Appendix 6. Model Archive Summary for Suspended-Sediment Concentration at U.S. Geological Survey Site 07144780, North Fork Ninnescah River above Cheney Reservoir, Kansas, during January 1, 1999, through December 31, 2019

This model archive summary summarizes the suspended-sediment concentration (SSC) model developed to compute hourly or daily SSC during January 1, 1999, through December 31, 2019. This model is used concomitantly with other models during this period to calculate concentrations when other explanatory variables are not available for the purposes of load and concentration model calculations. The methods used follow U.S. Geological Survey (USGS) guidance as referenced in relevant Office of Surface Water/Office of Water Quality Technical Memoranda and USGS Techniques and Methods, book 3, chapter C4 (Rasmussen and others, 2009), and other standard USGS methods (Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010).

Site and Model Information

Site number: 07144780
Site name: North Fork Ninnescah River above Cheney Reservoir, Kansas
Location: Lat 37°51'45", long 98°00'49" referenced to North American Datum of 1927, in NE 1/4 SE 1/4 NE 1/4 sec.19, T.25 S., R.6 W., Reno County, Kans., Hydrologic Unit 11030014, on right bank at upstream side of county highway bridge, 10 miles south of Hutchinson, 18.1 miles upstream from Cheney Dam.

Equipment: A Sutron Satlink 2 High Data Rate Collection Platform and a Design Analysis Water Log H350/355 nonsubmersible pressure transducer transfers real-time stage, precipitation, and water quality data via satellite. The primary reference gage is a Type-A wire-weight gage located on the downstream bridge guardrail. Check-bar elevation is 21.804 feet. The orifice is enclosed in 1 1/4-inch pipe, which runs from the gage house, under the bridge, and along an I-beam where it is attached to the concrete pier closest to the left edge of water.

Date model was developed: April 26, 2019

Model calibration data period: January 31, 1999, to September 28, 2017

Model Data

All data were collected using USGS protocols (U.S. Geological Survey, 2006; Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010) and are stored in the National Water Information System (NWIS) database (https://doi.org/10.5066/F7P55KJN; U.S. Geological Survey, 2020). Explanatory variables were evaluated individually and in combination. Potential explanatory variables included streamflow, water temperature, specific conductance, pH, dissolved oxygen, and turbidity. Seasonal components (sine and cosine variables) were also evaluated as explanatory variables.

The regression model is based on 94 concomitant values of discretely collected SSC samples and continuously measured streamflow during January 31, 1999, through September 28, 2017. Discrete samples were collected over a range of streamflows. No samples were less than laboratory detection limits. Summary statistics and the complete model-calibration data are provided below. Outliers were identified using studentized residuals (for values greater than 3 or less than −3). None of the samples in this dataset were deemed outliers or removed from the model calibration dataset. Other data deemed outliers and removed in previously published versions of this model (Christensen and others, 2006; Stone and others, 2013) were examined and retained in the dataset if there were no clear issues, explanations, or conditions that would cause a result to be invalid for model calibration.

Suspended Sediment

Discrete samples were collected from the downstream side of the bridge or instream within 50 feet of the bridge using equal-width-increment, multiple vertical, single vertical, or grab methods following U.S. Geological Survey (2006) and Rasmussen and others (2014). Discrete samples were collected on a semifixed to event-based schedule ranging from 1 to 10 samples per year with a Federal Interagency Sedimentation Project U.S. DH–95 or D–95 with a Teflon bottle, cap, and nozzle depth-integrating sampler; a DH–81 with a Teflon bottle, cap, and nozzle hand

sampler; or a grab sample with a Teflon bottle depending on sample location. Samples are analyzed for SSC, loss on ignition, and occasionally 5-point grain size in the USGS Sediment Laboratory in Iowa City, Iowa.

Continuous Data

Streamflow was measured using a nonsubmersible pressure transducer during January 1, 1999, through December 31, 2019. The continuous streamflow data used were time interpolated values from the continuous time series. If the continuous data were not available, the sample was not included in the dataset.

Model Development

Ordinary least squares regression analysis was done using R programming language (R Core Team, 2019) to relate discretely collected SSC to streamflow and other continuously measured data. The distribution of residuals was examined for normality and plots of residuals (the difference between the measured and model calculated values) compared to model calculated SSC were examined for homoscedasticity (departures from zero did not change substantially over the range of model calculated values). Previously published explanatory variables were also strongly considered for continuity; however, the best explanatory variable(s) was ultimately selected.

Streamflow was selected as a good predictor of logarithm base 10 ($\log_{10}$) (SSC) based on residual plots, relatively high coefficient of determination (R^2), and relatively low model standard percentage error (MSPE). This model was developed with the sole purpose to fill in gaps of missing data of the primary models for concentration and load estimations.

Model Summary

Summary of final SSC regression analysis at USGS site 07144780:

SSC-based model:

$$\log_{10}(SSC) = 0.752 \times \log_{10}(Q) + 0.488$$

where,

SSC = suspended-sediment concentration, in milligrams per liter, and
Q = streamflow, in cubic feet per second.

The log-transformed model may be retransformed to original units so that SSC 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; Duan, 1983). For this model, the calculated BCF is 1.29. The retransformed model, accounting for BCF, is as follows:

$$SSC = (Q^{0.752} \times 10^{0.488}) \times 1.29$$

Previous Models

Version	Model Equation	Reference
1.0	$\log_{10}(SSC) = 0.934 \times \log_{10}(Q) + 0.043$	Christensen and others (2006)
1.1	$\log_{10}(SSC) = 0.861 \times \log_{10}(Q) + 0.209$	Stone and others (2013)

Model Statistics, Data, and Plots

Definitions for terms used in this output can be found at the end of this document.

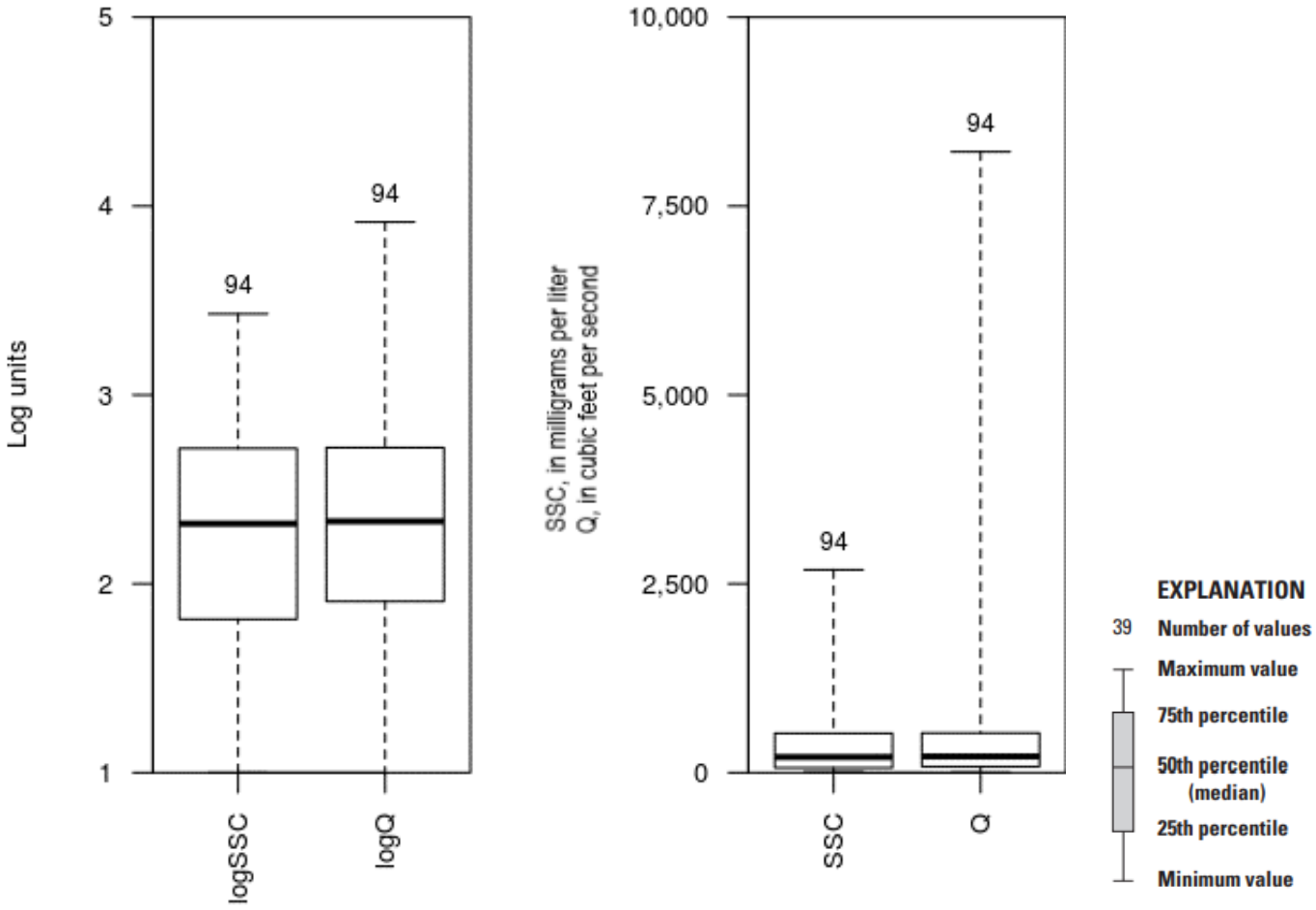
Model

logSSC = + 0.752 * log$Q$ + 0.488

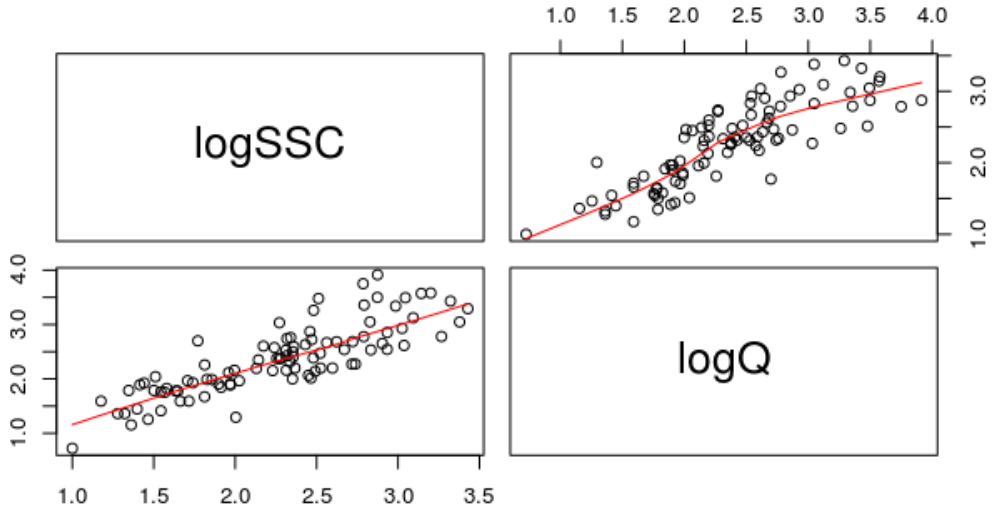
Variable Summary Statistics

	logSSC	SSC	logQ	Q
Minimum	1.00	10.0	0.724	5.29
1st Quartile	1.81	64.9	1.910	80.70
Median	2.32	208.0	2.330	214.00
Mean	2.26	393.0	2.360	677.00
3d Quartile	2.72	521.0	2.720	526.00
Maximum	3.43	2,690.0	3.910	8,220.00

Box Plots



Exploratory Plots



Red line shows the locally weighted scatterplot smoothing (LOWESS).

Basic Model Statistics

For a detailed definition and explanation of the terms used below, refer to Helsel and Hirsch (2002).

```
Number of Observations                              94
Standard error (RMSE)                            0.314
Average Model standard percentage error (MSPE)    78.8
Coefficient of determination (R²)                0.704
Adjusted Coefficient of Determination (Adj. R²) 0.701
Bias Correction Factor (BCF)                      1.29
```

Explanatory Variables

```
            Coefficients Standard Error t value Pr(>|t|)
(Intercept)        0.488         0.1240    3.93 1.66e-04
logQ               0.752         0.0508   14.80 4.87e-26
```

Correlation Matrix

```
          Intercept E.vars
Intercept     1.000 -0.965
E.vars       -0.965  1.000
```

Outlier Test Criteria

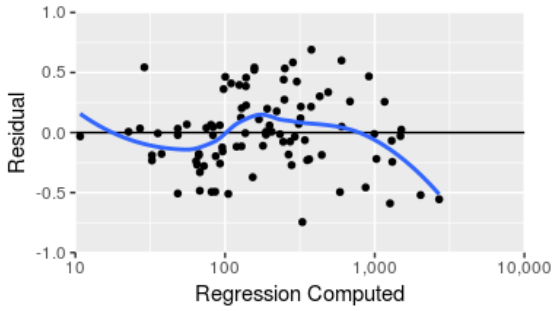
```
Leverage Cook's D   DFFITS
  0.0638   0.1944   0.2917
```

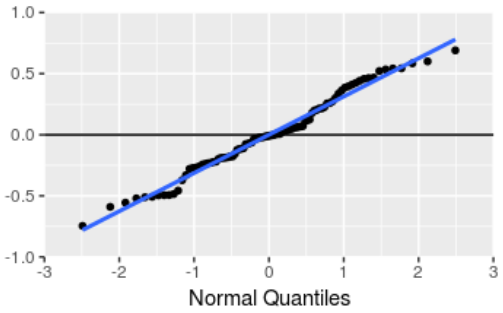
Flagged Observations

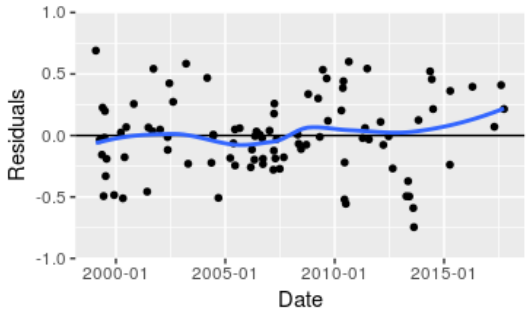
```
               logSSC Estimate Residual Standard Residual Studentized Residual Leverage Cook's D  DFFITS
6/14/2010 11:30   2.79     3.31  -0.5200           -1.710               -1.730   0.0614 0.095700 -0.4420
7/6/2010 10:30    2.87     3.43  -0.5560           -1.840               -1.860   0.0741 0.135000 -0.5270
8/25/2010 11:00   3.38     2.78   0.6000            1.930                1.960   0.0231 0.044200  0.3020
6/28/2011 10:00   2.00     1.46   0.5440            1.770                1.790   0.0403 0.065600  0.3670
```

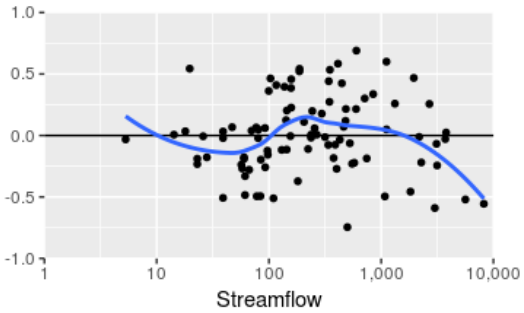
```
7/27/2011 11:20    1.00     1.03  -0.0316            -0.105               -0.104   0.0807 0.000483 -0.0309
8/5/2013 10:05     2.51     3.10  -0.5900            -1.920               -1.950   0.0435 0.083900 -0.4160
```

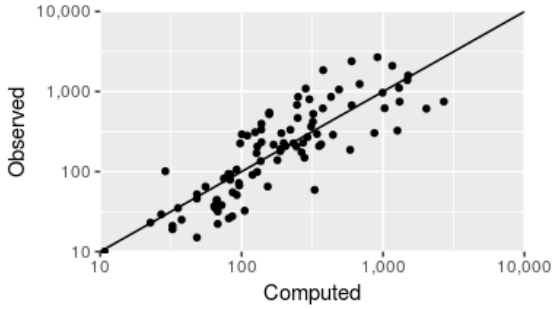
Statistical Plots

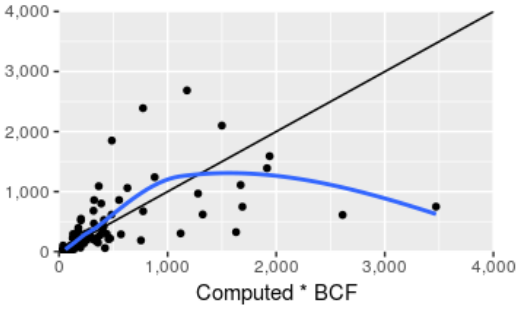


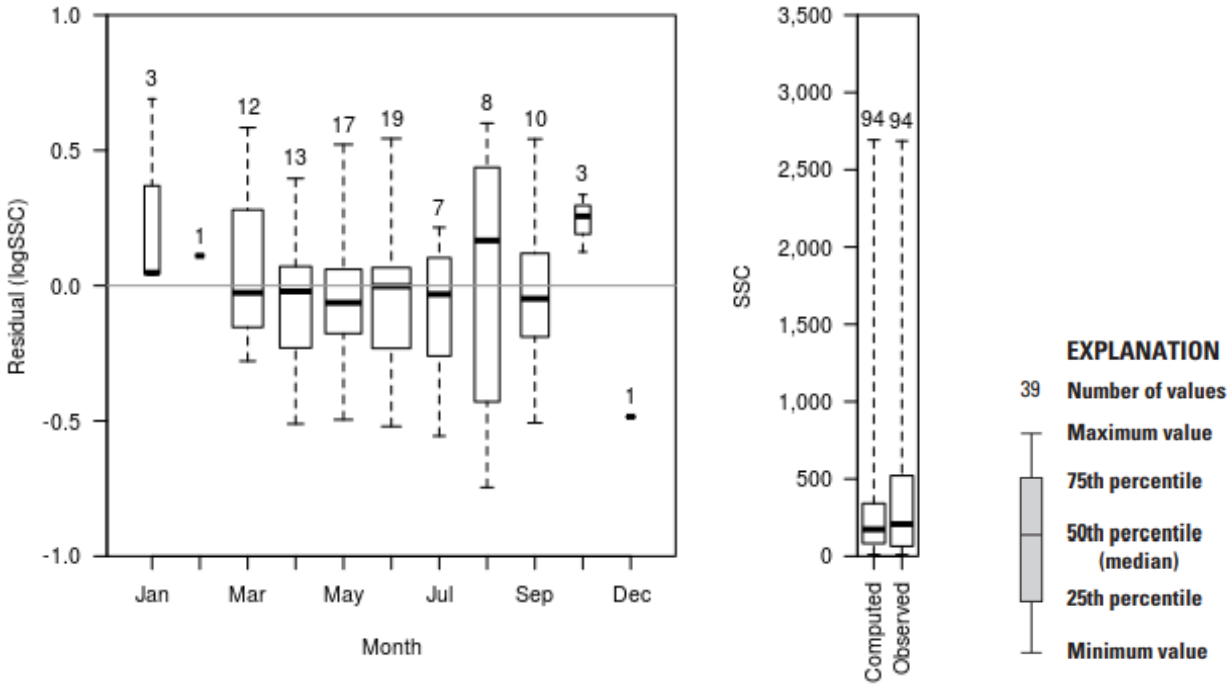


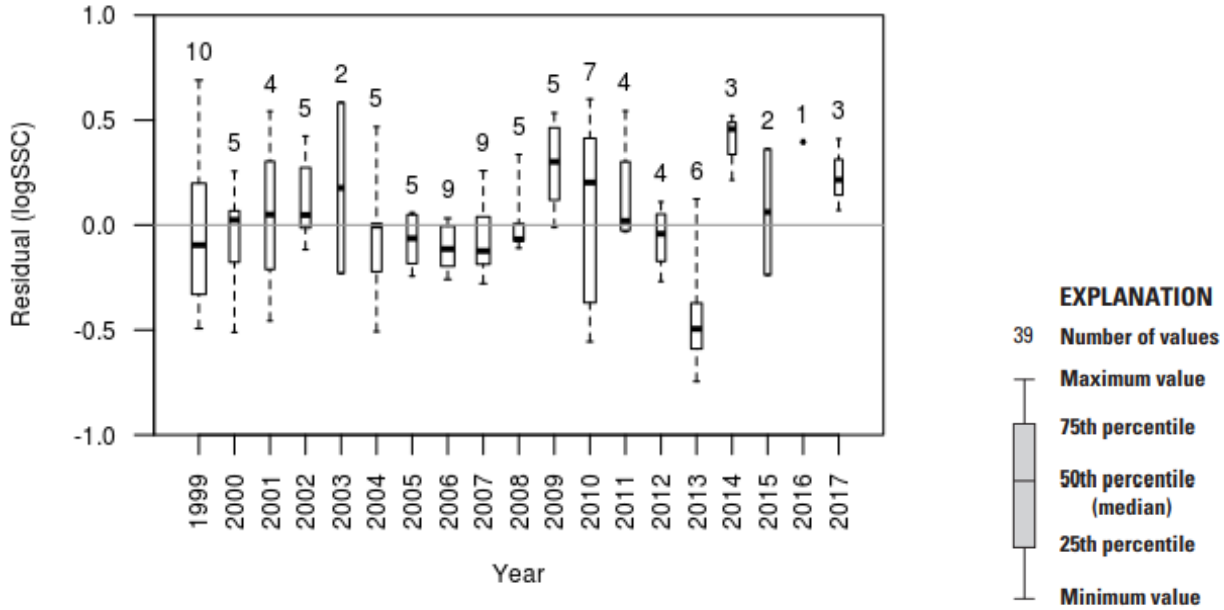




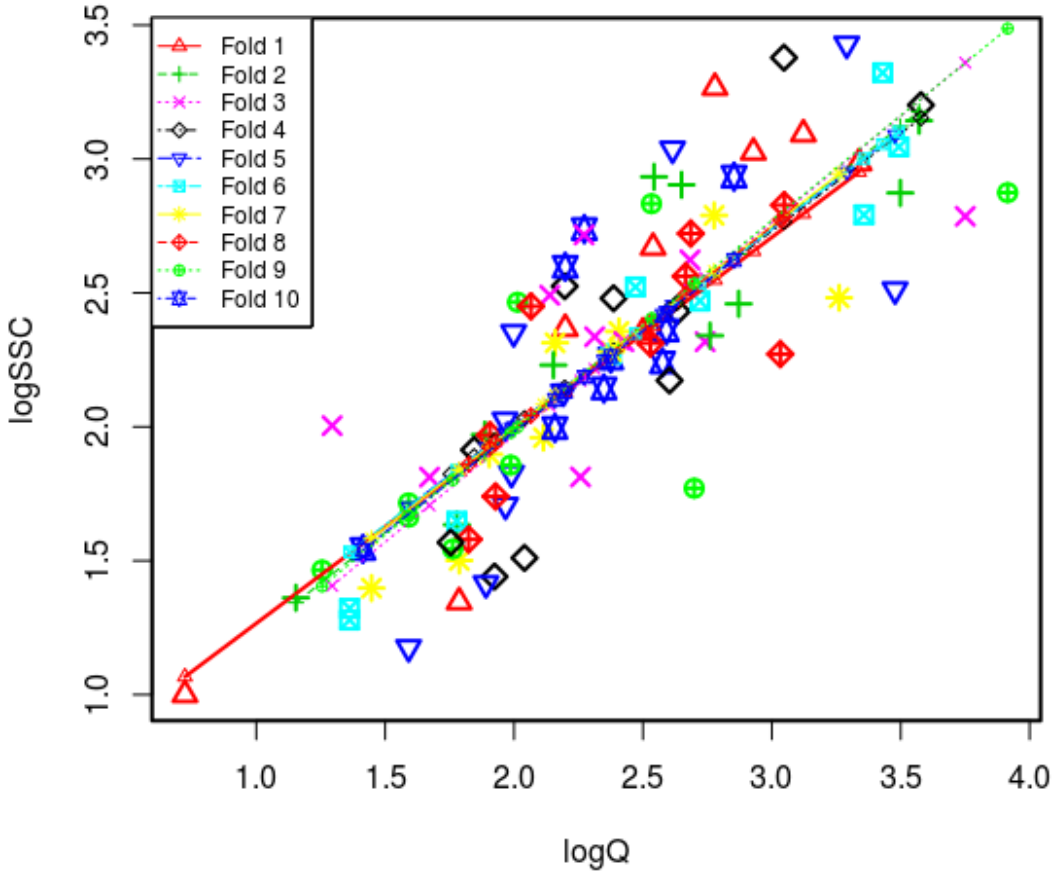





Residual (logSSC)
1.0
0.5
0.0
-0.5
-1.0
3
1
12
13
17
19
7
8
10
3
1
Jan
Mar
May
Jul
Sep
Dec
Month
SSC
3,500
3,000
2,500
2,000
1,500
1,000
500
0
94
94
Computed
Observed
EXPLANATION
39 Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value


Residual (logSSC)
1.0
0.5
0.0
-0.5
-1.0
10
5
4
5
2
5
5
9
9
5
5
7
4
4
6
3
2
1
3
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Year
EXPLANATION
39 Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value

Cross Validation



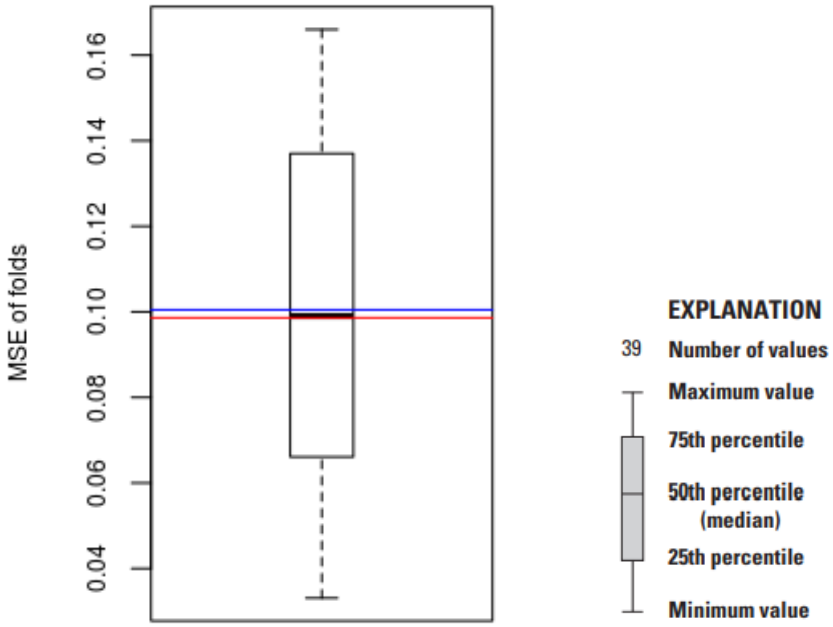

```
Fold – equal partition of the data (10 percent of the data)

Large symbols – observed value of a data point removed in a fold

Small symbols – recomputed value of a data point removed in a fold

Recomputed regression lines – adjusted regression line with one fold removed


              Minimum MSE of folds:  0.0331
                 Mean MSE of folds:  0.1000
               Median MSE of folds:  0.0990
              Maximum MSE of folds:  0.1660
 (Mean MSE of folds) / (Model MSE):  1.0200
```



Red line - Model MSE

Blue line - Mean MSE of folds

Model-Calibration Data Set

	Date	logSSC	logQ	SSC	Q	Computed logSSC	Computed SSC	Residual	Normal Quantiles	Censored Values
1	1999-01-31	3.27	2.78	1850	602	2.58	486	0.69	2.49	--
2	1999-04-06	2.43	2.63	270	428	2.47	377	-0.0345	-0.201	--
3	1999-05-13	1.83	1.99	67.1	97.7	1.98	124	-0.157	-0.454	--
4	1999-05-24	2.37	2.2	233	158	2.14	178	0.227	0.741	--
5	1999-06-10	1.44	1.92	27.6	84	1.93	111	-0.493	-1.33	--
6	1999-06-25	2.26	2.38	180	237	2.27	242	-0.0178	-0.0666	--
7	1999-07-02	2.48	2.39	302	243	2.28	246	0.199	0.607	--
8	1999-07-14	1.5	1.79	31.7	61.3	1.83	87.5	-0.33	-1.11	--
9	1999-07-29	1.63	1.78	43.1	60	1.82	86	-0.19	-0.64	--
10	1999-12-02	1.35	1.79	22.2	61.2	1.83	87.4	-0.485	-1.27	--
11	2000-03-24	3.2	3.58	1590	3790	3.18	1940	0.0241	0.174	--
12	2000-04-27	1.51	2.04	32.4	110	2.02	135	-0.511	-1.66	--
13	2000-05-25	1.65	1.78	44.4	60	1.82	86	-0.177	-0.484	--
14	2000-06-21	1.81	1.67	64.9	47	1.74	71.6	0.0677	0.425	--
15	2000-10-26	3.32	3.43	2100	2690	3.07	1500	0.257	0.777	--
16	2001-06-06	2.48	3.26	303	1820	2.94	1120	-0.457	-1.21	--
17	2001-06-27	1.97	1.89	93.5	77	1.91	104	0.0651	0.396	--
18	2001-09-04	1.47	1.26	29.2	18	1.43	34.8	0.0341	0.228	--
19	2001-09-19	2.74	2.27	547	187	2.2	202	0.542	1.66	--
20	2002-01-08	1.97	1.91	93.1	80.7	1.92	107	0.0481	0.283	--
21	2002-05-13	2.35	2.5	226	316	2.37	300	-0.0131	-0.0399	--
22	2002-05-15	1.96	2.11	91.1	130	2.08	154	-0.117	-0.396	--
23	2002-06-12	2.9	2.65	801	446	2.48	389	0.424	1.16	--
24	2002-08-14	2.67	2.54	468	346	2.4	321	0.274	0.851	--

25	2003-03-18	3.04	2.61	1090	412	2.45	366	0.584	1.92	--
26	2003-04-21	2.32	2.74	208	551	2.55	455	-0.23	-0.777	--
27	2004-03-05	3.43	3.29	2690	1950	2.96	1180	0.468	1.4	--
28	2004-05-14	2.34	2.76	219	576	2.56	471	-0.222	-0.741	--
29	2004-06-14	2.27	2.38	187	238	2.27	242	-0.00223	0.0666	--
30	2004-06-14	2.28	2.38	191	238	2.27	242	0.00696	0.147	--
31	2004-09-08	1.18	1.59	15	39	1.68	62.2	-0.508	-1.56	--
32	2005-03-24	2.24	2.58	174	377	2.42	342	-0.183	-0.545	--
33	2005-05-16	2.47	2.72	295	526	2.53	440	-0.0631	-0.228	--
34	2005-06-10	2.83	3.05	673	1120	2.78	774	0.0493	0.311	--
35	2005-06-13	2.87	3.5	747	3150	3.12	1690	-0.244	-0.89	--
36	2005-08-29	2.36	2.41	227	255	2.3	255	0.0592	0.339	--
37	2006-03-02	1.71	1.97	51	92.7	1.97	119	-0.259	-0.93	--
38	2006-03-22	2	2.16	99	144	2.11	166	-0.114	-0.367	--
39	2006-05-01	1.74	1.93	55	84.8	1.94	112	-0.197	-0.673	--
40	2006-05-12	2.13	2.19	135	155	2.14	176	-0.0048	0.0399	--
41	2006-06-05	1.72	1.59	52	39	1.68	62.2	0.0324	0.201	--
42	2006-07-31	1.36	1.15	23	14.2	1.36	29.2	0.00673	0.0933	--
43	2006-09-07	1.66	1.59	46	39	1.68	62.2	-0.0209	-0.0933	--
44	2006-09-21	1.28	1.36	19	23	1.51	41.8	-0.233	-0.813	--
45	2006-09-21	1.32	1.36	21	23	1.51	41.8	-0.189	-0.607	--
46	2007-01-09	1.91	1.85	82	70	1.87	96.6	0.0392	0.256	--
47	2007-03-14	1.58	1.82	38	66.7	1.86	93.1	-0.279	-1.06	--
48	2007-03-22	1.86	1.99	72	97	1.98	123	-0.124	-0.425	--
49	2007-03-26	2.52	2.47	333	296	2.34	285	0.178	0.576	--
50	2007-03-31	3.09	3.12	1240	1320	2.83	881	0.259	0.813	--
51	2007-04-16	2.46	2.87	288	744	2.65	570	-0.187	-0.576	--
52	2007-05-07	3.14	3.57	1390	3720	3.17	1920	-0.0289	-0.147	--
53	2007-06-29	2.17	2.6	149	401	2.44	359	-0.271	-1.02	--
54	2007-09-04	1.4	1.45	25	28	1.58	48.5	-0.178	-0.514	--
55	2008-04-24	2.32	2.43	208	267	2.31	264	0.00694	0.12	--
56	2008-05-09	3.05	3.49	1110	3110	3.11	1670	-0.0677	-0.256	--
57	2008-06-19	2.14	2.35	139	223	2.25	231	-0.11	-0.339	--
58	2008-09-15	2.36	2.59	229	390	2.43	351	-0.0751	-0.283	--
59	2008-10-16	3.03	2.93	1060	848	2.69	630	0.336	0.93	--
60	2009-03-31	2.93	2.85	859	713	2.63	553	0.302	0.89	--
61	2009-04-27	2.99	3.34	967	2180	3	1280	-0.0115	-0.0133	--
62	2009-06-17	2.93	2.54	858	349	2.4	323	0.534	1.56	--
63	2009-08-20	2.47	2.01	292	103	2	129	0.464	1.33	--
64	2009-09-10	2.62	2.68	420	481	2.5	411	0.119	0.514	--
65	2010-04-23	2.31	2.16	206	144	2.11	166	0.203	0.64	--
66	2010-05-17	2.53	2.2	335	157	2.14	177	0.386	1.02	--
67	2010-05-27	2.83	2.53	681	341	2.39	318	0.441	1.21	--
68	2010-06-14	2.79	3.75	611	5630	3.31	2610	-0.52	-1.77	--
69	2010-06-16	2.79	3.36	619	2280	3.01	1320	-0.22	-0.707	--
70	2010-07-06	2.87	3.91	749	8220	3.43	3470	-0.556	-1.92	--
71	2010-08-25	3.38	3.05	2390	1110	2.78	773	0.6	2.12	--
72	2011-04-13	1.9	1.9	79	80.2	1.92	107	-0.0212	-0.12	--
73	2011-05-23	2.03	1.96	106	92.2	1.96	119	0.0606	0.367	--
74	2011-06-28	2	1.29	101	19.7	1.46	37.2	0.544	1.77	--
75	2011-07-27	1	0.724	10	5.29	1.03	13.9	-0.0316	-0.174	--
76	2012-02-06	2.34	2.31	217	205	2.23	217	0.111	0.484	--
77	2012-03-23	2.31	2.53	205	338	2.39	315	-0.0766	-0.311	--
78	2012-06-20	1.54	1.41	35	25.9	1.55	45.8	-0.00636	0.0133	--
79	2012-08-27	1.54	1.76	35	57.8	1.81	83.7	-0.268	-0.972	--

```
 80 2013-04-11   1.41  1.89   26 77.8     1.91       105   -0.494      -1.4       --
 81 2013-05-10   1.81  2.26   65  181     2.18       197   -0.372     -1.16       --
 82 2013-05-31   2.27  3.03  187 1080     2.77       755   -0.496     -1.48       --
 83 2013-08-05   2.51  3.48  325 3010      3.1      1630    -0.59     -2.12       --
 84 2013-08-16   1.77   2.7   59  500     2.52       423   -0.746     -2.49       --
 85 2013-10-31   2.23  2.15  170  142     2.11       164    0.125     0.545       --
 86 2014-05-13   2.72  2.27  521  187      2.2       202    0.522      1.48       --
 87 2014-06-10    2.6   2.2  396  158     2.14       178    0.457      1.27       --
 88 2014-07-02   2.79  2.78  616  597     2.57       484    0.215     0.673       --
 89 2015-04-08   1.57  1.75   37 56.8     1.81      82.5   -0.238    -0.851       --
 90 2015-04-14   2.35     2  225 99.7     1.99       126    0.362     0.972       --
 91 2016-04-19   2.49  2.14  310  138      2.1       160    0.396      1.06       --
 92 2017-04-20   2.56  2.67  365  463     2.49       400   0.0708     0.454       --
 93 2017-08-11   2.45  2.07  282  116     2.04       141     0.41      1.11       --
 94 2017-09-28   2.72  2.69  527  485     2.51       414    0.215     0.707       --
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Definitions

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SSC: suspended sediment concentration, in milligrams per liter (80154)
Q: streamflow, instantaneous, in cubic feet per second (00061)
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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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