

# **Appendix 1. Model Archive Summary for Turbidity Regression Model to Estimate Suspended Sediment Concentration at U.S. Geological Survey Site Number 07017610; Big River below Bonne Terre, Missouri**

This model archive summary describes the suspended sediment concentration (SSC) model developed to compute real-time SSC using real-time turbidity data from October 1, 2018, to the publishing of this report. This model supersedes all previous models used. The methods used follow U.S. Geological Survey (USGS) guidance as referenced in relevant Office of Surface Water/Office of Water Quality Technical Memoranda (USGS, 2016) and Rasmussen and others (2009). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

## **Site and Model Information**

Site number: 07017610

Site name: Big River below Bonne Terre, Missouri

Location: Latitude 37°57'54.9", longitude 90°34'28.2", referenced to North American Datum of 1983, in St. Francois County, Missouri, hydrologic unit 07140104, on downstream left wingwall of State Highway E, approximately 3 miles north of Bonne Terre, Missouri.

Equipment: A Yellow Springs Instruments (YSI) EXO2 is deployed at the site through a 4-inch polyvinyl chloride (PVC) pipe at the same location as the orifice line. Water temperature and stream

turbidity are recorded at 15-minute intervals and transmitted to the USGS National Water Information System (NWIS) database by satellite telemetry (USGS, 2023).

Model number: 07017610.SSC.WY18.1

Date model was created: April 28, 2023

Model-calibration data period: November 28, 2018, to September 10, 2021

Model application date: October 1, 2018, to present

Computed by: Kendra M. Markland

Reviewed by: Jessica Garrett

Approved by: Dan Christensen

## **Model Data**

All data were collected using USGS protocols and are stored in the NWIS database (USGS, 2023). The turbidity regression model is based on 35 measurements of suspended sediment concentration and turbidity samples collected from November 28, 2018, through September 10, 2021. Samples were collected throughout the range of continuously observed hydrologic and turbidity conditions. Summary statistics and the complete model-calibration data are provided. Studentized residuals from the final model were inspected for outliers; no outliers were excluded from the model.

## **Sediment Data**

Traditional cross-sectional sampling methods were used to collect suspended sediment samples during base-flow and stormflow conditions. During base-flow conditions, suspended sediment samples were collected approximately 40 feet upstream from the bridge by wading the stream and using the equal-width increment (EWI) method (USGS, 2006). A US DH-81 sampler was used. Samples were collected at each equally spaced location (vertical) with a consistent transit rate (vertical speed). The

samples at each vertical were composited into one or more sampling bottles. If the minimum mean stream velocity was less than 1.5 feet per second, the sample was collected using grab sample methodology because of the lack of isokinetic conditions (USGS, 2006). Streamflow measurements were collected in the same location as the sediment sample.

During stormflow event sampling, measurements and samples were collected from the downstream side of the bridge deck on Highway E using the same EWI method. Samples were collected across the hydrologic event, targeting the rising limb, peak, and falling limb when possible. Streamflow was measured nearest to the peak as possible. Depending on stream conditions, either a US DH-95 or US DH-2 sampler was used. USGS personnel operated the sampler, which was attached to a reel and cable mechanism mounted on a vehicle. The sampler was raised and lowered at a constant speed according to the transit rate, which is calculated from the maximum stream velocity and depth. Samples were analyzed in the USGS Central Midwest Water Science Center Sediment Laboratory in Rolla, Missouri.

### **Surrogate Data**

The turbidity data used in this analysis were measured using a YSI EXO2 sonde, which includes a central wiper. The turbidity probe measures formazin nephelometric units (FNU) and is calibrated using a three-point calibration and YSI's calibration standards (Wagner and others, 2006). The YSI EXO2 was serviced approximately every 8–12 weeks, which included cleaning the sonde and calibration checks on the turbidity sensor.

## Model Development

Outliers were identified in the dataset by reviewing data for erroneous entries and errors in sampling or laboratory methods. Duration curves of turbidity data indicate that turbidity remained within the range of sensor accuracy (1,000 FNU). Forty discrete suspended sediment samples were collected, although only 35 were used in the development of the turbidity-derived regression model because of missing turbidity data from the sensor at the time of discrete sampling. Graphing nontransformed SSC against turbidity values identified a strong relation between the two properties. Inspection of the data and residual plots identified no outliers. The 35 data pairs were used to calibrate the SSC-turbidity model, with both variables being log-transformed. Regression analysis was done using R (version 4.1.3; R Core Team, 2022).

## Model Summary

Turbidity regression model for calculation of SSC:

$$SSC = 2.7435 \times Turb^{0.999},$$

where

*SSC* is suspended sediment concentration, in milligrams per liter; and

*Turb* is turbidity, in formazin nephelometric units, measured with a YSI EXO2.

The model information is as follows:

- number of calibration measurements=35;
- adjusted coefficient of determination=0.96;
- root mean squared error=0.153; and

- bias-correction factor=1.06.

Previous model for October 2011 through September 2013 (Barr, 2016):

$$SSC = 1.8239 \times Turb^{0.984}$$

## Suspended-Sediment Concentration Record

The SSC record computed using this regression mode, as well as the daily loads, are available in NWIS (USGS, 2023).

## Model Statistics, Data, and Plots

### Definitions

SSC: Suspended sediment concentration (SSC) in milligrams per liter (parameter code 80154)

Turb: Turbidity in FNU (parameter code 63680)

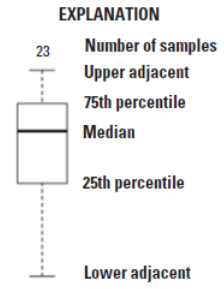
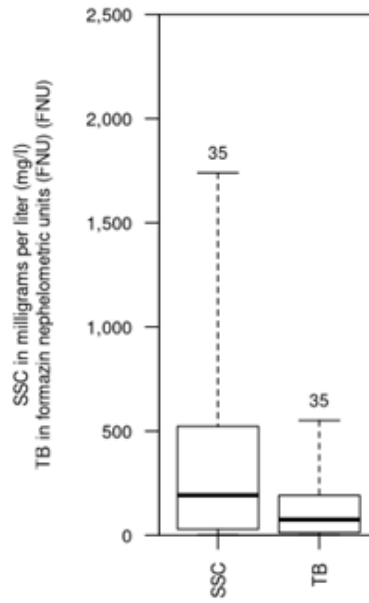
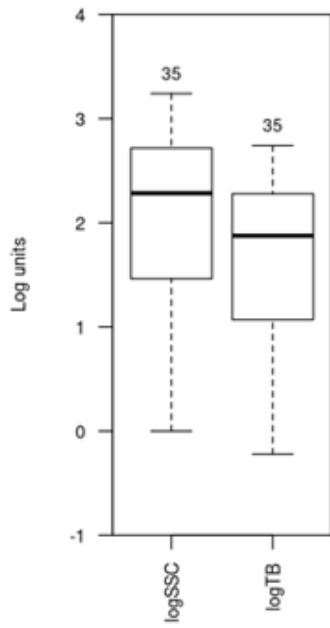
### Model

$$SSC = 2.7435 \times Turb^{0.999}$$

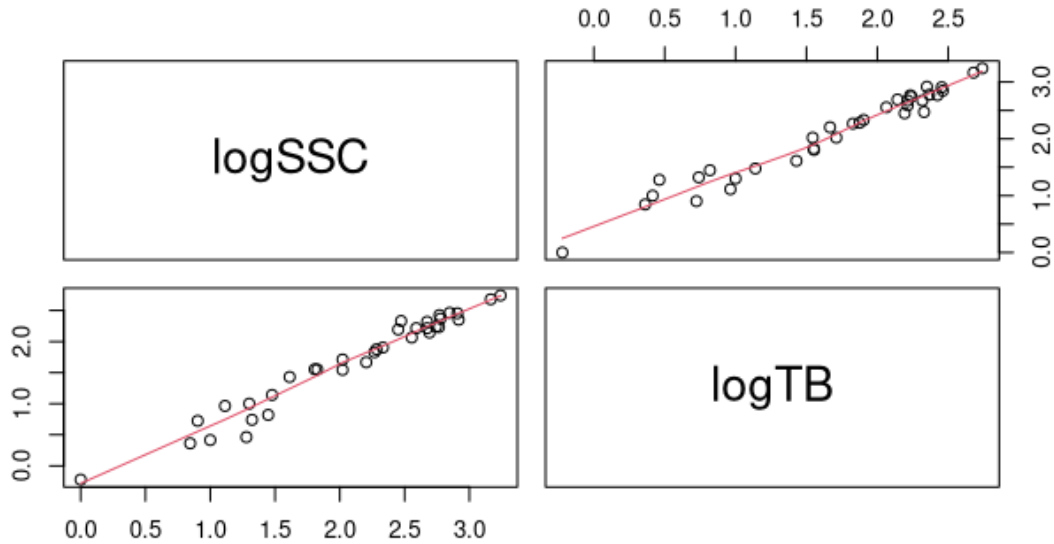
Variable summary statistics.

Statistic	logSSC	SSC	logTurb	Turb
Minimum	0.00	1	-0.222	0.6
1st quartile	1.45	28	1.000	10.0
Median	2.28	192	1.880	75.0
Mean	2.09	340	1.680	124
3rd quartile	2.74	554	2.320	208
Maximum	3.24	1,740	2.740	551

# Box Plots



## Exploratory Plots



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

Basic model statistics.

Statistic	Value
Observations	35
Root mean square error (RMSE)	0.153
Average model standard percentage error (MSPE)	36
Coefficient of determination ( $R^2$ )	0.963
Adjusted coefficient of determination (Adj. $R^2$ )	0.961
Bias correction factor (BCF)	1.06

Explanatory variables.

	Coefficients	Standard error	t value	Pr(> t )
(Intercept)	0.413	0.0633	6.53	0.000000204
logTurb	0.999	0.0343	29.10	0.000000000

Correlation matrix.

	Intercept	E.vars
Intercept	1.000	-0.912
E.vars	-0.912	1.000

Outlier test criteria.

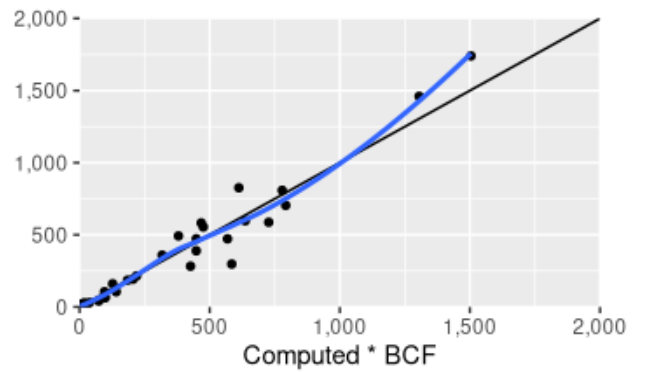
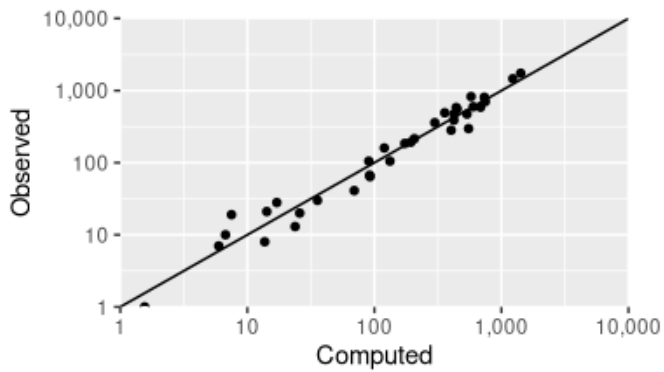
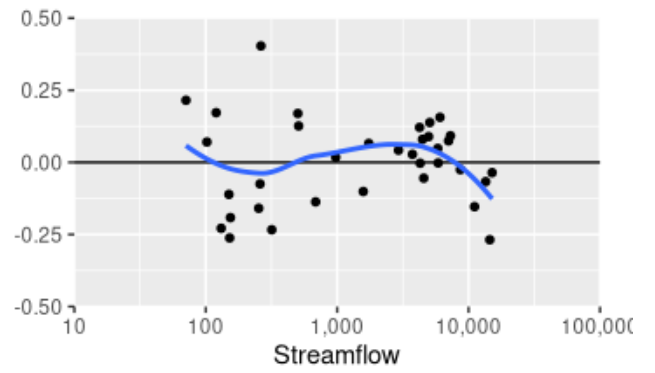
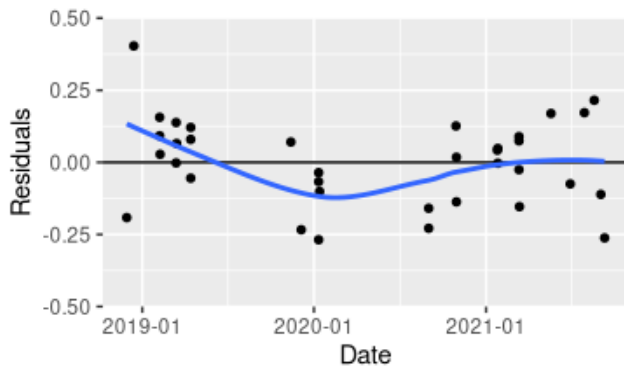
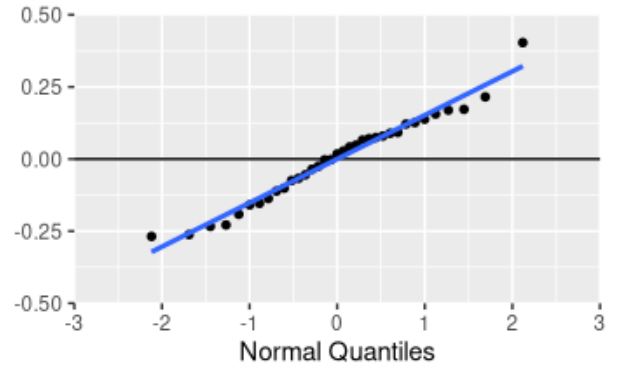
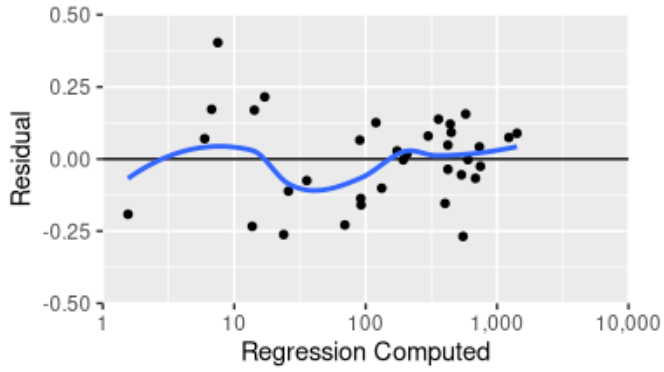
	Test criteria
Leverage	0.171
Cook's D	0.194
DFFITs	0.478

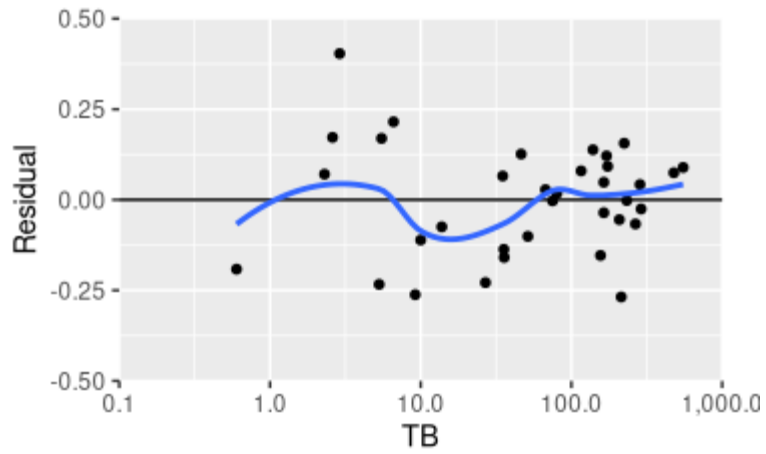
Flagged observations.

Date	Time	logSSC	Cooks D	DFFITs	Leverage	Studentized residual
11/29/2018	8:00	0.00	0.265	-0.739	0.211	-1.43
12/14/2018	12:00	1.28	0.446	1.060	0.103	3.13

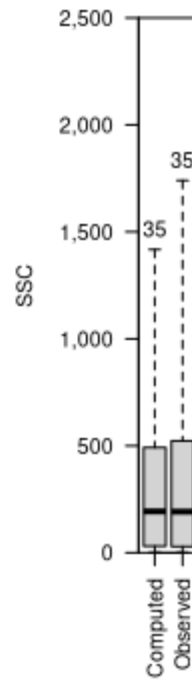
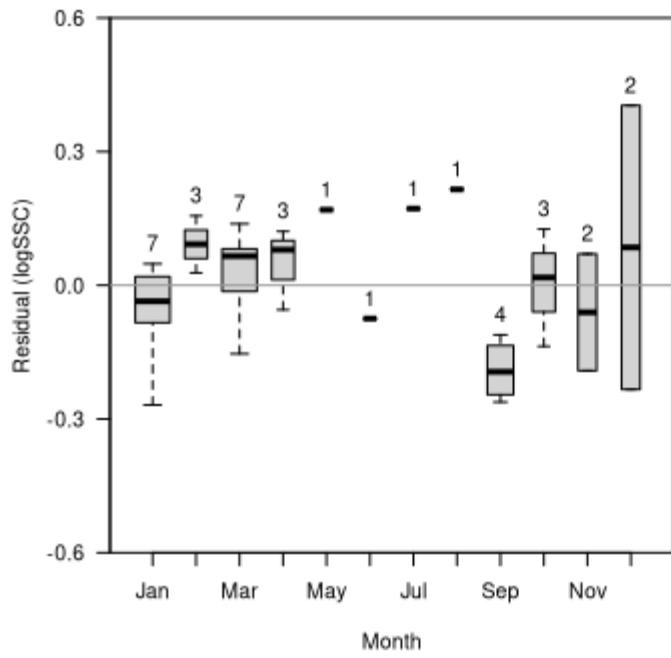


# Statistical Plots



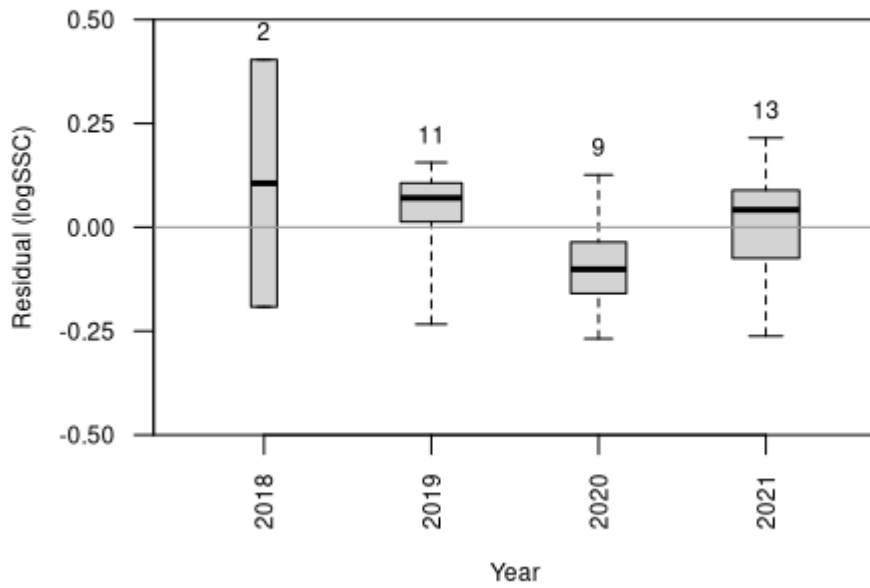


The blue line shows the locally estimated scatterplot smoothing (LOESS). The black dots correspond to observed values. The black line represents the 1:1 line.

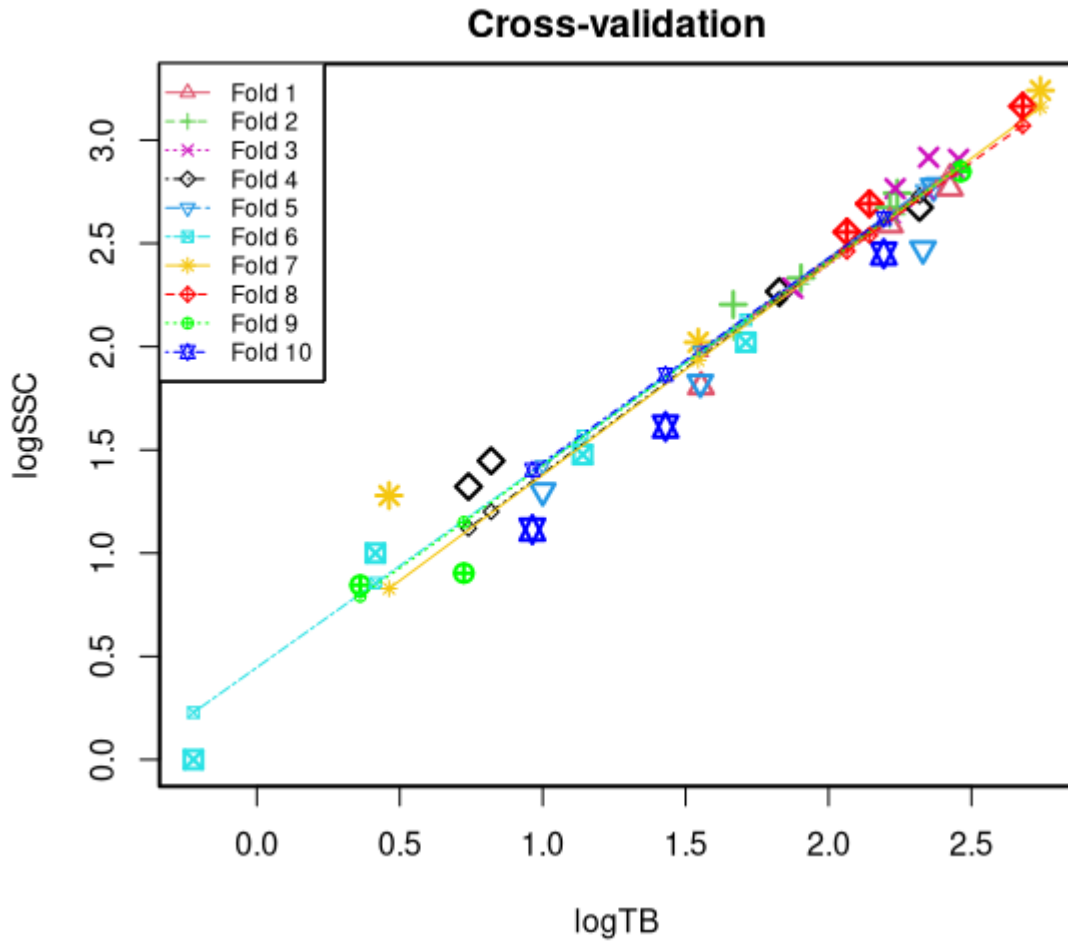


**EXPLANATION**

- 9 Number of samples
- Upper adjacent
- 75th percentile
- Median
- 25th percentile
- Lower adjacent



# Cross Validation



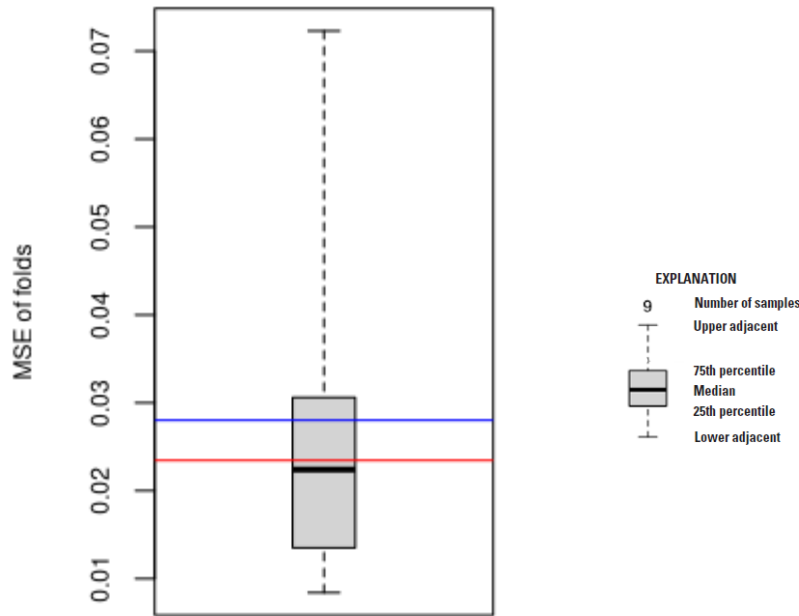
Fold – equal partition of the data (10 percent of the data).

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

Statistic	Value
Minimum mean square error (MSE) of folds	0.0084
Mean MSE of folds	0.0280
Median MSE of folds	0.0224
Maximum MSE of folds	0.0723
(Mean MSE of folds)/(Model MSE)	1.1900



Red line – Model mean square error (MSE)  
 Blue line – Mean MSE of folds

Model-calibration dataset.

Date	Time	Turb	SSC	logTurb	logSSC	Computed logSSC	Computed SSC
11/29/2018	8:00	0.6	1	-0.22185	0	0.192	1.65
12/14/2018	12:00	2.9	19	0.462398	1.278754	0.875	7.96
2/7/2019	12:20	224	826	2.350248	2.91698	2.76	612
2/7/2019	16:40	174	554	2.240549	2.74351	2.65	476
2/8/2019	10:25	67.3	185	1.828015	2.267172	2.24	184
3/14/2019	10:52	139	492	2.143015	2.691965	2.55	380
3/14/2019	13:59	233	597	2.367356	2.775974	2.78	637
3/15/2019	10:22	35	105	1.544068	2.021189	1.96	95.8
4/14/2019	7:25	171	582	2.232996	2.764923	2.64	467
4/14/2019	8:54	208	472	2.318063	2.673942	2.73	568
4/14/2019	10:04	116	359	2.064458	2.555094	2.48	317
7/11/2019	11:00	--	9	--	0.954243	--	--

9/5/2019	12:30	--	10	--	1	--	--
9/5/2019	13:00	--	11	--	1.041393	--	--
11/13/2019	9:30	2.3	7	0.361728	0.845098	0.775	6.32
12/5/2019	9:30	5.3	8	0.724276	0.90309	1.14	14.5
1/11/2020	9:00	266	587	2.424882	2.768638	2.84	727
1/11/2020	10:34	214	297	2.330414	2.472756	2.74	585
1/11/2020	12:13	164	389	2.214844	2.58995	2.63	448
1/13/2020	12:34	51.4	105	1.710963	2.021189	2.12	141
9/1/2020	12:00	26.9	41	1.429752	1.612784	1.84	73.7
9/1/2020	16:05	35.8	64	1.553883	1.80618	1.97	98
10/26/2020	11:00	--	2	--	0.30103	--	--
10/29/2020	12:30	46.4	160	1.666518	2.20412	2.08	127
10/30/2020	3:05	80.1	215	1.903633	2.332438	2.31	219
10/30/2020	15:10	35.6	67	1.55145	1.826075	1.96	97.5
1/12/2021	11:30	--	10	--	1	--	--
1/25/2021	12:30	285	808	2.454845	2.907411	2.87	779
1/26/2021	3:15	164	472	2.214844	2.673942	2.63	448
1/26/2021	9:20	75	192	1.875061	2.283301	2.29	205
3/11/2021	19:35	551	1740	2.741152	3.240549	3.15	1500
3/11/2021	21:00	478	1460	2.679428	3.164353	3.09	1310
3/12/2021	0:15	290	704	2.462398	2.847573	2.87	792
3/12/2021	21:00	156	282	2.193125	2.450249	2.6	426
5/19/2021	10:00	5.5	21	0.740363	1.322219	1.15	15.1
6/29/2021	11:35	13.8	30	1.139879	1.477121	1.55	37.8
7/29/2021	11:25	2.6	10	0.414973	1	0.828	7.14
8/19/2021	11:15	6.6	28	0.819544	1.447158	1.23	18.1
9/2/2021	12:00	10	20	1	1.30103	1.41	27.4
9/10/2021	10:45	9.2	13	0.963788	1.113943	1.38	25.2

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