09	0.6232	2.675	0.801	-0.5986	-0.2833	-0.959	4.2	472.8	0.7481	9.153	-0.125	-0.394	--
249	2013-05-20	1.114	2.649	0.6752	-0.7376	0.08811	-0.9961	13	445.4	0.8326	11.12	0.281	0.578	--
250	2013-05-21	0.433	2.65	0.6638	-0.7479	0.1188	-0.9929	2.71	447	0.8339	11.15	-0.401	-0.951	--
251	2013-06-05	0.938	2.692	0.4508	-0.8926	0.5936	-0.8048	8.67	492	0.773	9.693	0.165	0.252	--
252	2013-07-29	-0.05799	2.149	-0.4466	-0.8947	0.6011	0.7992	0.875	141	0.2059	2.627	-0.264	-0.683	--
253	2013-08-07	-0.7496	2.017	-0.5789	-0.8154	0.3297	0.9441	0.178	104	0.124	2.175	-0.874	-1.7	--
254	2013-10-30	0.2279	2.604	-0.8809	0.4733	-0.552	-0.8338	1.69	402	-0.3628	0.709	0.591	1.23	--
255	2014-04-09	-1.377	2.996	0.9923	-0.1241	-0.9692	-0.2463	0.042	990.5	0.07358	1.937	-1.45	-2.11	--
256	2014-05-14	0.8768	2.766	0.7468	-0.665	-0.1155	-0.9933	7.53	583.3	0.7261	8.702	0.151	0.213	--
257	2014-06-03	0.7543	2.796	0.4805	-0.877	0.5382	-0.8428	5.68	625.6	0.7151	8.484	0.0392	-0.0288	--
258	2014-06-09	0.8785	2.358	0.3853	-0.9228	0.703	-0.7112	7.56	228	0.9633	15.02	-0.0848	-0.242	--
259	2014-07-15	0.1818	2.879	-0.2224	-0.975	0.9011	0.4336	1.52	757.3	0.007402	1.663	0.174	0.282	--
260	2014-08-04	-0.2967	2.915	-0.5357	-0.8444	0.426	0.9047	0.505	821.5	-0.4225	0.6181	0.126	0.135	--
261	2014-09-03	-0.5129	2.182	-0.8837	-0.468	-0.562	0.8272	0.307	152	-0.3151	0.7913	-0.198	-0.522	--

Definitions

ATR: Atrazine in ug/l (39632)

SC: Specific conductance in uS/cm @25C (00095)

DY: Date in decimal years

Model Archive Summary for Total Organic Carbon at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the total organic carbon (TOC) model developed to compute hourly TOC from January 1, 2007 onward.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 Turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly.

Date model was created: April 6, 2015

Model calibration data period: July 27, 2004 to August 4, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. The regression model is based on 82 concurrent measurements of total organic carbon, streamflow, and turbidity collected from July 27, 2004 through August 4, 2014. Samples were collected throughout the range of continuously observed hydrologic conditions. There were no samples below laboratory reporting levels. Summary statistics and the complete model-calibration dataset are provided below. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. A sample collected May 13, 2010 was deemed an outlier and was removed from the dataset.

Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and also during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado; the Wichita Municipal Water and Wastewater Laboratory, Wichita, Kansas; the USGS Ohio Microbiology Lab in Columbus, Ohio; the USGS Organic Lab in Lawrence, Kansas; and ALS Environmental at various locations in the U.S.

Model Development

Regression analysis was done using R by examining SC, streamflow, and other continuously measured data as explanatory variables for estimating total organic carbon. A variety of models that predict TOC and models that predict $\log_{10}(\text{TOC})$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and predicted values) as compared to predicted TOC

were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{TOC})$.

Turbidity was selected as the best predictor of TOC based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for total organic carbon at site number 07144100.

Total organic carbon-based model:

$$\log_{10}(\text{TOC}) = 0.391 \times \log_{10}(\text{TURB}) + 0.318,$$

where

TOC = total organic carbon in milligrams per liter (mg/L); and,

TURB = Turbidity, YSI model 6136, in formazin nephelometric units (FNU).

Turbidity makes physical and statistical sense as an explanatory variable for organic carbon. Organic matter is one of the major components of total suspended solids; turbidity may be a suitable surrogate for total organic carbon in water. Turbidity makes statistical sense as an explanatory variable because it resulted in a model with low standard error, Mallows' C_p and $PRESS$ values, and high R^2 values. The model selected was the simplest model (one explanatory variable) even though some of the other models were marginally better statistically.

The log-transformed model may be retransformed to the original units so that TOC can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.03. The retransformed model, accounting for BCF is:

$$\text{TOC} = 2.14 \times \text{TURB}^{0.391}.$$

Previous models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	2007	--	$\log_{10}(\text{TOC}) = 0.391 \times \log_{10}(\text{TURB}) + 0.318$

Total Organic Carbon Record

The TOC record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at hourly intervals. The complete water-quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

None

Computed: Patrick Eslick

Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

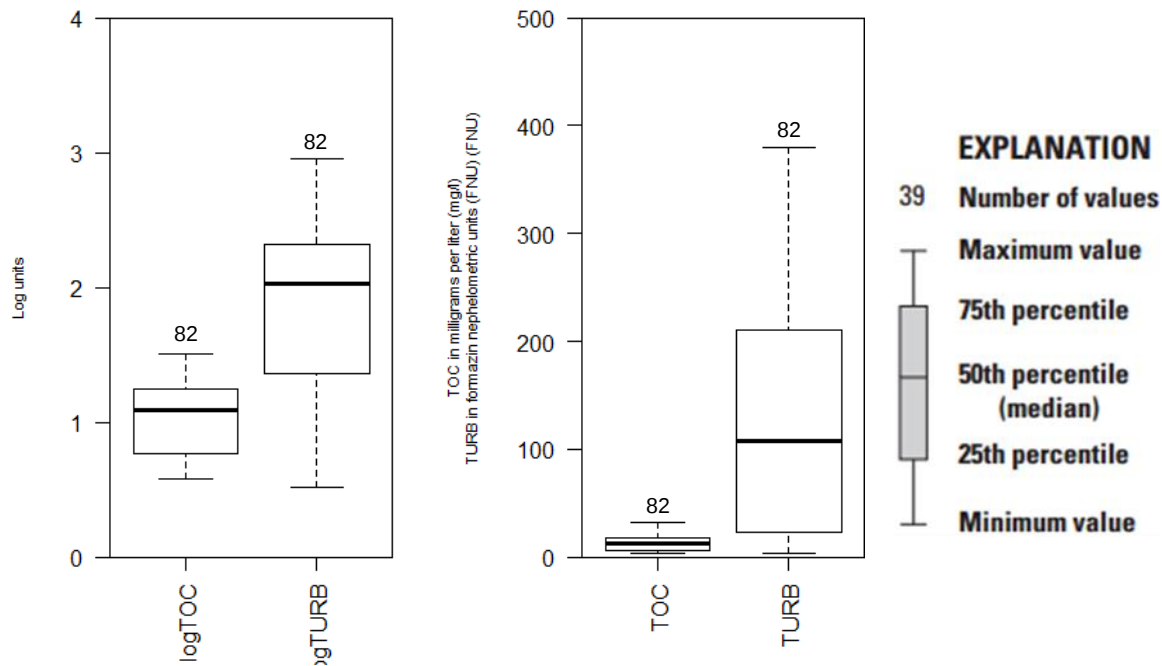
Model

$\log\text{TOC} = + 0.391 * \log\text{TURB} + 0.318$

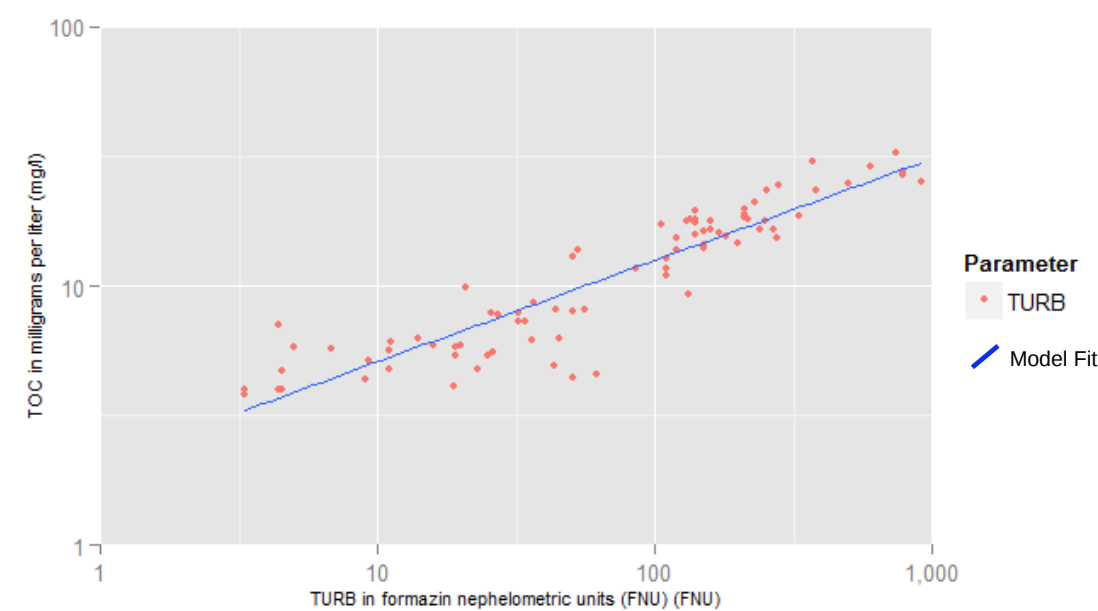
Variable Summary Statistics

	logTOC	logTURB	TOC	TURB
Minimum	0.580	0.519	3.80	3.3
1st Quartile	0.768	1.360	5.86	23.0
Median	1.090	2.030	12.20	107.0
Mean	1.030	1.820	12.80	150.0
3rd Quartile	1.250	2.320	17.80	210.0
Maximum	1.510	2.960	32.40	910.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	82
Standard error (RMSE)	0.109
Upper Model standard percentage error (MSPE)	28.5
Lower Model standard percentage error (MSPE)	22.2
Coefficient of determination (R ²)	0.838
Adjusted Coefficient of Determination (Adj. R ²)	0.836
Bias Correction Factor (BCF)	1.03

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.318	0.0370	8.58	5.77e-13
logTURB	0.391	0.0192	20.30	2.40e-33

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.946
E.vars	-0.946	1.000

Outlier Test Criteria

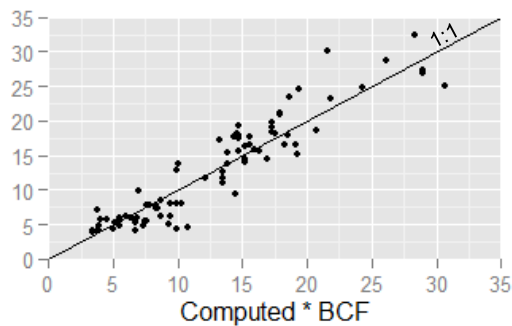
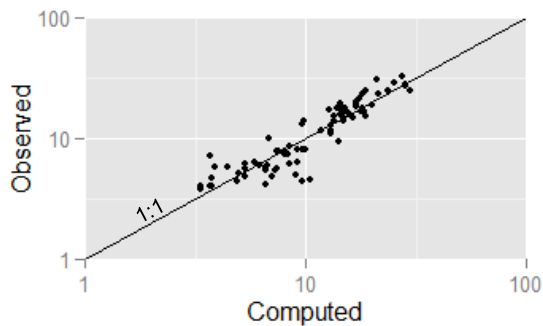
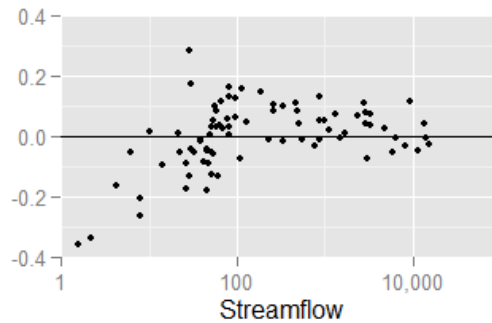
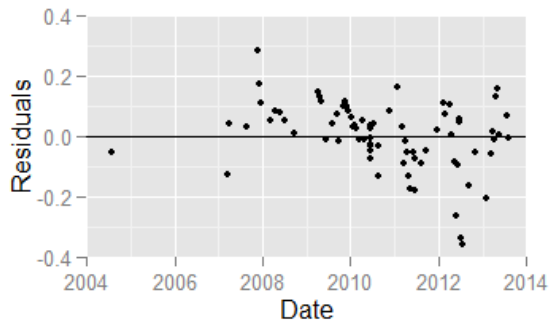
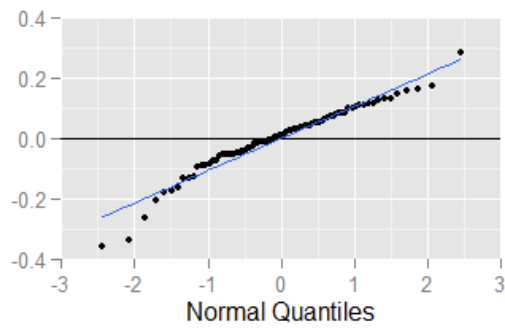
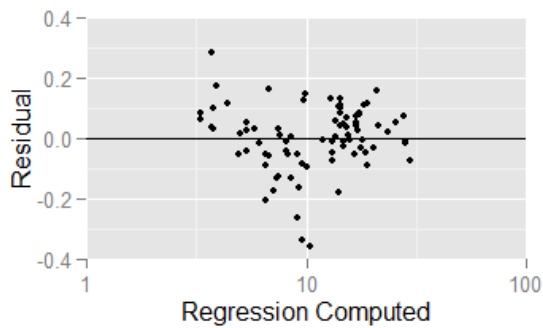
Leverage	Cook's D	DFFITS
0.03658537	0.10549768	0.22086305

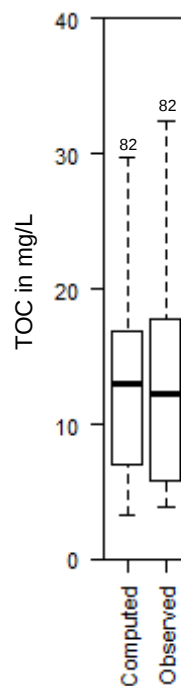
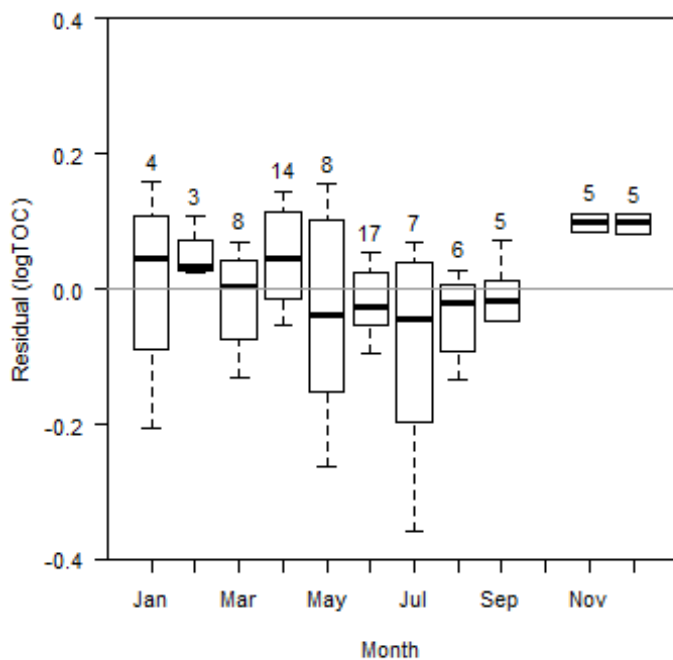
Flagged Observations

	logTOC	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
11/26/2007 10:40	0.8513	0.5692	0.28210	2.6620	2.7710	0.05524	0.2071000	0.66990
12/6/2007 11:45	0.7634	0.5909	0.17250	1.6250	1.6420	0.05127	0.0713200	0.38170

3/6/2008 10:35	1.4580	1.4040	0.05363	0.5023	0.4999	0.04083	0.0053690	0.10310
6/16/2009 12:51	1.4380	1.4500	-0.01188	-0.1117	-0.1110	0.04817	0.0003156	-0.02497
9/24/2009 11:15	1.4300	1.4480	-0.01858	-0.1746	-0.1736	0.04795	0.0007680	-0.03895
11/19/2009 11:40	0.7559	0.6439	0.11190	1.0490	1.0500	0.04239	0.0243600	0.22090
12/1/2009 12:40	0.6721	0.5730	0.09908	0.9346	0.9339	0.05453	0.0251900	0.22430
12/17/2009 12:00	0.6021	0.5204	0.08170	0.7750	0.7730	0.06487	0.0208300	0.20360
1/6/2010 11:50	0.5798	0.5204	0.05943	0.5637	0.5612	0.06487	0.0110200	0.14780
1/19/2010 10:00	0.6021	0.5730	0.02904	0.2739	0.2724	0.05453	0.0021640	0.06541
2/4/2010 10:40	0.6021	0.5679	0.03415	0.3223	0.3205	0.05548	0.0030510	0.07767
6/9/2010 9:46	1.3980	1.4750	-0.07656	-0.7215	-0.7193	0.05256	0.0144400	-0.16940
5/16/2011 11:31	0.6767	0.8500	-0.17330	-1.6050	-1.6210	0.01872	0.0245700	-0.22390
3/1/2012 12:01	1.5110	1.4400	0.07016	0.6591	0.6568	0.04661	0.0106200	0.14520
5/30/2012 9:11	0.6946	0.9580	-0.26340	-2.4320	-2.5120	0.01322	0.0396400	-0.29080
7/12/2012 10:16	0.6444	0.9839	-0.33950	-3.1330	-3.3240	0.01261	0.0627000	-0.37570
7/19/2012 10:16	0.6599	1.0180	-0.35790	-3.3030	-3.5320	0.01222	0.0675000	-0.39290
1/29/2013 10:06	0.6117	0.8167	-0.20500	-1.9000	-1.9330	0.02138	0.0394500	-0.28570
5/9/2013 13:50	1.4770	1.3220	0.15470	1.4400	1.4500	0.02970	0.0317500	0.25370

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logTOC ~ logTURB	1	0.109	83.79	83.59	76.07	0.9952	1 ± 25	
logTOC ~ SC	1	0.162	64.2	63.75	262.2	2.201	1 ± 38	
logTOC ~ TURB	1	0.1781	56.75	56.21	333	2.787	1 ± 42	
logTOC ~ logTURB + logQ	2	0.09407	88.08	87.78	37.26	0.7685	1.699 ± 22	
logTOC ~ logTURB + SC	2	0.1065	84.72	84.34	69.17	0.9548	2.962 ± 25	
logTOC ~ logTURB + logSC	2	0.1078	84.34	83.94	72.81	0.9789	2.138 ± 25	
logTOC ~ Q + logTURB + logQ	3	0.08085	91.31	90.97	8.61	0.5635	2.324 ± 19	
logTOC ~ logTURB + logQ + logSC	3	0.08977	89.28	88.87	27.84	0.7025	2.146 ± 21	
logTOC ~ TURB + logTURB + logQ	3	0.09385	88.29	87.84	37.32	0.7754	2.611 ± 22	
logTOC ~ Q + logTURB + logQ + SC	4	0.08086	91.42	90.97	9.578	0.5708	2.583 ± 19	
logTOC ~ logTURB + logQ + SC + logSC	4	0.08103	91.38	90.93	9.914	0.5777	3.386 ± 19	
logTOC ~ Q + logTURB + logQ + logSC	4	0.08135	91.31	90.86	10.58	0.5753	3.526 ± 19	
logTOC ~ Q + logTURB + logQ + SC + logSC	5	0.07834	92.05	91.52	5.578	0.5369	4.655 ± 18	
logTOC ~ TURB + logTURB + logQ + SC + logSC	5	0.08064	91.57	91.02	10.08	0.5789	2.75 ± 19	
logTOC ~ TURB + Q + logTURB + logQ + SC	5	0.08134	91.43	90.86	11.48	0.5883	2.831 ± 19	
logTOC ~ TURB + Q + logTURB + logQ + SC + logSC	6	0.07856	92.11	91.48	7	0.5475	2.925 ± 18	

Model-Calibration Data Set

0	Date	logTOC	logTURB	TOC	TURB	Computed logTOC	Computed TOC	Residual	Normal Quantiles	Censored Values
1	2004-07-27	1.161	2.301	14.5	200	1.217	16.98	-0.0559	-0.792	--
2	2007-03-21	0.7412	1.415	5.51	26	0.8708	7.646	-0.13	-1.19	--
3	2007-04-02	1.367	2.58	23.3	380	1.326	21.82	0.0411	0.391	--
4	2007-08-16	0.8976	1.412	7.9	25.8	0.8695	7.623	0.0281	0.169	--
5	2007-11-26	0.8513	0.6435	7.1	4.4	0.5692	3.818	0.282	2.44	--
6	2007-12-06	0.7634	0.699	5.8	5	0.5909	4.013	0.173	2.06	--

7	2007-12-13	1.369	2.406	23.4	254.7	1.258	18.66	0.111	1.13	--
8	2008-03-06	1.458	2.779	28.7	601.7	1.404	26.11	0.0536	0.527	--
9	2008-04-14	1.324	2.362	21.1	230	1.241	17.93	0.0833	0.835	--
10	2008-05-29	1.32	2.362	20.9	230	1.241	17.93	0.0792	0.751	--
11	2008-06-30	1.279	2.324	19	211	1.226	17.33	0.0524	0.458	--
12	2008-09-16	1.201	2.23	15.9	170	1.19	15.93	0.0117	0.0152	--
13	2009-04-06	1.137	1.724	13.7	53	0.9918	10.1	0.145	1.59	--
14	2009-04-13	1.288	2.146	19.4	140	1.157	14.77	0.131	1.49	--
15	2009-04-28	1.389	2.447	24.5	280	1.274	19.36	0.115	1.26	--
16	2009-06-16	1.438	2.895	27.4	786	1.45	28.99	-0.0119	-0.231	--
17	2009-07-30	1.265	2.322	18.4	210	1.226	17.3	0.0393	0.358	--
18	2009-09-09	1.297	2.322	19.8	210	1.226	17.3	0.0711	0.711	--
19	2009-09-24	1.43	2.892	26.9	780	1.448	28.9	-0.0186	-0.358	--
20	2009-11-03	1.255	2.146	18	140	1.157	14.77	0.0986	0.924	--
21	2009-11-19	0.7559	0.8346	5.7	6.833	0.6439	4.534	0.112	1.19	--
22	2009-12-01	0.6721	0.6532	4.7	4.5	0.573	3.851	0.0991	0.972	--
23	2009-12-17	0.6021	0.5185	4	3.3	0.5204	3.411	0.0817	0.792	--
24	2010-01-06	0.5798	0.5185	3.8	3.3	0.5204	3.411	0.0594	0.598	--
25	2010-01-19	0.6021	0.6532	4	4.5	0.573	3.851	0.029	0.2	--
26	2010-02-04	0.6021	0.6402	4	4.367	0.5679	3.806	0.0341	0.262	--
27	2010-02-23	0.7482	1.041	5.6	11	0.7248	5.462	0.0234	0.107	--
28	2010-03-10	1.158	2.176	14.4	150	1.168	15.17	-0.01	-0.2	--
29	2010-04-14	0.7803	1.049	6.03	11.2	0.7278	5.501	0.0525	0.492	--
30	2010-04-23	1.104	2.041	12.7	110	1.116	13.44	-0.0119	-0.262	--
31	2010-06-09	1.398	2.959	25	910	1.475	30.7	-0.0766	-0.924	--
32	2010-06-10	1.217	2.204	16.5	160	1.179	15.56	0.0381	0.294	--
33	2010-06-13	1.27	2.522	18.6	333	1.304	20.72	-0.0343	-0.458	--
34	2010-06-14	1.217	2.431	16.5	269.5	1.268	19.08	-0.0504	-0.598	--
35	2010-06-14	1.143	2.176	13.9	150	1.168	15.17	-0.0254	-0.391	--
36	2010-06-15	1.25	2.398	17.8	250	1.255	18.52	-0.00471	-0.107	--
37	2010-06-16	1.258	2.339	18.1	218.2	1.232	17.56	0.0257	0.138	--
38	2010-07-06	1.196	2.146	15.7	140	1.157	14.77	0.0392	0.326	--
39	2010-08-19	0.7924	1.559	6.2	36.2	0.927	8.702	-0.135	-1.33	--
40	2010-08-25	1.217	2.38	16.5	240	1.248	18.23	-0.0307	-0.424	--
41	2010-11-16	1.241	2.146	17.4	140	1.157	14.77	0.0839	0.879	--
42	2011-01-19	0.9912	1.315	9.8	20.67	0.8319	6.989	0.159	1.86	--
43	2011-03-07	0.7973	1.146	6.27	14	0.7657	6.002	0.0315	0.231	--
44	2011-03-16	0.7284	1.279	5.35	19	0.8176	6.763	-0.0892	-1.02	--
45	2011-04-06	0.7723	1.203	5.92	15.97	0.788	6.319	-0.0157	-0.326	--
46	2011-04-18	0.7657	1.279	5.83	19	0.8176	6.763	-0.0519	-0.711	--
47	2011-05-02	0.7308	1.396	5.38	24.9	0.8635	7.518	-0.133	-1.26	--
48	2011-05-16	0.6767	1.362	4.75	23	0.85	7.288	-0.173	-1.49	--
49	2011-06-07	0.9069	1.643	8.07	43.97	0.96	9.389	-0.0532	-0.751	--
50	2011-06-21	1.041	2.041	11	110	1.116	13.44	-0.0743	-0.879	--
51	2011-06-22	0.9689	2.124	9.31	133	1.148	14.47	-0.179	-1.59	--
52	2011-08-15	1.182	2.444	15.2	277.7	1.273	19.3	-0.0911	-1.08	--
53	2011-09-22	1.068	2.041	11.7	110	1.116	13.44	-0.0476	-0.562	--
54	2011-12-20	1.393	2.698	24.7	498.7	1.372	24.26	0.0203	0.0763	--
55	2012-02-06	1.258	2.129	18.1	134.7	1.15	14.54	0.108	1.08	--
56	2012-03-01	1.511	2.872	32.4	744.3	1.44	28.38	0.0702	0.673	--
57	2012-04-07	1.248	2.114	17.7	130	1.144	14.34	0.104	1.02	--
58	2012-04-17	0.934	1.562	8.59	36.47	0.9283	8.727	0.00572	-0.0763	--

59	2012-05-09	0.8998	1.703	7.94	50.52	0.9836	9.913	-0.0838	-0.972	--
60	2012-05-30	0.6946	1.638	4.95	43.45	0.958	9.346	-0.263	-1.86	--
61	2012-06-12	0.9053	1.748	8.04	55.92	1.001	10.31	-0.0956	-1.13	--
62	2012-06-18	1.212	2.176	16.3	150	1.168	15.17	0.0438	0.424	--
63	2012-06-19	1.185	2.079	15.3	120	1.131	13.9	0.0542	0.562	--
64	2012-07-12	0.6444	1.704	4.41	50.6	0.9839	9.919	-0.339	-2.06	--
65	2012-07-19	0.6599	1.791	4.57	61.8	1.018	10.73	-0.358	-2.44	--
66	2012-09-11	0.798	1.653	6.28	45	0.964	9.475	-0.166	-1.4	--
67	2012-11-07	0.6405	0.9574	4.37	9.065	0.6919	5.064	-0.0515	-0.635	--
68	2013-01-29	0.6117	1.276	4.09	18.9	0.8167	6.749	-0.205	-1.71	--
69	2013-03-13	0.7679	1.301	5.86	20	0.8263	6.9	-0.0584	-0.835	--
70	2013-03-27	0.7135	0.9694	5.17	9.32	0.6966	5.119	0.0168	0.0458	--
71	2013-04-15	0.8927	1.505	7.81	32	0.9061	8.292	-0.0134	-0.294	--
72	2013-04-24	1.236	2.02	17.2	104.8	1.108	13.19	0.128	1.4	--
73	2013-05-09	1.477	2.57	30	371.7	1.322	21.63	0.155	1.71	--
74	2013-05-21	1.137	2.079	13.7	120	1.131	13.9	0.00621	-0.0458	--
75	2013-07-29	1.248	2.204	17.7	160	1.179	15.56	0.0686	0.635	--
76	2013-08-07	1.064	1.932	11.6	85.53	1.073	12.18	-0.00857	-0.138	--
77	2014-04-09	0.6794	1.041	4.78	11	0.7248	5.462	-0.0454	-0.492	--
78	2014-05-14	1.111	1.705	12.9	50.65	0.9841	9.923	0.127	1.33	--
79	2014-06-03	0.8645	1.531	7.32	34	0.9164	8.491	-0.0519	-0.673	--
80	2014-06-09	1.19	2.255	15.5	180	1.199	16.29	-0.00903	-0.169	--
81	2014-07-15	0.8621	1.509	7.28	32.27	0.9075	8.319	-0.0454	-0.527	--
82	2014-08-04	0.8865	1.437	7.7	27.33	0.8793	7.797	0.00716	-0.0152	--

Definitions

TOC: Organic carbon in mg/l (00680)

TURB: Turbidity in FNU (63680)

Model Archival Summary for Suspended-Sediment Concentration at Station 07144100; Little Arkansas River near Sedgwick, Kansas

This model archive summary (MAS) summarizes the suspended-sediment concentration (SS) model developed to compute hourly SS from January 1, 2007 onward. This model supersedes all models used from 1999 to 2007.

Site and Model Information

Site number: 07144100

Site name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas, Hydrologic Unit 11030012, on left bank at downstream side from county highway bridge, 2.1 miles (mi) south of Sedgwick, and at mile marker 23.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance (SC), dissolved oxygen, and pH, and a YSI Model 6136 Turbidity sensor for turbidity. The monitor is housed in a 4-inch plastic pipe. Readings from the YSI 6600 are recorded every 30 minutes and transmitted by way of satellite, hourly. Date model was created: December 26, 2014

Model calibration data period: July, 27 2004 to August 4, 2014

Model application date: January 1, 2007 onward

Model Data

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in National Water Information System (NWIS) database. The regression model is based on 120 concurrent measurements of suspended-sediment concentration, streamflow, and turbidity samples collected from July 27, 2004 through August 04, 2014. Samples were collected throughout the range of continuously observed hydrologic and turbidity conditions. Summary statistics and complete model-calibration dataset are provided in the dataset. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. Samples collected May 29, 2008; December 1, 2009; December 17, 2009; and December 11, 2013; June 13, 2010; July 6, 2010; and August 15, 2013 were deemed outliers and were removed from the dataset.

Sediment Sampling Details

Cross-section samples are collected either from the downstream side of the bridge or instream upstream near the bridge. The equal-width-increment or multi-vertical method is used, and samples typically are composited for analysis. Cross-section samples are obtained during all discrete sample collections every month and during selected runoff events. A FISP US D-95 with a teflon bottle, cap, and nozzle depth integrating sampler is used from the bridge; and DH-81 with a teflon bottle, cap, and nozzle hand sampler or a grab sample with a teflon bottle for wading samples. Samples are analyzed for SS and/ or LOI and 5-point grain size in the USGS Sediment Laboratory in Iowa City, Iowa.

Model Development

Regression analysis was done using R by examining turbidity and other continuously measured data as explanatory variables for estimating suspended-sediment concentration. A variety of models that predict SS and models that predict $\log_{10}(\text{SS})$ were evaluated. The distribution of residuals was examined for normality and plots of residuals (the difference between the measured and predicted values) as compared to predicted SS were examined for homoscedasticity (meaning that their departures from zero did not change substantially over the range of predicted values). This comparison of several models led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{SS})$.

Turbidity and streamflow were selected as the best predictors of $\log_{10}(SS)$ based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error ($MSPE$), prediction error sum of squares ($PRESS$), and Mallows' C_p . Values for all of the aforementioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for suspended-sediment concentration at site number 07144100.
Suspended sediment concentration-based model:

$$\log_{10}(SS) = 0.933 \times \log_{10}(TURB) + 0.0431 \times \log_{10}(Q) + 0.262,$$

where

SS = suspended sediment concentration, in milligrams per liter (mg/L);

Q = streamflow in cubic feet per second (ft^3/s); and,

$TURB$ = Turbidity, YSI model 6136, in formazin nephelometric units (FNU).

The use of turbidity and streamflow as explanatory variables is appropriate physically and statistically. Turbidity makes sense physically because suspended sediment is composed of particles that scatter light in water. Suspended sediment correlates well with streamflow because high streamflow values tend to increase concentrations of SS. The relation between turbidity and SS can vary given varying concentrations of organic suspended particles that increase turbidity, but are not included in the SS analysis.

The log-transformed model may be retransformed to the original units so that SS can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's Bias Correction Factor (BCF). For this model, the calculated BCF is 1.02. The retransformed model, accounting for BCF is:

$$SS = 1.865 \times TURB^{0.933} \times Q^{0.0431}.$$

Previous models

<u>Model</u>	<u>Start year</u>	<u>End year</u>	<u>Model</u>
1.0	1999	2006	$\log_{10}(SS) = 0.715 \times \log_{10}(TURB) + 0.188 \times \log_{10}(Q) + 0.185$
1.1	2007	--	$\log_{10}(SS) = 0.933 \times \log_{10}(TURB) + 0.0431 \times \log_{10}(Q) + 0.262$

Suspended-Sediment Concentration Record

The SS record is computed using this regression model in the National Real-Time Water Quality (NRTWQ) Web site from 2015 onward. Data are computed at hourly intervals. The complete water quality record can be found at <http://nrtwq.usgs.gov/ks>.

Remarks

The turbidity data used in this analysis was measured using a YSI model 6136 installed and in use from 2007 onward. The 6136 replaced the old YSI model 6026 sensor. Data from the YSI 6026 and 6136 sensors are not equivalent and therefore cannot be used interchangeably with this new SS model.

Computed: Patrick Eslick

Reviewed: Patrick Rasmussen

Model Statistics, Data, and Plots

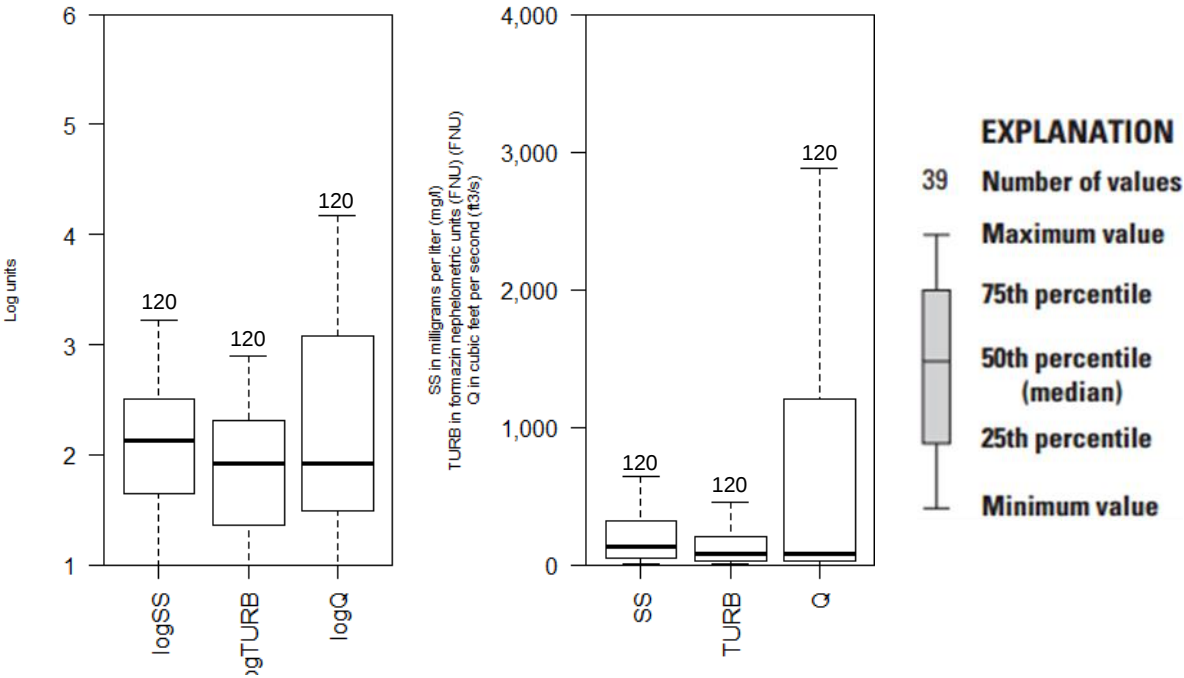
Model

$$\log SS = + 0.933 * \log TURB + 0.0431 * \log Q + 0.262$$

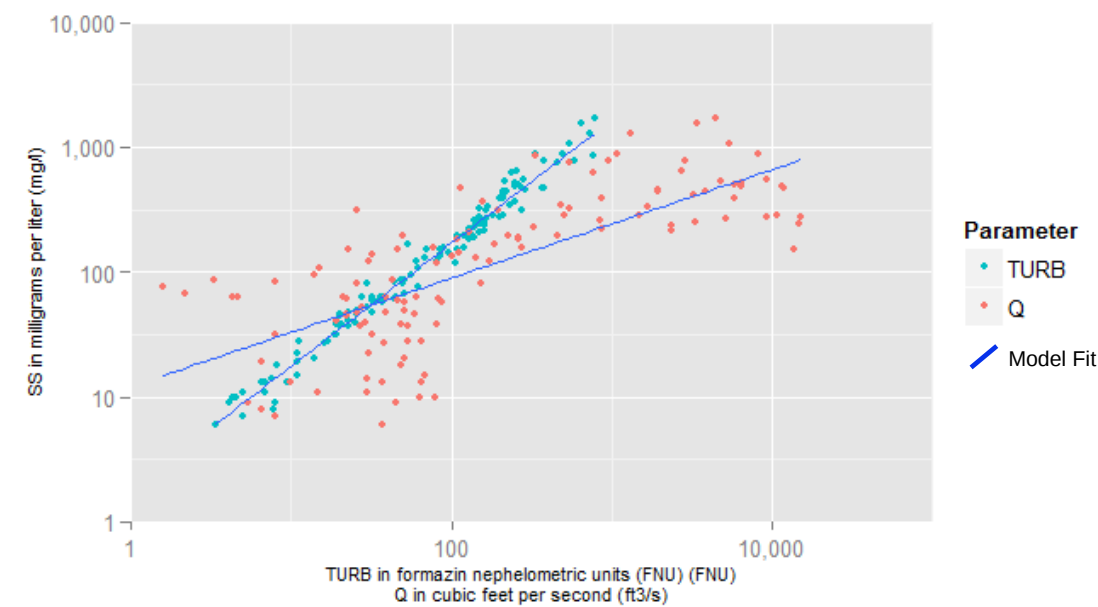
Variable Summary Statistics

	logSS	logTURB	logQ	SS	TURB	Q
Minimum	0.778	0.531	0.204	6	3.4	1.6
1st Quartile	1.650	1.360	1.490	45	23.0	30.6
Median	2.130	1.920	1.920	136	83.0	82.4
Mean	2.050	1.820	2.230	243	138.0	1630.0
3rd Quartile	2.500	2.310	3.080	318	204.0	1200.0
Maximum	3.230	2.890	4.180	1680	784.0	15100.0

Box Plots



Exploratory Plot



Basic Model Statistics

Number of Observations	120
Standard error (RMSE)	0.0848
Upper Model standard percentage error (MSPE)	21.6
Lower Model standard percentage error (MSPE)	17.7
Coefficient of determination (R ²)	0.98
Adjusted Coefficient of Determination (Adj. R ²)	0.979
Bias Correction Factor (BCF)	1.02
Variance Inflation Factors (VIF)	
logTURB	logQ
2.043725	2.043725

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.2620	0.0250	10.50	1.60e-18
logTURB	0.9330	0.0187	49.80	1.27e-80
logQ	0.0431	0.0110	3.93	1.45e-04

Correlation Matrix

	Intercept	logTURB	logQ
Intercept	1.0000	-0.660	-0.0075
logTURB	-0.6600	1.000	-0.7150
logQ	-0.0075	-0.715	1.0000

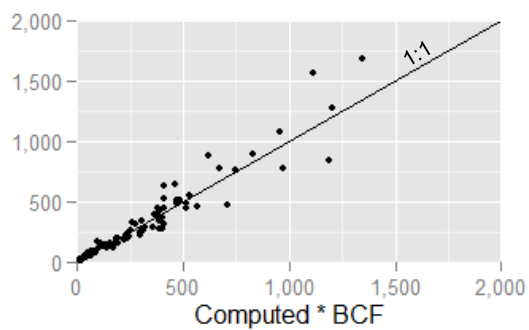
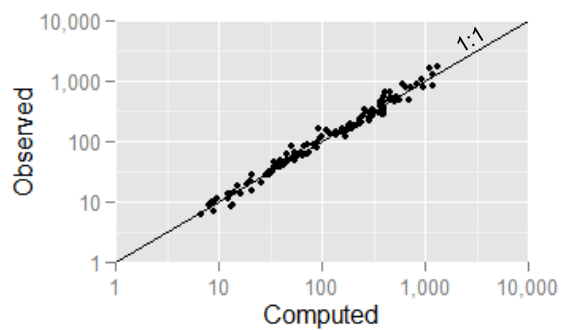
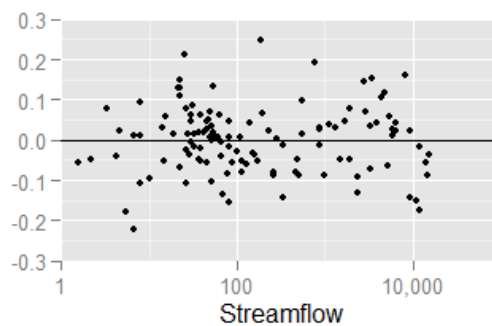
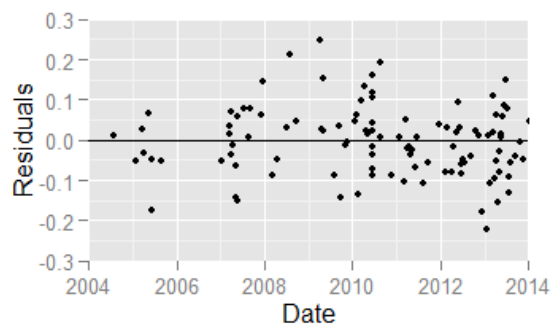
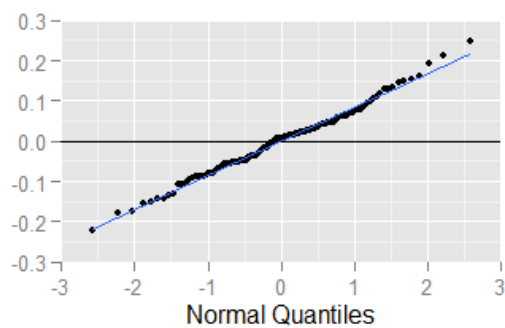
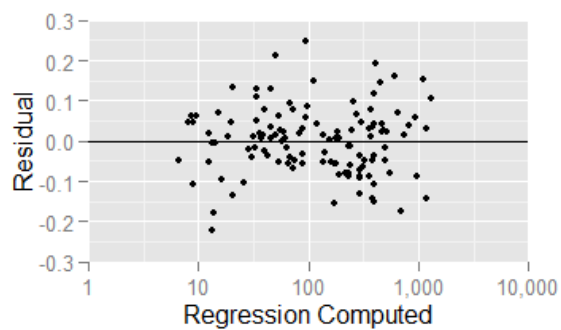
Outlier Test Criteria

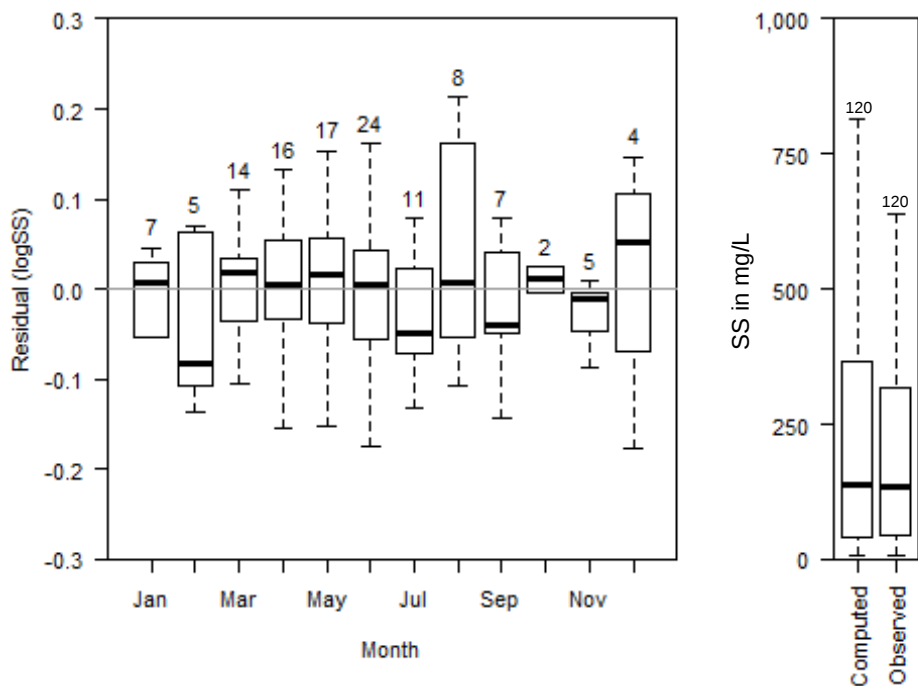
Leverage	Cook's D	DFFITS
0.0500000	0.1944518	0.2581989

Flagged Observations

	logSS	Estimate	Residual	Standard	Residual	Studentized	Residual	Leverage	Cook's D	DFITS
6/9/2005 10:55	2.6710	2.8450	-0.17380		-2.0880		-2.1190	0.036260	0.054660	-0.4109
5/8/2007 11:30	2.4390	2.5800	-0.14090		-1.6920		-1.7060	0.035960	0.035610	-0.3295
5/25/2007 13:10	2.4470	2.6000	-0.15260		-1.8350		-1.8540	0.038210	0.044580	-0.3695
8/5/2008 9:30	1.9140	1.7010	0.21280		2.5270		2.5870	0.013910	0.030020	0.3073
4/6/2009 13:05	2.2170	1.9690	0.24850		2.9440		3.0460	0.008928	0.026020	0.2891
5/8/2009 12:55	3.1930	3.0390	0.15390		1.8450		1.8650	0.032180	0.037730	0.3400
9/24/2009 11:20	2.9250	3.0680	-0.14230		-1.7250		-1.7400	0.053220	0.055760	-0.4125
1/19/2010 10:00	1.0000	0.9537	0.04625		0.5627		0.5611	0.060530	0.006801	0.1424
2/4/2010 10:40	1.0000	0.9374	0.06262		0.7610		0.7596	0.058410	0.011980	0.1892
2/23/2010 12:55	1.1760	1.3130	-0.13680		-1.6360		-1.6480	0.027680	0.025420	-0.2781
4/14/2010 9:05	1.4470	1.3140	0.13280		1.5870		1.5970	0.025520	0.021990	0.2585
6/13/2010 15:20	2.9460	2.7850	0.16100		1.9290		1.9520	0.031600	0.040490	0.3527
8/25/2010 11:00	2.8010	2.6070	0.19390		2.3050		2.3490	0.015940	0.028690	0.2990
8/15/2011 10:45	2.4960	2.6030	-0.10730		-1.3050		-1.3090	0.059590	0.035960	-0.3295
7/12/2012 10:15	1.8200	1.8680	-0.04864		-0.5916		-0.5900	0.060180	0.007472	-0.1493
7/19/2012 10:15	1.8860	1.9430	-0.05686		-0.6972		-0.6957	0.075270	0.013190	-0.1985
12/12/2012 10:00	0.9542	1.1310	-0.17710		-2.1210		-2.1540	0.030880	0.047780	-0.3844
1/16/2013 9:30	0.9031	1.1250	-0.22160		-2.6530		-2.7250	0.030260	0.073240	-0.4814
2/13/2013 9:30	0.8451	0.9531	-0.10800		-1.2980		-1.3020	0.038140	0.022280	-0.2593
6/24/2013 9:40	2.1880	2.0400	0.14730		1.7560		1.7720	0.022180	0.023320	0.2669
8/7/2013 9:45	2.1880	2.2430	-0.05581		-0.6792		-0.6776	0.061060	0.010000	-0.1728
11/25/2013 9:10	0.7782	0.8259	-0.04774		-0.5811		-0.5795	0.061530	0.007380	-0.1484
1/14/2014 10:20	0.9542	0.9085	0.04571		0.5548		0.5531	0.055830	0.006066	0.1345

Statistical Plots





Models Considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logSS ~ logTURB	1	0.08984	97.71	97.69	32.58	0.9894	1 ± 21	
logSS ~ TURB	1	0.3501	65.27	64.97	2141	15.46	1 ± 90	
logSS ~ SC	1	0.3578	63.74	63.43	2241	15.79	1 ± 92	
logSS ~ logTURB + logQ	2	0.0848	97.98	97.95	17.27	0.8862	2.044 ± 20	
logSS ~ logTURB + Q	2	0.08956	97.75	97.71	32.42	0.9914	1.235 ± 21	
logSS ~ logTURB + SC	2	0.08998	97.73	97.69	33.8	0.9967	2.965 ± 21	
logSS ~ logTURB + logQ + logSC	3	0.0792	98.25	98.21	1.514	0.7779	2.402 ± 18	
logSS ~ logTURB + logQ + SC	3	0.08008	98.21	98.17	4.062	0.7925	3.044 ± 19	
logSS ~ logTURB + Q + logQ	3	0.08364	98.05	98	14.62	0.8651	2.167 ± 19	
logSS ~ logTURB + logQ + SC + logSC	4	0.07937	98.26	98.2	3.022	0.7915	3.225 ± 18	
logSS ~ logTURB + Q + logQ + logSC	4	0.07952	98.25	98.19	3.469	0.7861	3.075 ± 18	
logSS ~ TURB + logTURB + logQ + logSC	4	0.07954	98.25	98.19	3.502	0.801	2.969 ± 18	
logSS ~ logTURB + Q + logQ + SC + logSC	5	0.07971	98.26	98.18	5	0.8002	3.413 ± 18	
logSS ~ TURB + logTURB + logQ + SC + logSC	5	0.07971	98.26	98.18	5.02	0.8142	2.999 ± 18	
logSS ~ TURB + logTURB + Q + logQ + logSC	5	0.07987	98.25	98.18	5.45	0.8093	3.005 ± 18	
logSS ~ TURB + logTURB + Q + logQ + SC + logSC	6	0.08006	98.26	98.17	7	0.8227	3.103 ± 19	

Model-Calibration Data Set

0	Date	logSS	logTURB	logQ	SS	TURB	Q	Computed logSS	Computed SS	Residual	Normal Quantiles	Censored Values
1	2004-07-27	2.584	2.301	3.767	384	200	5853	2.572	380	0.0127	0.0731	--
2	2005-01-27	2.086	1.908	2.234	122	81	171.4	2.139	140.4	-0.0529	-0.584	--
3	2005-03-23	2.704	2.415	3.766	506	260	5837	2.678	485.3	0.0263	0.351	--
4	2005-03-31	1.908	1.699	2.183	81	50	152.5	1.942	89.07	-0.0331	-0.329	--
5	2005-05-10	2.497	2.217	2.293	314	165	196.4	2.43	274.3	0.0669	0.917	--
6	2005-06-06	2.652	2.462	3.289	449	290	1944	2.702	512.5	-0.0493	-0.56	--
7	2005-06-09	2.671	2.58	4.076	469	380	11900	2.845	713.1	-0.174	-2.02	--
8	2005-08-31	2.149	1.985	2.047	141	96.5	111.5	2.202	162.3	-0.0529	-0.609	--

9	2007-01-10	1.041	0.8388	1.161	11	6.9	14.5	1.095	12.68	-0.0536	-0.634	--
10	2007-03-12	1.602	1.362	1.279	40	23	19	1.588	39.45	0.0142	0.115	--
11	2007-03-21	1.69	1.415	1.708	49	26	51	1.656	46.15	0.0341	0.488	--
12	2007-03-27	2.559	2.398	2.199	362	250	158	2.594	400.4	-0.0357	-0.351	--
13	2007-04-02	2.889	2.58	3.46	775	380	2882	2.818	670.8	0.0709	0.982	--
14	2007-04-18	2.348	2.114	2.935	223	130	861	2.361	234.1	-0.0128	-0.178	--
15	2007-05-08	2.439	2.301	3.968	275	200	9280	2.58	387.6	-0.141	-1.6	--
16	2007-05-10	2.427	2.217	3.713	267	165	5165	2.491	315.8	-0.0648	-0.825	--
17	2007-05-24	3.029	2.732	3.732	1070	540	5393	2.973	956.5	0.0568	0.796	--
18	2007-05-25	2.447	2.319	4.036	280	208.3	10870	2.6	405.4	-0.153	-1.77	--
19	2007-07-11	2.649	2.322	3.284	446	210	1922	2.571	379	0.0788	1.09	--
20	2007-08-16	1.663	1.412	1.771	46	25.8	59	1.656	46.11	0.0071	-0.0104	--
21	2007-09-06	1.672	1.362	1.415	47	23	26	1.594	39.99	0.0783	1.05	--
22	2007-12-06	1.041	0.699	1.477	11	5	30	0.9781	9.688	0.0633	0.855	--
23	2007-12-13	2.805	2.409	3.438	638	256.3	2740	2.658	463.6	0.147	1.6	--
24	2008-03-06	2.892	2.773	2.985	779	593.3	966.3	2.979	969.8	-0.087	-1.05	--
25	2008-04-14	2.535	2.362	2.685	343	230	484	2.582	388.8	-0.0463	-0.465	--
26	2008-06-30	2.59	2.326	2.941	389	211.8	872.2	2.559	369.3	0.0307	0.465	--
27	2008-08-05	1.914	1.477	1.407	82	30	25.5	1.701	51.19	0.213	2.22	--
28	2008-09-16	2.528	2.23	3.227	337	170	1687	2.482	309.5	0.0452	0.66	--
29	2009-04-06	2.217	1.724	2.272	165	53	187	1.969	94.87	0.249	2.58	--
30	2009-04-13	2.418	2.146	2.933	262	140	856.3	2.391	250.7	0.0272	0.373	--
31	2009-04-28	2.74	2.447	3.963	549	280	9190	2.716	530.3	0.0232	0.285	--
32	2009-05-08	3.193	2.813	3.535	1560	650	3430	3.039	1115	0.154	1.77	--
33	2009-07-30	2.458	2.322	2.705	287	210	507	2.546	357.9	-0.0877	-1.09	--
34	2009-09-09	2.616	2.322	3.509	413	210	3230	2.58	387.6	0.0357	0.512	--
35	2009-09-24	2.925	2.89	2.522	842	776.7	333	3.068	1191	-0.142	-1.68	--
36	2009-11-03	2.362	2.146	2.516	230	140	328	2.373	240.6	-0.0114	-0.157	--
37	2009-11-19	1.114	0.8346	1.813	13	6.833	65	1.119	13.41	-0.00518	-0.136	--
38	2010-01-19	1	0.6532	1.903	10	4.5	80	0.9537	9.16	0.0463	0.713	--
39	2010-02-04	1	0.6402	1.806	10	4.367	64	0.9374	8.822	0.0626	0.825	--
40	2010-02-23	1.176	1.041	1.834	15	11	68.17	1.313	20.95	-0.137	-1.53	--
41	2010-03-10	2.508	2.176	2.74	322	150	549	2.411	262.3	0.0971	1.21	--
42	2010-04-14	1.447	1.048	1.724	28	11.17	53	1.314	21.01	0.133	1.53	--
43	2010-04-23	2.292	2.041	2.358	196	110	228	2.269	189.1	0.0237	0.307	--
44	2010-05-13	2.88	2.663	2.733	758	460	541	2.865	745.9	0.0152	0.136	--
45	2010-06-09	3.225	2.894	3.649	1680	784	4460	3.12	1343	0.105	1.25	--
46	2010-06-10	2.4	2.204	3.517	251	160	3291	2.47	301	-0.0707	-0.885	--
47	2010-06-13	2.946	2.523	3.915	883	333.3	8223	2.785	621.1	0.161	1.88	--
48	2010-06-14	2.685	2.427	4.066	484	267.5	11630	2.702	513.4	-0.0175	-0.242	--
49	2010-06-14	2.435	2.176	4.178	272	150	15070	2.473	302.6	-0.0382	-0.396	--
50	2010-06-14	2.384	2.176	4.173	242	150	14880	2.473	302.5	-0.0887	-1.17	--
51	2010-06-15	2.708	2.398	3.809	510	250	6440	2.664	469.9	0.0438	0.609	--
52	2010-06-15	2.687	2.398	3.805	486	250	6378	2.664	469.7	0.023	0.264	--
53	2010-06-16	2.72	2.337	3.682	525	217.3	4807	2.602	407.2	0.119	1.35	--
54	2010-08-19	1.799	1.559	1.785	63	36.25	61	1.794	63.42	0.00526	-0.0313	--
55	2010-08-25	2.801	2.38	2.886	633	240	770	2.607	412.7	0.194	2.02	--
56	2010-11-16	2.281	2.146	2.418	191	140	262	2.369	238.3	-0.0879	-1.13	--
57	2011-01-19	1.58	1.315	1.908	38	20.67	81	1.572	38.01	0.00809	0.0313	--
58	2011-03-07	1.301	1.146	1.708	20	14	51	1.405	25.9	-0.104	-1.3	--
59	2011-03-16	1.58	1.279	1.681	38	19	48	1.528	34.35	0.052	0.74	--
60	2011-04-06	1.431	1.204	1.58	27	16	38	1.454	28.97	-0.0224	-0.264	--
61	2011-04-18	1.505	1.279	1.505	32	19	32	1.52	33.76	-0.0151	-0.199	--
62	2011-05-02	1.591	1.396	1.462	39	24.92	29	1.628	43.29	-0.0372	-0.373	--
63	2011-05-16	1.568	1.362	1.431	37	23	27	1.594	40.05	-0.0263	-0.285	--
64	2011-06-07	1.785	1.643	1.342	61	44	22	1.853	72.72	-0.0682	-0.855	--
65	2011-06-21	2.26	2.041	2.041	182	110	110	2.255	183.3	0.00516	-0.0522	--
66	2011-08-15	2.496	2.443	1.415	313	277.5	26	2.603	408.3	-0.107	-1.35	--
67	2011-09-22	2.182	2.041	1.66	152	110	45.75	2.238	176.5	-0.0566	-0.713	--
68	2011-12-20	2.952	2.699	3.037	895	500	1090	2.911	830.9	0.0404	0.535	--
69	2012-02-06	2.283	2.13	2.667	192	135	464	2.365	236.1	-0.0816	-0.982	--
70	2012-03-01	3.104	2.869	3.117	1270	740	1310	3.074	1207	0.0301	0.419	--
71	2012-04-07	2.26	2.114	2.414	182	130	259.5	2.339	222.3	-0.0786	-0.917	--
72	2012-04-17	1.785	1.562	1.918	61	36.5	82.75	1.803	64.67	-0.0172	-0.221	--

73	2012-05-09	1.94	1.703	1.628	87	50.5	42.5	1.922	85.08	0.0179	0.221	--
74	2012-05-30	1.924	1.638	0.8976	84	43.5	7.9	1.83	68.84	0.0946	1.17	--
75	2012-06-12	1.973	1.748	1.146	94	56	14	1.943	89.31	0.0304	0.441	--
76	2012-06-18	2.322	2.176	2.114	210	150	130	2.384	246.5	-0.0615	-0.796	--
77	2012-06-19	2.199	2.079	1.886	158	120	77	2.283	195.7	-0.0848	-1.02	--
78	2012-07-12	1.82	1.705	0.3424	66	50.75	2.2	1.868	75.22	-0.0486	-0.535	--
79	2012-07-19	1.886	1.792	0.2041	77	62	1.6	1.943	89.44	-0.0569	-0.74	--
80	2012-09-11	1.792	1.653	0.6335	62	45	4.3	1.832	69.21	-0.0396	-0.419	--
81	2012-10-24	1.792	1.583	0.6721	62	38.25	4.7	1.768	59.7	0.0246	0.329	--
82	2012-11-14	1.279	1.041	0.8195	19	11	6.6	1.269	18.94	0.00956	0.0522	--
83	2012-12-12	0.9542	0.8976	0.7324	9	7.9	5.4	1.131	13.79	-0.177	-2.22	--
84	2013-01-16	0.9031	0.8865	0.8195	8	7.7	6.6	1.125	13.58	-0.222	-2.58	--
85	2013-01-29	1.505	1.277	0.8976	32	18.92	7.9	1.492	31.65	0.0129	0.094	--
86	2013-02-13	0.8451	0.699	0.8976	7	5	7.9	0.9531	9.146	-0.108	-1.41	--
87	2013-03-12	1.643	1.301	1.342	44	20	22	1.534	34.85	0.109	1.3	--
88	2013-03-13	1.568	1.301	1.73	37	20	53.75	1.551	36.22	0.0175	0.199	--
89	2013-03-27	1.114	0.9696	1	13	9.325	10	1.21	16.53	-0.0961	-1.25	--
90	2013-04-15	1.681	1.505	1.591	48	32	39	1.735	55.38	-0.0539	-0.66	--
91	2013-04-15	1.799	1.505	1.591	63	32	39	1.735	55.38	0.0642	0.885	--
92	2013-04-24	2.076	2.021	1.914	119	105	82	2.231	173.3	-0.155	-1.88	--
93	2013-05-06	2.121	1.929	2.004	132	85	101	2.149	143.6	-0.0283	-0.307	--
94	2013-05-09	2.666	2.565	2.055	463	367.5	113.5	2.744	565.5	-0.0787	-0.949	--
95	2013-05-15	2.146	1.932	1.505	140	85.5	32	2.13	137.4	0.0164	0.178	--
96	2013-05-21	2.283	2.079	1.699	192	120	50	2.275	192.1	0.0079	0.0104	--
97	2013-05-28	2.037	1.788	1.181	109	61.33	15.17	1.981	97.56	0.0563	0.768	--
98	2013-06-13	2.079	1.785	1.487	120	61	30.67	1.992	100.1	0.0871	1.13	--
99	2013-06-24	2.188	1.843	1.355	154	69.67	22.67	2.04	111.8	0.147	1.68	--
100	2013-07-09	1.934	1.685	0.5185	86	48.45	3.3	1.857	73.31	0.0775	1.02	--
101	2013-07-29	2.332	2.204	3.378	215	160	2390	2.464	296.9	-0.132	-1.46	--
102	2013-07-29	2.373	2.204	3.375	236	160	2370	2.464	296.8	-0.0913	-1.21	--
103	2013-08-07	2.188	1.932	4.14	154	85.5	13800	2.243	178.4	-0.0558	-0.686	--
104	2013-09-12	1.447	1.23	1.815	28	17	65.33	1.489	31.38	-0.0414	-0.441	--
105	2013-10-24	1.146	0.8827	1.477	14	7.633	30	1.15	14.38	-0.00338	-0.115	--
106	2013-11-25	0.7782	0.5315	1.572	6	3.4	37.33	0.8259	6.824	-0.0477	-0.488	--
107	2014-01-14	0.9542	0.6163	1.653	9	4.133	45	0.9085	8.255	0.0457	0.686	--
108	2014-02-20	1.255	0.9103	1.69	18	8.133	49	1.184	15.58	0.0709	0.949	--
109	2014-03-17	1.114	0.8195	1.568	13	6.6	37	1.094	12.67	0.0194	0.242	--
110	2014-04-09	1.342	1.041	1.484	22	11	30.5	1.298	20.23	0.0446	0.634	--
111	2014-05-08	1.663	1.301	1.342	46	20	22	1.534	34.85	0.129	1.41	--
112	2014-06-03	1.763	1.531	1.706	58	34	50.83	1.765	59.27	-0.00127	-0.094	--
113	2014-06-05	2.114	1.839	2.148	130	69	140.7	2.071	119.9	0.0434	0.584	--
114	2014-06-09	2.455	2.255	3.169	285	180	1475	2.503	324.5	-0.0483	-0.512	--
115	2014-06-12	2.644	2.342	3.589	441	220	3880	2.603	408	0.0419	0.56	--
116	2014-06-24	2.196	1.954	2.444	157	90	278	2.191	158.2	0.00493	-0.0731	--
117	2014-07-10	1.756	1.572	1.946	57	37.33	88.33	1.813	66.24	-0.0571	-0.768	--
118	2014-07-15	1.771	1.51	1.663	59	32.33	46	1.742	56.31	0.0284	0.396	--
119	2014-07-24	1.716	1.475	1.447	52	29.83	28	1.701	51.13	0.0155	0.157	--
120	2014-08-04	1.792	1.439	1.327	62	27.5	21.25	1.662	46.83	0.13	1.46	--

Definitions

SS: Suspended sediment concentration (SS) in mg/l (80154)

TURB: Turbidity in FNU (63680)

Q: Stream flow, mean. daily in ft3/s (00060)