

# Appendix 13. Model Archival Summary for Suspended-Sediment Concentration at U.S. Geological Survey Site 06888990, Kansas River above Topeka Weir at Topeka, Kansas, during December 2018 through June 2021

This model archival summary summarizes the suspended-sediment concentration (SSC; U.S. Geological Survey [USGS] parameter code 80154) model developed to compute 15-minute SSC concentrations from November 2018 onward. This model is specific to USGS site 06888990, the Kansas River above Topeka Weir at Topeka, Kansas, during this study period and cannot be applied to data collected from other sites on the Kansas River or data collected from other waterbodies.

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## Site and Model Information

Site number: 06888990

Site name: Kansas River above Topeka Weir at Topeka, Kans.

Location: Lat 39°04'19", long 95°42'58" referenced to North American Datum of 1927, in NW 1/4 sec.23, T.11 S., R.15 E., Shawnee County, Kans., hydrologic unit 10270102.

Equipment: A Xylem YSI EXO2 water-quality monitor equipped with sensors for water temperature, specific conductance, dissolved oxygen, pH, turbidity (TBY), and chlorophyll and phycocyanin fluorescence was installed during November 2018 through June 2021. Readings from the water-quality monitor were recorded every 15 minutes and transmitted by way of satellite, hourly.

Date model was created: December 8, 2021

Model-calibration data period: December 17, 2018, through June 21, 2021

Model-application date: December 17, 2018, onward

## Model-Calibration Dataset

All data were collected using USGS protocols (Wagner and others, 2006; U.S. Geological Survey, variously dated) and are stored in the USGS National Water Information System (U.S. Geological Survey, 2022) database and available to the public. Ordinary least squares analysis was used to develop regression models using R programming language (R Core Team, 2022). Potential explanatory variables that were evaluated individually and in combination included streamflow, water temperature, specific conductance, dissolved oxygen, pH, TBY, and chlorophyll and phycocyanin fluorescence. These potential explanatory variables were interpolated within the 15-minute continuous record based on sample time. The maximum time span between two continuous data points used for interpolation was 2 hours (in order to preserve the sample dataset, field monitor averages obtained during sample collection were used for model development data if no continuous data were available or if gaps larger than 2 hours in the continuous data record resulted in missing interpolated data). Seasonal components (sine and cosine variables) also were evaluated as potential explanatory variables. Previously published explanatory variables (Rasmussen and others, 2005; Foster and Graham, 2016; Williams, 2021) at other Kansas River sites were strongly considered for continuity in model form.

The final selected regression model was based on 33 concurrent measurements of SSC concentration and sensor-measured TBY during December 17, 2018, through June 21, 2021. Samples were collected throughout the range of continuously observed hydrologic conditions. No samples had concentrations below laboratory minimum reporting limits.

Potential outliers initially were identified using scatterplots of the SSC and TBY model-calibration data (Rasmussen and others, 2009). Studentized residuals from the model were inspected for values greater than three or less than negative three (Pardoe, 2020). Values outside of that range were considered potential outliers and were investigated. Additionally, computations of leverage, Cook's distance (Cook's D), and difference in fits (DFFITs) statistics were used to estimate potential outlier effect on the final selected regression model (Cook, 1977; Helsel and others, 2020). Outliers were investigated for potential removal from the model-calibration dataset by confirming correct database entry, evaluating laboratory analytical performance, and reviewing field notes associated with the sample in question (Rasmussen and others, 2009). One of the SSC results, from November 28, 2018, was deemed an outlier and removed from the model calibration dataset due to evidence of contamination from streambed material which likely introduced a high bias to this result. All other potential outliers were not determined to have errors associated with sample collection, processing, or analysis and were therefore considered valid.

## Suspended-Sediment Sampling Details

During November 2018 through February 2019, samples were collected using the equal-width increment collection method (U.S. Geological Survey, variously dated). In March 2019, sample collection location changed to the southern bank of the Kansas River above Topeka Weir using the single-vertical collection method (U.S. Geological Survey, variously dated) to avoid safety risks caused by a nearby low-head dam. All samples were composited for analysis (U.S. Geological Survey, variously dated). During November 2018 through June 2020, samples were collected on a biweekly to monthly basis. During July 2020 through June 2021, samples were collected on a monthly to quarterly basis, depending on flow conditions. Samples occasionally were collected during targeted reservoir release and runoff events to get a more representative dataset. A FISP US DH-81, DH-95, D-95, or D-96a depth integrating sampler was used. Samples were analyzed for SSC concentration at the USGS Iowa Sediment Laboratory in Iowa City, Iowa.

## Model Development

Ordinary least squares regression analysis was done using the *stats* (v4.3.0) package in R programming language (R Core Team, 2022) to relate discretely collected SSC concentration to sensor-measured TBY. The distribution of residuals (the difference between the measured and computed values) was examined for normality, and the plots of residuals were examined for homoscedasticity (departures from zero did not change substantially over the range of computed values).

TBY was selected as a good surrogate for SSC based on residual plots, coefficient of determination ( $R^2$ ), and model standard percentage error. Values for all the aforementioned statistics, all relevant sample data, and additional statistical information are included in the Model Statistics, Data, and Plots section of this appendix.

## Model Summary

The following is a summary of the final regression analysis for SSC concentration at USGS site 06888990:

SSC concentration-based model:

$$\log SSC = 1.07(\log TBY) + 0.29$$

where

$\log$  = logarithm base 10,

$SSC$  = suspended-sediment concentration, in milligrams per liter, and

$TBY$  = turbidity, in formazin nephelometric units.

TBY makes physical and statistical sense as an explanatory variable for SSC because of its positive correlation with suspended material.

The logarithmically ( $\log$ ) transformed model may be retransformed to the 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 1.01. The retransformed model, accounting for BCF is as follows:

$$SSC = 1.01 \times (TBY^{1.07} \times 10^{0.29})$$

This model was developed using continuous and discrete water-quality data collected during November 2018 through June 2021. These data were collected throughout the observed range of streamflow conditions during this time. However, a limitation in model accuracy during conditions outside of those observed during November 2018 through June 2021 should be considered when interpreting model computations beyond June 2021.

## Previous Models

There are no previously published models at this site. However, similar models have been published at other Kansas River sites, as documented by Rasmussen and others (2005), Foster and Graham (2016), and Williams (2021).

# Model Statistics, Data, and Plots

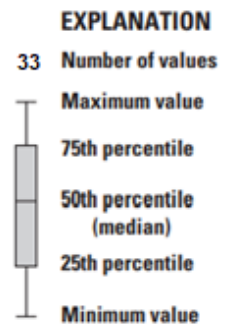
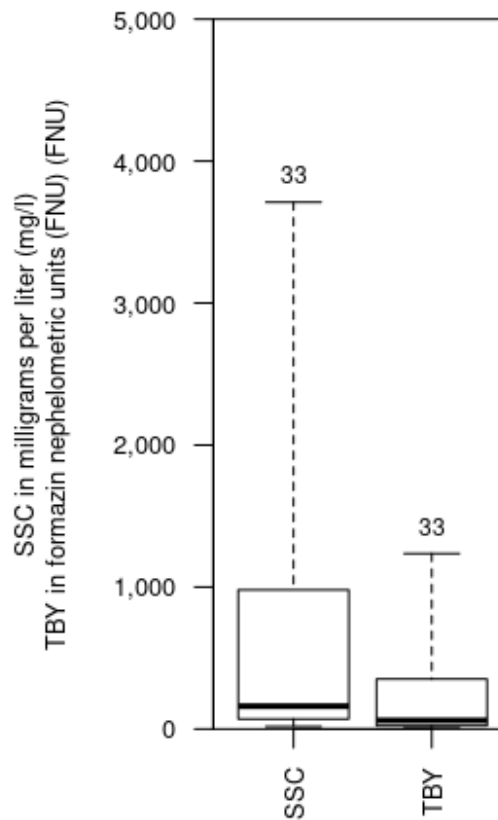
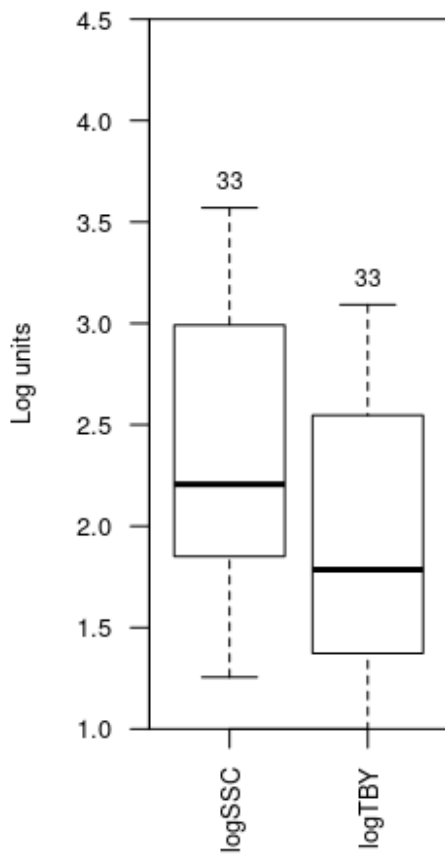
## Model

$$\log SSC = 1.07(\log TBY) + 0.29$$

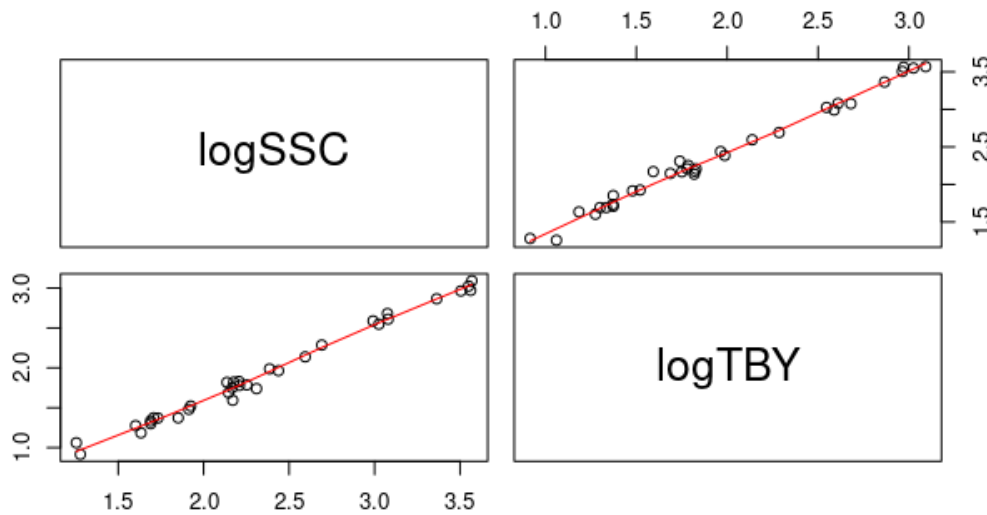
## Variable Summary Statistics

	logSSC	SSC	logTBY	TBY
Minimum	1.26	18	0.916	8.23
1st Quartile	1.85	71	1.370	23.6
Median	2.21	161	1.790	61.0
Mean	2.36	735	1.930	236
3rd Quartile	2.99	980	2.550	352
Maximum	3.57	3,710	3.090	1,240

## Box Plots



## Exploratory Plots



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

The x- and y-axis labels for a given bivariate plot are defined by the intersecting row and column labels.

## Basic Model Statistics

Number of observations	33
Standard error (RMSE)	0.0712
Mean model standard percentage error (MSPE)	16.5
Coefficient of determination ( $R^2$ )	0.989
Adjusted coefficient of determination (Adj. $R^2$ )	0.989
Bias correction factor (BCF)	1.01

## Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t )
(Intercept)	0.29	0.0405	7.15	4.83e-08
logTBY	1.07	0.0200	53.80	3.61e-32

## Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.952
E.vars	-0.952	1.000

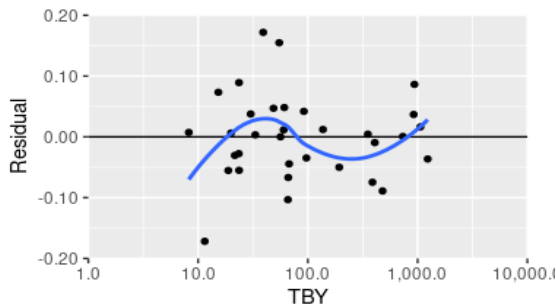
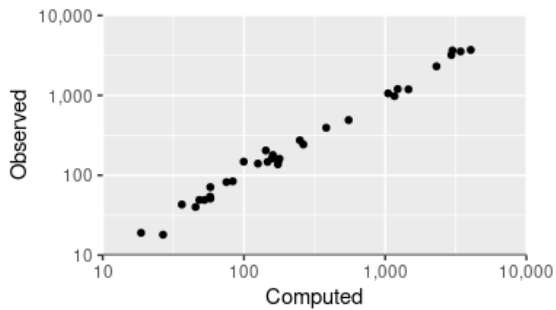
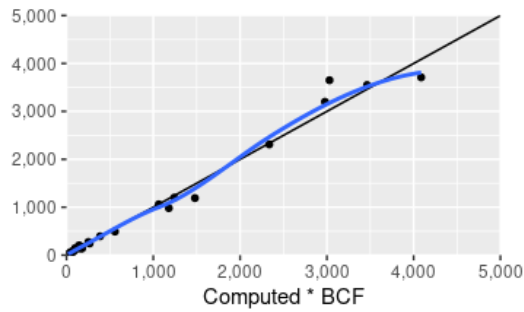
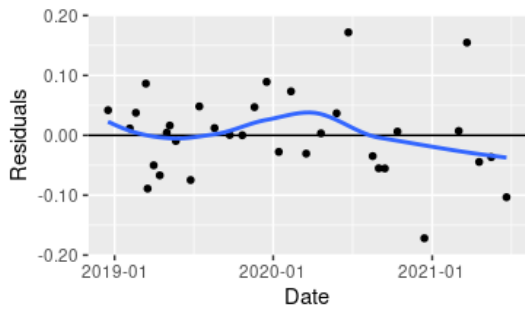
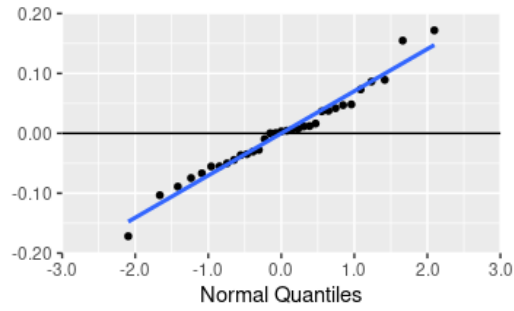
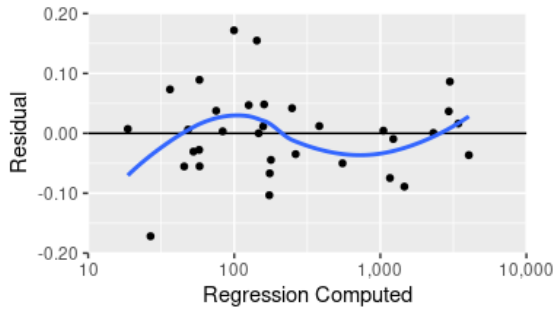
## Outlier Test Criteria

Leverage	Cook's D	DFFITS
0.182	0.194	0.492

## Flagged Observations

	logSSC Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
202006220740	2.17	2.00	0.172	2.46	2.70	0.0392	0.124 0.546
202012140820	1.26	1.43	-0.172	-2.53	-2.79	0.0897	0.315 -0.877

## Statistical Plots



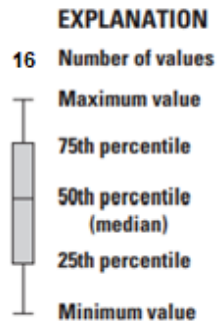
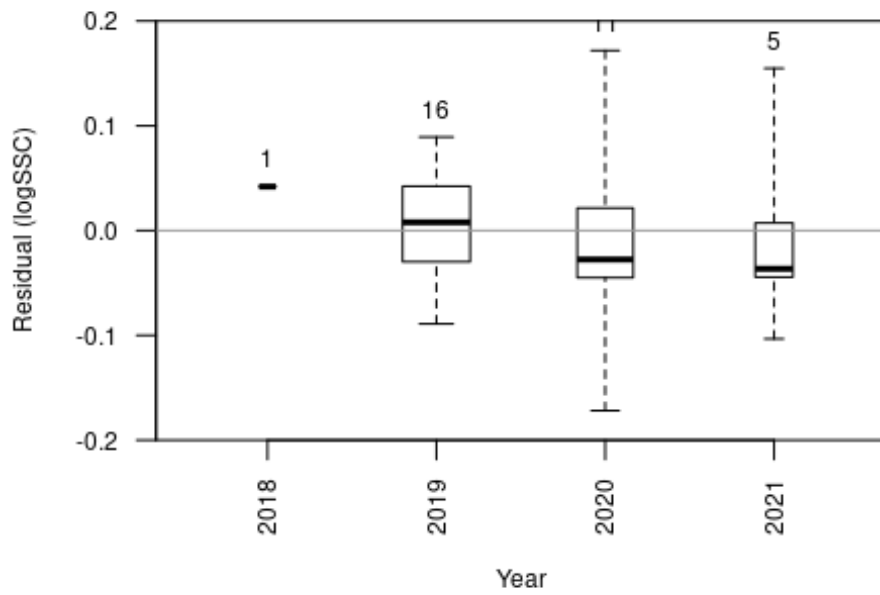
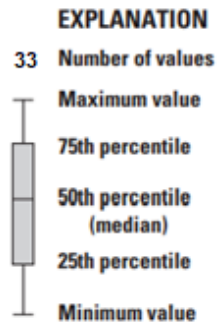
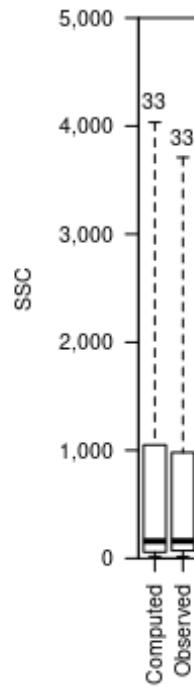
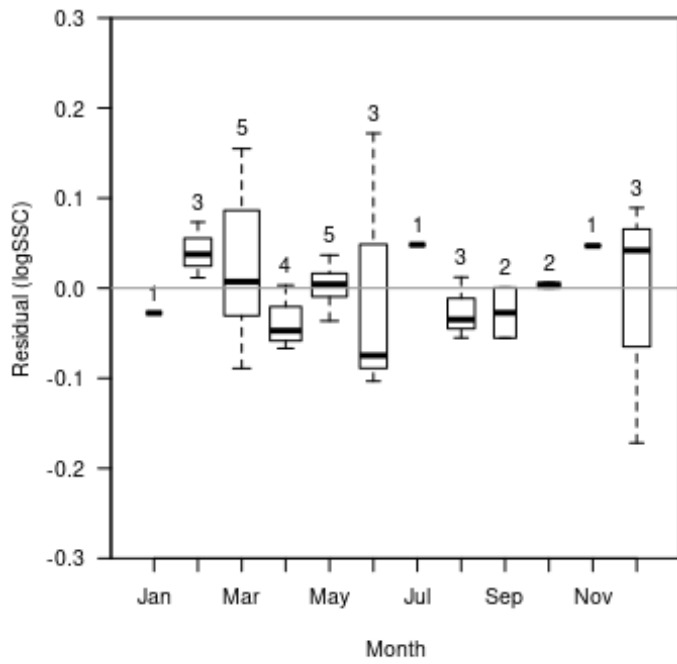
**First row (left):** Residual SSC related to regression computed SSC with local polynomial regression fitting, or locally estimated scatterplot smoothing (LOESS), indicated by the blue line.

**First row (right):** Residual SSC related to the corresponding normal quantile of the residual with simple linear regression, indicated by the blue line.

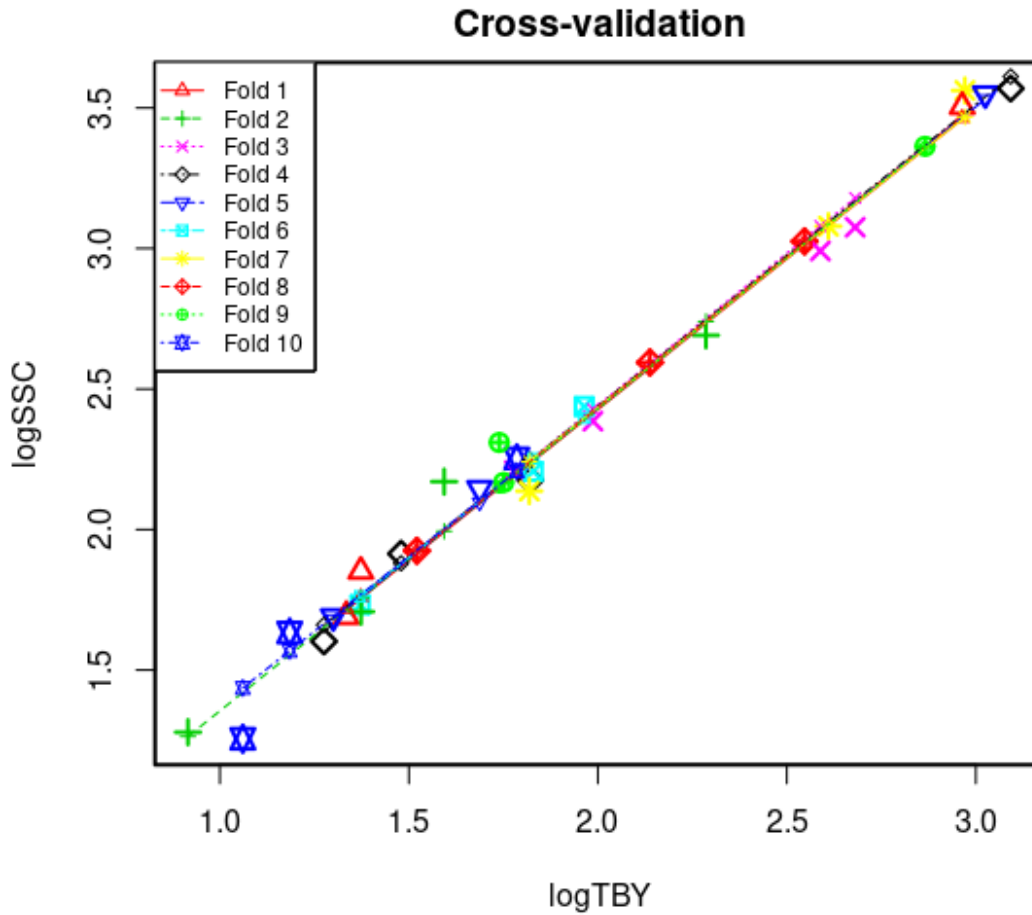
**Second row:** Residual SSC related to date (left) and regression computed SSC multiplied by the BCF (right) with LOESS, indicated by the blue line.

**Third row:** Observed SSC related to regression computed SSC.

**Fourth row:** Residual SSC related to TBY with LOESS, indicated by the blue line.



## Cross Validation



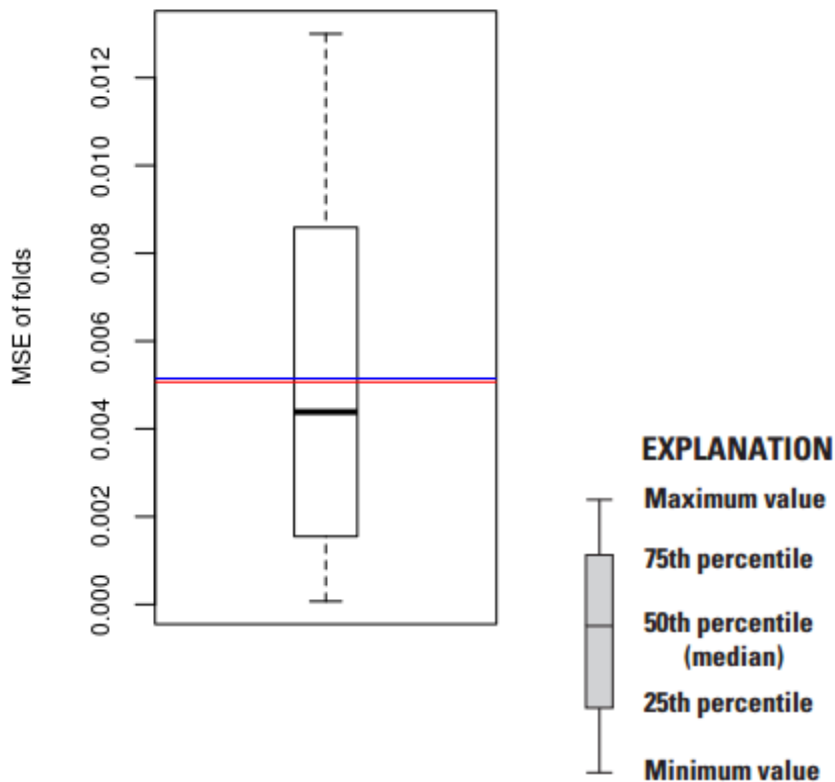
Fold - equal partition of the data (10 percent of the data).

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: 6.92e-05  
Mean MSE of folds: 5.15e-03  
Median MSE of folds: 4.38e-03  
Maximum MSE of folds: 1.30e-02  
(Mean MSE of folds) / (Model MSE): 1.02e+00



Red line - Model MSE

Blue line - Mean MSE of folds

### Model-Calibration Dataset

	Date	logSSC	logTBY	SSC	TBY	Computed logSSC	Computed SSC	Residual	Normal Quantiles	Censored Values
0										
1	2018-12-17	2.44	1.96	274	92	2.4	252	0.042	0.742	--
2	2019-02-05	2.21	1.78	162	60.2	2.2	160	0.0115	0.307	--
3	2019-02-19	1.91	1.48	82	30.2	1.88	76.2	0.0376	0.646	--
4	2019-03-14	3.56	2.97	3650	935	3.48	3030	0.0864	1.23	--
5	2019-03-18	3.08	2.68	1190	479	3.16	1480	-0.089	-1.42	--
6	2019-04-01	2.69	2.29	491	193	2.74	558	-0.0501	-0.742	--
7	2019-04-15	2.18	1.82	150	66.3	2.24	177	-0.0668	-1.09	--
8	2019-05-01	3.03	2.55	1060	352	3.02	1060	0.0044	0.0756	--
9	2019-05-08	3.55	3.03	3550	1060	3.53	3460	0.0163	0.47	--
10	2019-05-22	3.08	2.61	1200	407	3.09	1240	-0.00947	-0.228	--
11	2019-06-25	2.99	2.59	980	388	3.07	1180	-0.0747	-1.23	--
12	2019-07-15	2.25	1.79	179	61	2.2	162	0.0483	0.959	--
13	2019-08-19	2.59	2.14	393	137	2.58	387	0.0121	0.387	--
14	2019-09-23	3.36	2.87	2310	734	3.36	2340	0.000615	-0.0756	--
15	2019-10-22	2.17	1.75	147	56.3	2.17	149	0.000121	-0.152	--
16	2019-11-19	2.15	1.69	140	48.7	2.1	127	0.047	0.846	--
17	2019-12-17	1.85	1.37	71	23.6	1.76	58.6	0.0893	1.42	--
18	2020-01-14	1.73	1.37	54	23.5	1.76	58.3	-0.0276	-0.307	--
19	2020-02-11	1.63	1.18	43	15.3	1.56	36.8	0.0734	1.09	--
20	2020-03-17	1.69	1.33	49	21.6	1.72	53.2	-0.0305	-0.387	--



21	2020-04-20	1.92	1.52	84	33.2	1.92	84.4	0.00333	0	--
22	2020-05-26	3.51	2.96	3200	920	3.47	2980	0.0368	0.556	--
23	2020-06-22	2.17	1.59	148	39.2	2	101	0.172	2.1	--
24	2020-08-17	2.39	1.99	243	97	2.42	267	-0.0347	-0.47	--
25	2020-08-31	1.71	1.37	51	23.6	1.76	58.6	-0.0551	-0.846	--
26	2020-09-14	1.6	1.28	40	18.9	1.66	46	-0.0553	-0.959	--
27	2020-10-13	1.69	1.3	49	20	1.68	48.9	0.00623	0.152	--
28	2020-12-14	1.26	1.06	18	11.5	1.43	27.1	-0.172	-2.1	--
29	2021-03-03	1.28	0.916	19	8.23	1.27	18.9	0.00725	0.228	--
30	2021-03-22	2.31	1.74	204	54.8	2.15	145	0.155	1.66	--
31	2021-04-19	2.21	1.83	161	67.5	2.25	181	-0.0444	-0.646	--
32	2021-05-17	3.57	3.09	3710	1240	3.61	4090	-0.0364	-0.556	--
33	2021-06-21	2.14	1.82	137	65.9	2.24	176	-0.103	-1.66	--

## Definitions

**Cook's D:** Cook's distance (Helsel and others, 2020).

**DIFFITS:** Difference in fits statistic (Helsel and others, 2020).

**E.vars:** Explanatory variables.

**Leverage:** An outlier's measure in the x direction (Helsel and others, 2020).

**LOESS:** Local polynomial regression fitting, or locally estimated scatterplot smoothing (Helsel and others, 2020).

**LOWESS:** Locally weighted scatterplot smoothing (Cleveland, 1979; Helsel and others, 2020).

**MSE:** Mean square error (Helsel and others, 2020).

**MSPE:** Model standard percentage error (Helsel and others, 2020).

**Probability(>|t|):** The probability that the independent variable has no effect on the dependent variable (Helsel and others, 2020).

**RMSE:** Root mean square error (Helsel and others, 2020).

**SSC:** Suspended-sediment concentration, in milligrams per liter (USGS parameter code 80154).

**t value:** Student's t value; the coefficient divided by its associated standard error (Helsel and others, 2020).

**TBY:** Turbidity, in formazin nephelometric units (USGS parameter code 63680).

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Statistical Association, v. 74, no. 368, p. 829–836.

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