

Model Archive Summary for Suspended Sediment Concentration at Station 01480617; West Branch Brandywine Creek at Modena, Pennsylvania [2020 Version]

This model archive summary describes the regression model developed to estimate continuous instantaneous (15-minute) suspended sediment concentrations starting in 2007. The model was updated in June 2020, using all available calibration data. The previous model (Sloto and Olsen, 2011) was in use from October 1, 2008 to September 30, 2019. The new model is used to compute suspended sediment concentrations beginning in October 2019.

Site and Model Information

U.S. Geological Survey (USGS) station number: 01480617

Station name: West Branch Brandywine Creek at Modena, Pennsylvania

Lat 39°57'42", long 75°48'06" referenced to North American Datum of 1927, Chester County, PA, Hydrologic Unit 02040205, on left bank at bridge on SR 15068 at Modena, and 300 ft upstream from Dennis Run.

Date regression model was created: June 2020.

Period of data for model calibration: November 16, 2007 – March 22, 2019.

Model application date: October 2019 onward.

Database Reviewed by: Elizabeth A. Hillte, May 2020

Computed by: Matthew C. Gyves, June 2020.

Approved by: Joseph W. Duris, Water-Quality Specialist, June 2020.

Equipment

A Yellow Spring Instrument (YSI) 6920V2 monitor equipped with sensors for temperature, specific conductance, pH, dissolved oxygen, and turbidity (6136 sensor) is deployed at this site. The monitor is housed in a 4-inch perforated plastic pipe placed in the stream about 3 ft from the left bank. Readings from the sensors are recorded every 15 minutes and transmitted hourly by way of GOES satellite.

Model Calibration Dataset

All data were collected using standard USGS protocols and are stored in the National Water Information System (NWIS) database. Linear regression models were developed using RStudio Version 1.2.1335. Primary packages included (dataRetrieval, v 2.7.5; dplyr, v 0.8.3, plotly, v 4.9.0, and the Model Archive Summary Shiny App (available at <https://github.com/PatrickEslick/ModelArchiveSummary>). Explanatory variables evaluated as inputs to linear regression were turbidity and streamflow.

The final regression model is based on 95 concurrent measurements of suspended sediment and turbidity concentrations. Suspended sediment concentrations were determined from analysis of discrete samples, and turbidity concentrations were determined from continuous record of 15-minute values, interpolated when necessary to correspond with collection time of the discrete sample for sediment analysis. Suspended sediment samples were collected over a range of hydrologic conditions throughout each year during sampling period. Studentized residuals for final model were inspected and considered for potential removal as outliers if residual values were greater than 3 or less than -3. Although several samples met these criteria; other regression

diagnostics show their influence on model performance to be minimal, and no samples were removed from the dataset.

Prior Model

This model supersedes the prior model that was originally published in Sloto and Olsen (2011).

$$SSC = 1.9879 Turb - 9.6239 \text{ (October 1, 2008 to September 30, 2019)}$$

Data Collection

Discrete samples for suspended sediment analysis were collected using an ISCO automatic sampler which was set to sample based on stage and turbidity thresholds to provide data for a broad range of turbidity values. Over time, these thresholds were changed to collect samples under different conditions, covering the range of measured values. Water was pulled by the sampler peristaltic pump through 0.5-inch tubing from an intake located near the turbidity probe and stored in 1-liter polypropylene bottles. Once collected, sample times were recorded in the field during bottle retrieval as reported by the ISCO. Samples were analyzed for suspended sediment concentration (SSC) in the laboratory at the USGS office in Exton, Pennsylvania and the USGS Kentucky Sediment Laboratory in Louisville, Kentucky using standard USGS methods. Suspended sediment concentrations ranged from 24 to 2,800 mg/L in the 95 analyzed samples.

Turbidity data were collected according to USGS Techniques and Methods 1-D3 (Wagner and Others, 2006). Turbidity concentrations ranged from 14 to 560 formazin nephelometric units (FNU) during collection of concurrent discrete suspended sediment samples used for model calibration.

Model Development

Regression analysis was done using R by examining turbidity ($Turb$) and streamflow (Q) as explanatory variables for SSC. A variety of linear regression models that predict SSC and $\log_{10}(SSC)$ were evaluated and computed using methods described by Rasmussen and others, 2011.

The model with $\log_{10}(Turb)$ as the explanatory variable was selected as the best predictor of $\log_{10}(SSC)$ on the basis of residual plots, maximizing adjusted coefficient of determination (adjusted R^2), and minimizing model residual standard error (or root mean square error, $RMSE$) and standard percentage error ($MSPE$). The addition of discharge as a variable showed minimal improvement on model performance.

Model Summary

Final regression model for suspended sediment concentration (SSC) at site number 01480617:

$$\log_{10} SSC = 0.958 \log_{10} Turb + 0.349$$

where

SSC = suspended sediment concentration in milligrams per liter (mg/L) (parameter 80154);

$Turb$ = turbidity in formazin nephelometric units (FNU) (parameter 63680);

$Turb$ makes physical and statistical sense as explanatory variable for SSC because previous studies showed suspended sediment concentrations were directly related to turbidity concentrations. The transformed model may be retransformed to the original units so that SSC concentrations can be calculated directly. A potential bias that is introduced because of retransformation can be corrected using Duan's bias correction factor (BCF). For this model the BCF is 1.08. The retransformed model, using the BCF, is:

$$SSC = 2.412 Turb^{.958}$$

References

Rasmussen, P.P., Gray, J.R., Glysson, G.D., and Ziegler, A.C., 2009, revised 2011, Guidelines and procedures for computing time-series suspended-sediment concentrations and loads from in-stream turbidity-sensor and streamflow data: U.S. Geological Survey Techniques and Methods, book 3, chap. C4, 52 p.

Sloto, R.A., and Olson, L.E., Estimated suspended-sediment loads and yields in the French and Brandywine Creek Basins, Chester County, Pennsylvania, water years 2008–09: U.S. Geological Survey Scientific Investigations Report 2011–5109, 31 p.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at <http://pubs.water.usgs.gov/tm1d3>

Model Statistics, Data, and Plots

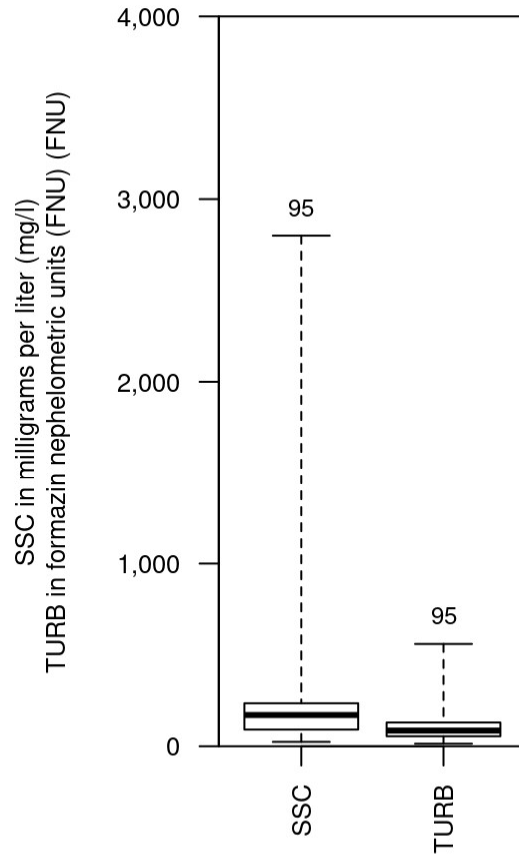
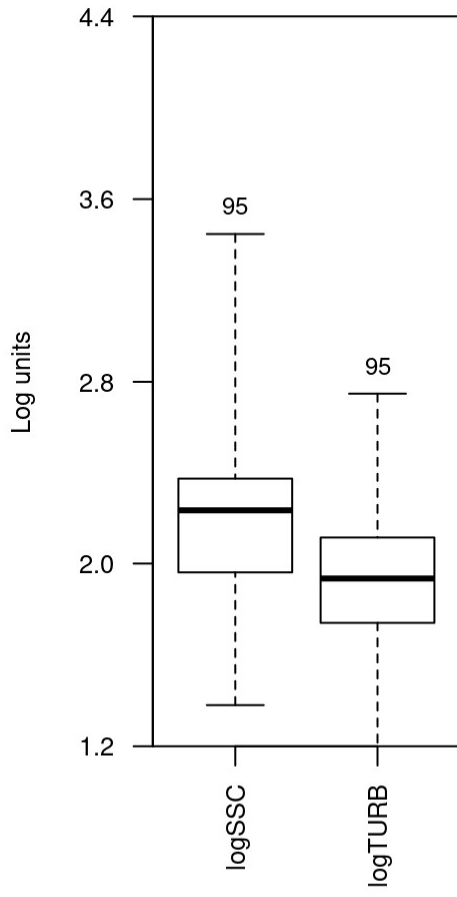
Model

$$\log\text{SSC} = + 0.958 * \log\text{TURB} + 0.349$$

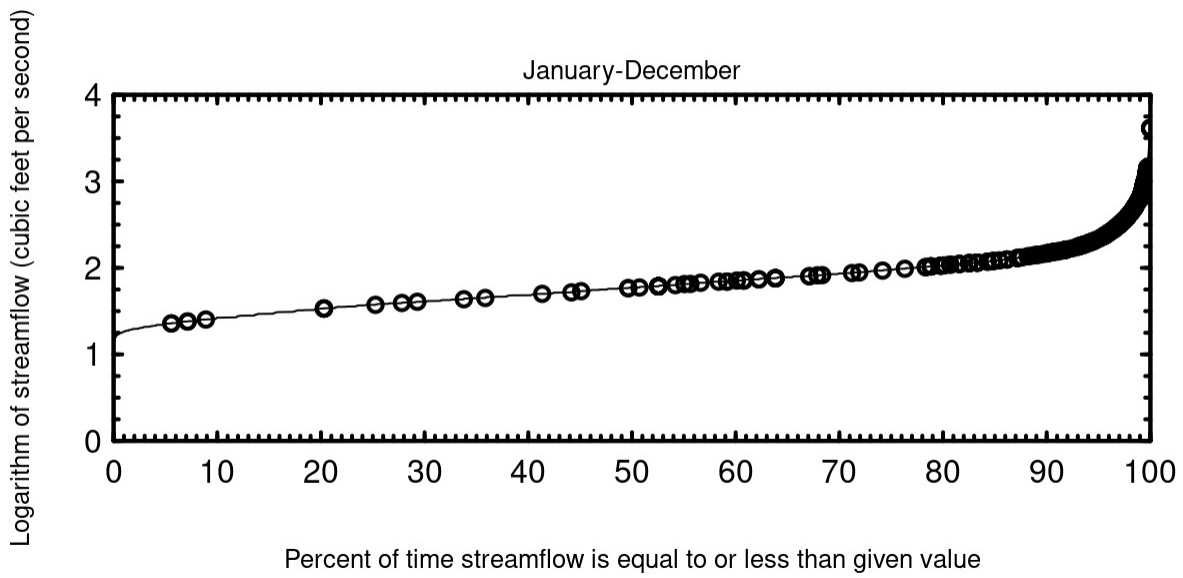
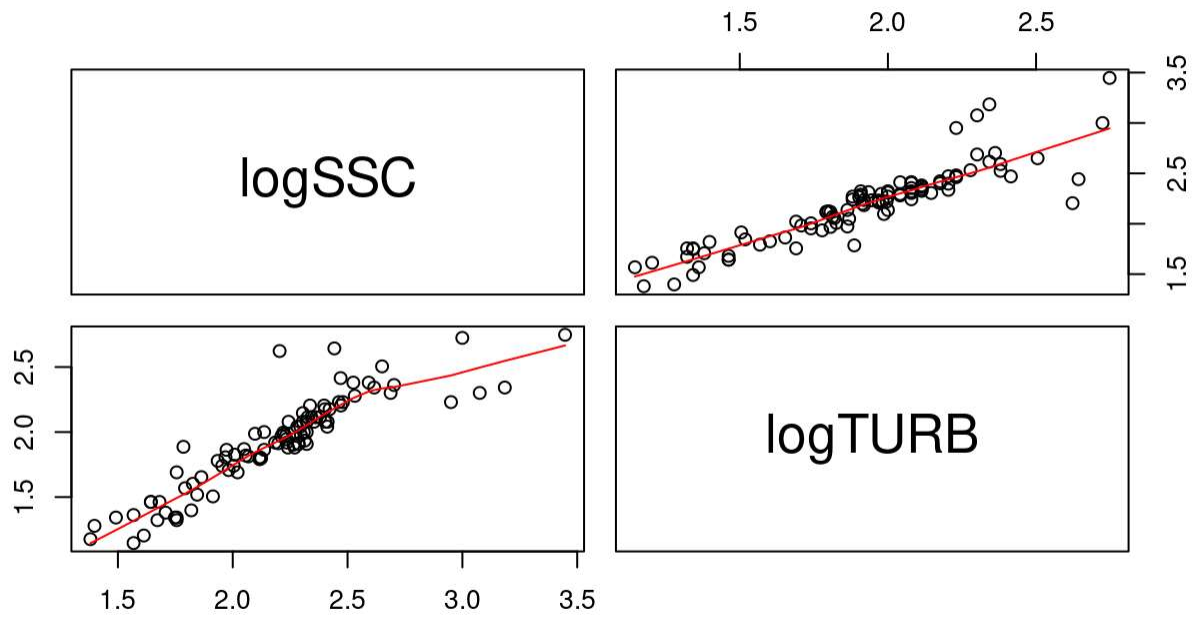
Variable Summary Statistics

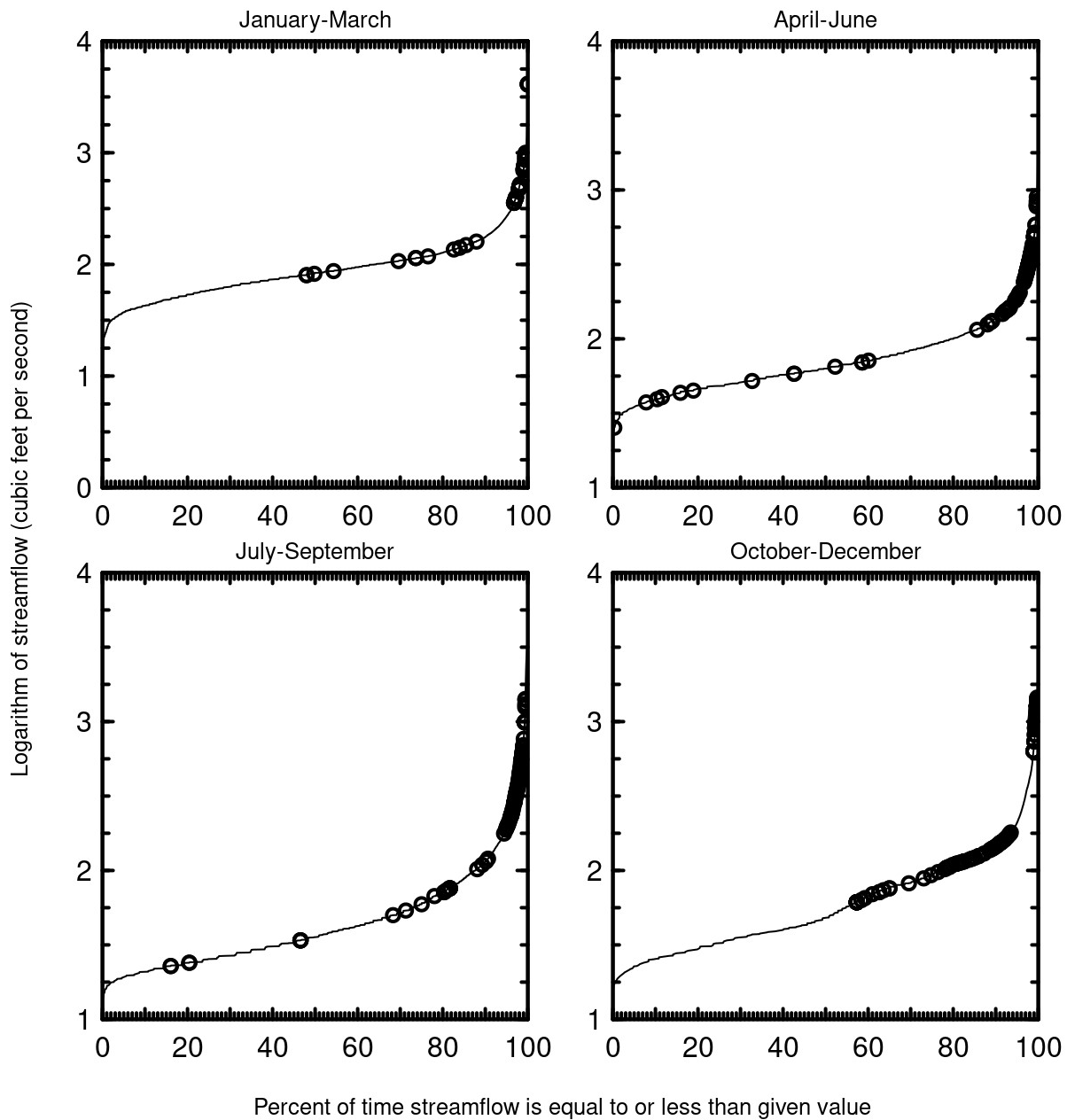
	logSSC	SSC	logTURB	TURB
Minimum	1.38	24	1.15	14
1st Quartile	1.95	90	1.74	55
Median	2.23	171	1.93	86
Mean	2.19	238	1.92	114
3rd Quartile	2.38	240	2.11	130
Maximum	3.45	2800	2.75	560

Box Plots



Exploratory Plots





Basic Model Statistics

Number of Observations	95
Standard error (RMSE)	0.163
Average Model standard percentage error (MSPE)	38.4
Coefficient of determination (R^2)	0.814
Adjusted Coefficient of Determination (Adj. R^2)	0.812
Bias Correction Factor (BCF)	1.08

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.349	0.0928	3.77	2.90e-04
logTURB	0.958	0.0476	20.10	1.11e-35

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.984
E.vars	-0.984	1.000

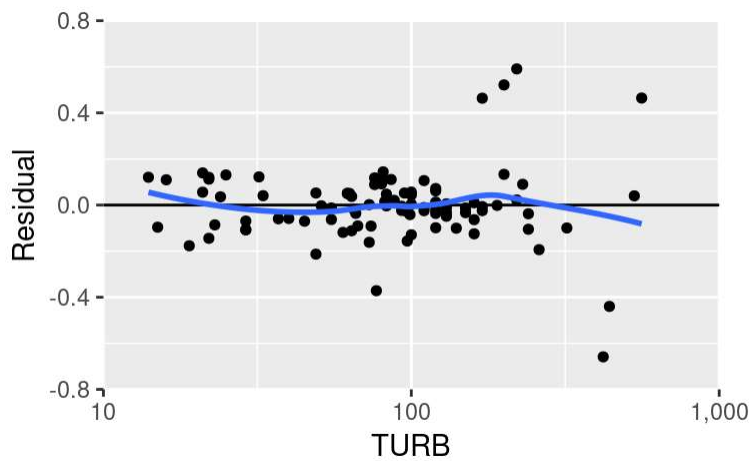
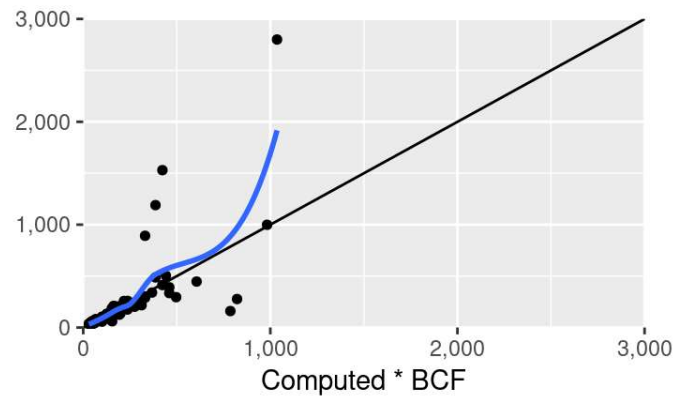
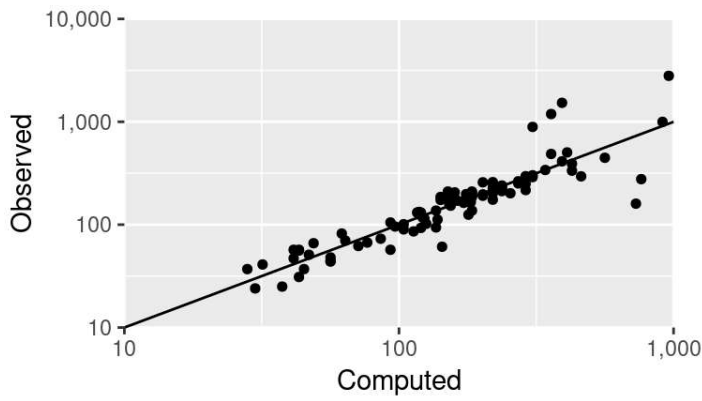
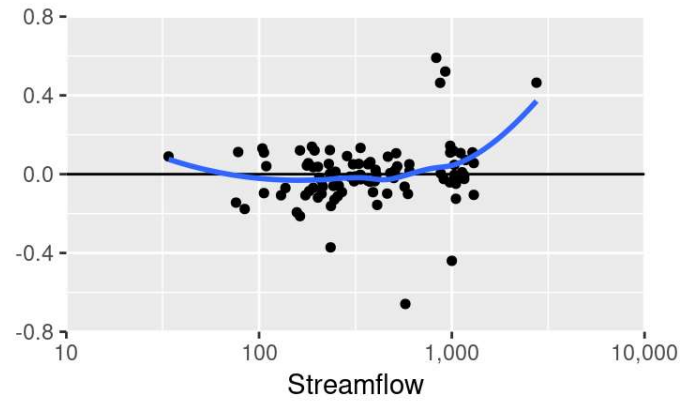
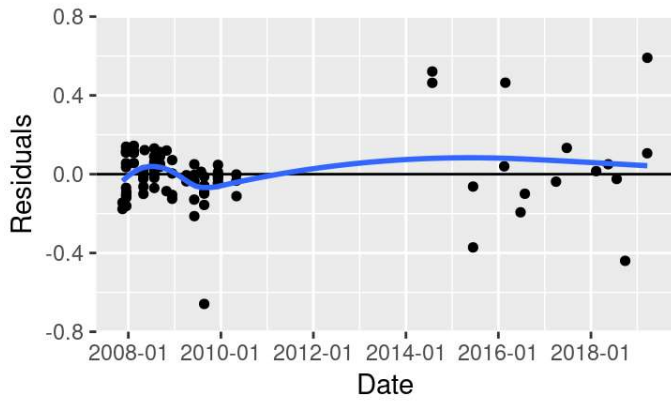
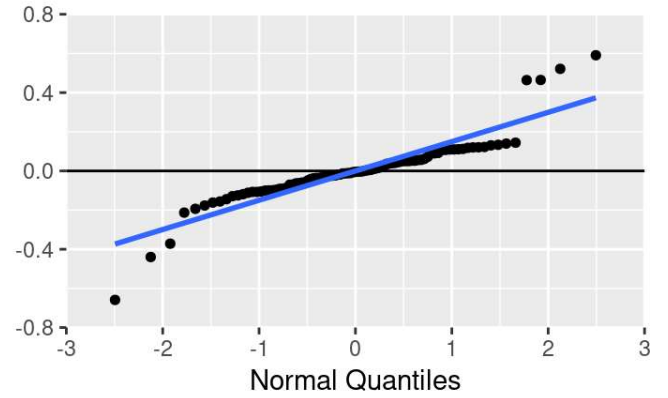
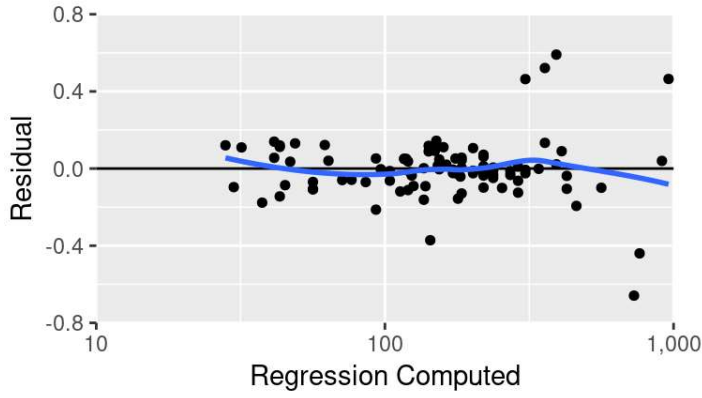
Outlier Test Criteria

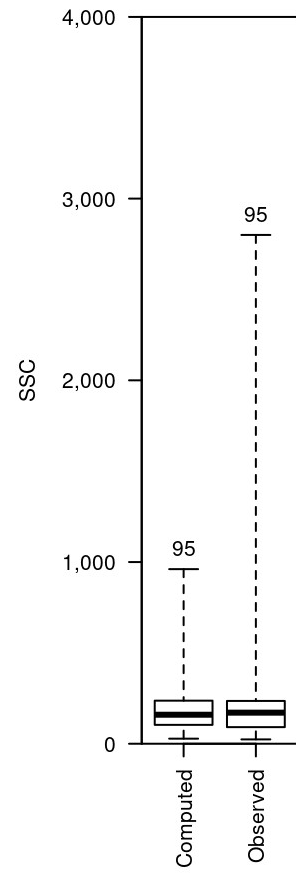
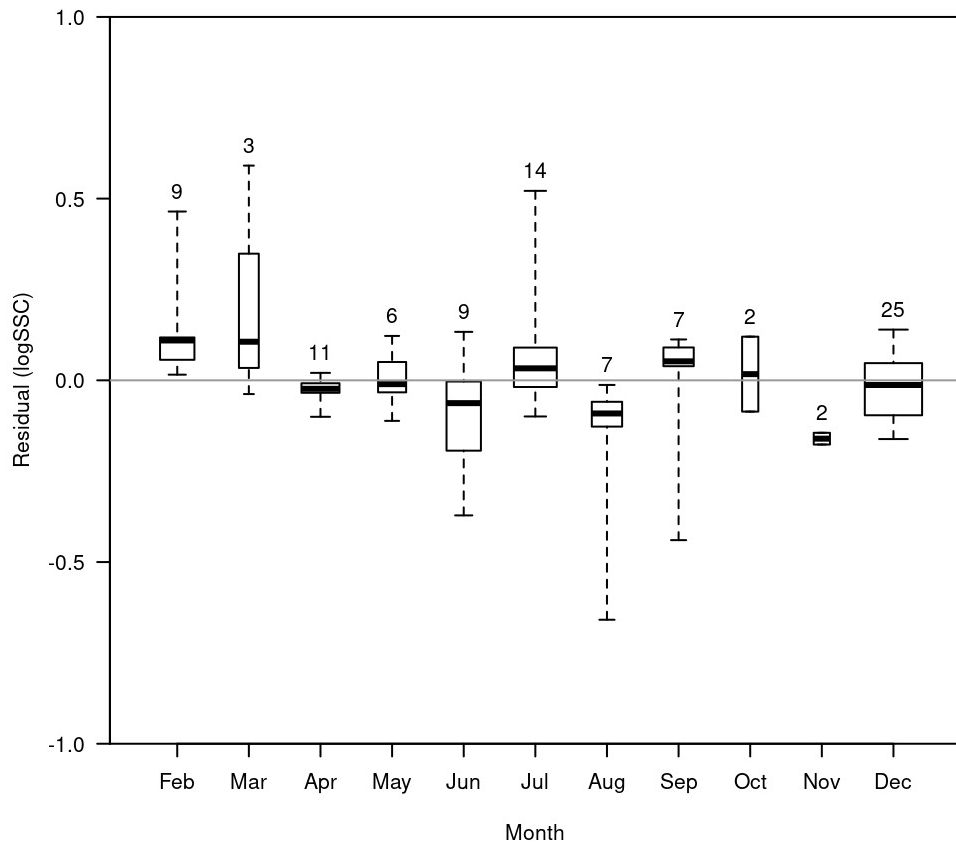
Leverage	Cook's D	DFFITS
0.0632	0.1944	0.2902

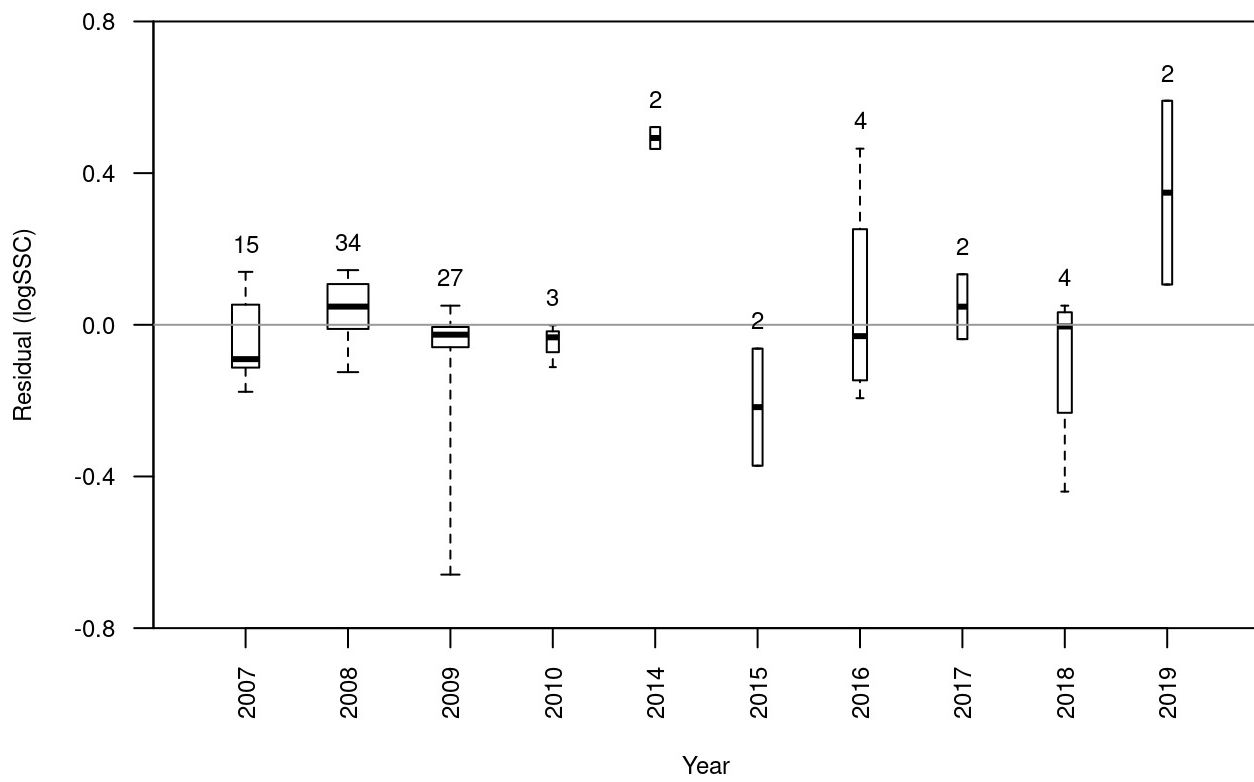
Flagged Observations

	logSSC	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
2009-08-22 00:00	2.20	2.86	-0.6590	-4.160	-4.580	0.0529	0.48300	-1.0800
2014-07-28 11:00	3.08	2.55	0.5210	3.240	3.420	0.0230	0.12400	0.5250
2014-07-28 11:30	2.95	2.49	0.4640	2.880	3.000	0.0188	0.07940	0.4150
2016-02-16 13:00	3.00	2.96	0.0398	0.253	0.252	0.0660	0.00226	0.0669
2016-02-25 05:00	3.45	2.98	0.4650	2.960	3.090	0.0693	0.32500	0.8430
2018-09-28 11:45	2.44	2.88	-0.4400	-2.780	-2.890	0.0554	0.22600	-0.6990
2019-03-22 01:00	3.18	2.59	0.5910	3.680	3.950	0.0259	0.17900	0.6450

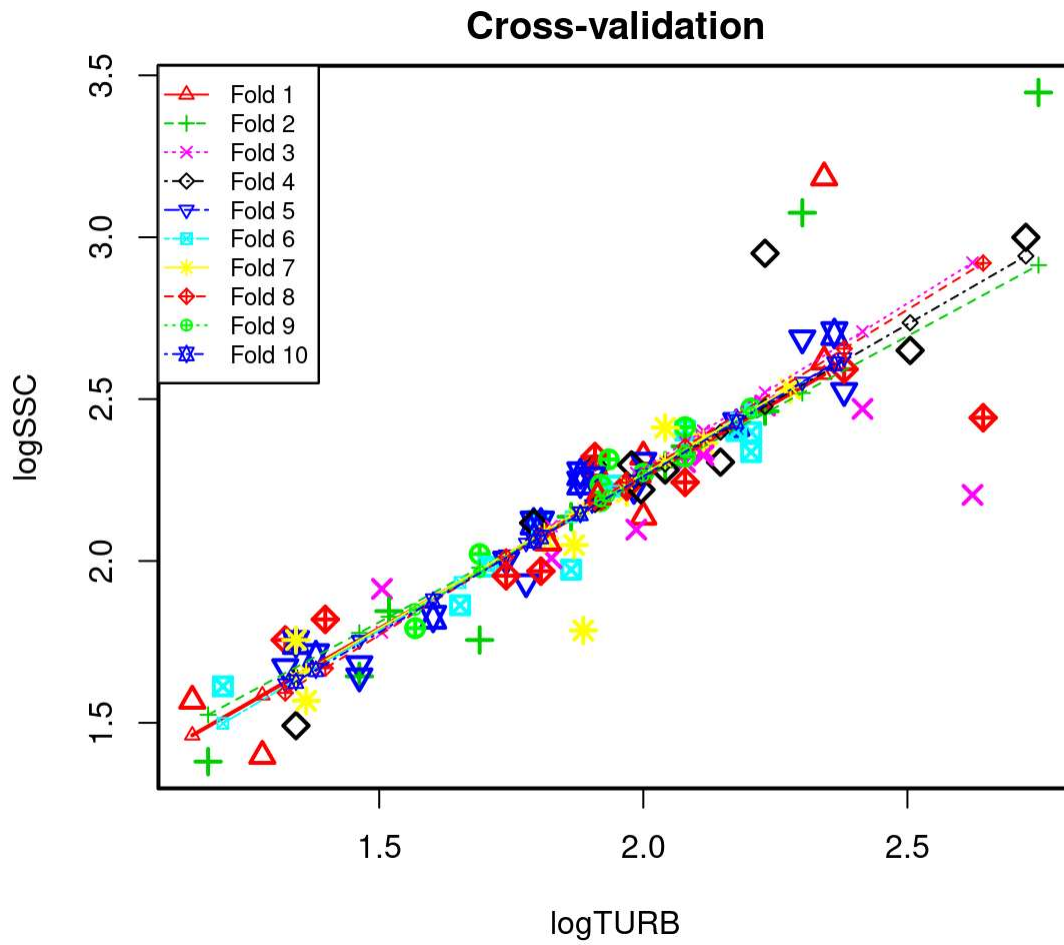
Statistical Plots







Cross Validation



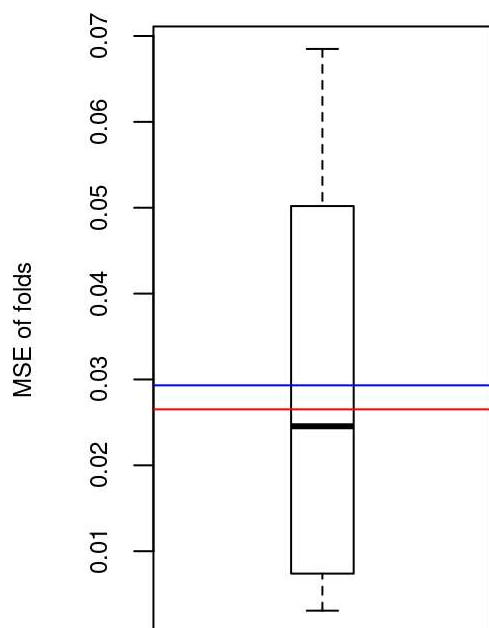
Minimum MSE of folds: 0.00307

Mean MSE of folds: 0.02930

Median MSE of folds: 0.02460

Maximum MSE of folds: 0.06850

(Mean MSE of folds) / (Model MSE): 1.11000



Red line - Model MSE

Blue line - Mean MSE of folds

Model-Calibration Data Set

	Date	logSSC	logTURB	SSC	TURB	Computed logSSC	Computed SSC	Residual	Normal Quantiles	Censored Values
0										
1	2007-11-16	1.4	1.28	25	19	1.57	40.5	-0.177	-1.56	--
2	2007-11-16	1.49	1.34	31	22	1.64	46.6	-0.144	-1.34	--
3	2007-12-13	1.61	1.2	41	16	1.5	34.3	0.11	0.979	--
4	2007-12-14	1.57	1.15	37	14	1.45	30.2	0.121	1.28	--
5	2007-12-14	1.67	1.32	47	21	1.62	44.6	0.0558	0.648	--
6	2007-12-14	1.71	1.38	51	24	1.67	50.6	0.0357	0.321	--
7	2007-12-14	1.68	1.46	48	29	1.75	60.7	-0.0694	-0.648	--
8	2007-12-14	1.76	1.32	57	21	1.62	44.6	0.14	1.56	--
9	2007-12-14	1.64	1.46	44	29	1.75	60.7	-0.107	-1.07	--
10	2007-12-16	1.38	1.18	24	15	1.48	32.3	-0.0961	-0.821	--
11	2007-12-16	1.64	1.46	44	29	1.75	60.7	-0.107	-1.02	--

12	2007-12-16	1.93	1.78	86	60	2.05	122	-0.119	-1.17	--
13	2007-12-16	1.97	1.86	94	73	2.13	147	-0.162	-1.48	--
14	2007-12-16	2.01	1.83	102	67	2.1	135	-0.0905	-0.749	--
15	2007-12-16	2.12	1.8	133	63	2.07	128	0.0504	0.493	--
16	2008-02-13	2.32	1.91	210	81	2.18	162	0.144	1.66	--
17	2008-02-13	2.29	1.91	194	81	2.18	162	0.11	1.02	--
18	2008-02-13	2.27	1.88	186	76	2.15	153	0.118	1.17	--
19	2008-02-13	2.29	1.91	193	81	2.18	162	0.107	0.937	--
20	2008-02-13	2.31	1.93	206	86	2.2	172	0.111	1.07	--
21	2008-02-13	2.32	2	210	100	2.27	199	0.0565	0.681	--
22	2008-04-28	2.21	1.97	163	93	2.24	185	-0.0234	-0.212	--
23	2008-04-29	2.38	2.11	240	130	2.37	256	0.00529	0.159	--
24	2008-04-29	2.29	2.04	197	110	2.31	218	-0.0109	-0.0527	--
25	2008-04-29	2.23	1.94	171	88	2.21	176	0.0204	0.266	--
26	2008-04-29	2.31	2.15	202	140	2.41	274	-0.1	-0.937	--
27	2008-04-29	2.4	2.2	250	160	2.46	312	-0.0634	-0.616	--
28	2008-05-09	1.91	1.51	82	32	1.79	66.7	0.122	1.34	--
29	2008-07-23	2.7	2.36	504	230	2.61	442	0.0901	0.821	--
30	2008-07-24	1.82	1.4	66	25	1.69	52.7	0.131	1.41	--
31	2008-07-24	2.31	2	204	100	2.27	199	0.0439	0.435	--
32	2008-07-24	2.62	2.34	413	220	2.59	423	0.0221	0.294	--
33	2008-07-24	2.4	2.08	253	120	2.34	237	0.0615	0.715	--
34	2008-07-24	2.3	1.98	198	95	2.24	189	0.0523	0.585	--
35	2008-07-24	2.14	1.86	137	73	2.13	147	0.00193	0.106	--
36	2008-07-24	2.07	1.81	117	65	2.09	132	-0.0183	-0.159	--
37	2008-07-24	1.86	1.65	73	45	1.93	92.5	-0.0701	-0.681	--
38	2008-09-06	2.24	1.88	174	76	2.15	153	0.089	0.784	--
39	2008-09-07	2.02	1.69	105	49	1.97	100	0.0523	0.616	--
40	2008-09-07	2.26	1.9	184	80	2.17	161	0.0919	0.858	--
41	2008-09-07	2.12	1.81	131	64	2.08	130	0.0372	0.349	--
42	2008-09-07	1.85	1.52	70	33	1.8	68.7	0.0407	0.406	--
43	2008-09-07	1.75	1.34	56	22	1.64	46.6	0.113	1.12	--
44	2008-10-28	1.57	1.36	37	23	1.65	48.6	-0.086	-0.715	--
45	2008-10-29	1.76	1.34	57	22	1.64	46.6	0.12	1.22	--
46	2008-12-12	2.53	2.38	335	240	2.63	460	-0.105	-0.979	--
47	2008-12-12	2.41	2.08	259	120	2.34	237	0.0717	0.749	--
48	2008-12-12	2.34	2.2	217	160	2.46	312	-0.125	-1.22	--
49	2008-12-12	2.27	2	186	100	2.27	199	0.00376	0.132	--

50	2009-04-03	2.34	2.11	220	130	2.37	256	-0.0325	-0.321	--
51	2009-04-03	2.36	2.11	231	130	2.37	256	-0.0113	-0.0791	--
52	2009-04-03	2.31	2.08	202	120	2.34	237	-0.0363	-0.406	--
53	2009-04-04	2.22	1.98	167	96	2.25	191	-0.026	-0.294	--
54	2009-04-04	2.23	1.97	170	93	2.24	185	-0.0051	0	--
55	2009-05-07	2.32	2.08	210	120	2.34	237	-0.0194	-0.185	--
56	2009-06-04	2.14	2	137	100	2.27	199	-0.129	-1.28	--
57	2009-06-05	1.76	1.69	57	49	1.97	100	-0.213	-1.78	--
58	2009-06-05	1.98	1.71	96	51	1.99	104	-0.00328	0.0527	--
59	2009-06-05	2.12	1.79	131	62	2.07	126	0.0504	0.523	--
60	2009-06-06	2.06	1.82	114	66	2.09	134	-0.0359	-0.377	--
61	2009-07-28	2.35	2.08	226	120	2.34	237	0.0125	0.212	--
62	2009-08-22	2.2	2.62	160	420	2.86	786	-0.659	-2.49	--
63	2009-08-22	2.24	2.08	175	120	2.34	237	-0.0986	-0.858	--
64	2009-08-22	2.1	1.99	125	97	2.25	193	-0.156	-1.41	--
65	2009-08-22	2.05	1.87	112	74	2.14	149	-0.0912	-0.784	--
66	2009-08-22	2	1.74	101	55	2.02	112	-0.0127	-0.106	--
67	2009-08-22	1.83	1.6	67	40	1.88	82.6	-0.0584	-0.523	--
68	2009-08-22	1.79	1.57	62	37	1.85	76.7	-0.0596	-0.554	--
69	2009-12-09	2.18	1.92	153	83	2.19	166	-0.00352	0.0263	--
70	2009-12-09	2.24	1.92	172	83	2.19	166	0.0473	0.464	--
71	2009-12-09	2.22	2	166	99	2.26	197	-0.0415	-0.464	--
72	2009-12-09	2.33	2.11	212	130	2.37	256	-0.0486	-0.493	--
73	2009-12-09	2.42	2.18	264	150	2.43	293	-0.0129	-0.132	--
74	2009-12-09	2.48	2.23	302	170	2.49	331	-0.00655	-0.0263	--
75	2009-12-09	2.46	2.23	290	170	2.49	331	-0.0242	-0.239	--
76	2009-12-09	2.47	2.2	296	160	2.46	312	0.00996	0.185	--
77	2010-05-03	2.53	2.28	340	190	2.53	368	-0.00136	0.0791	--
78	2010-05-03	2.4	2.18	252	150	2.43	293	-0.0331	-0.349	--
79	2010-05-04	1.97	1.81	93	64	2.08	130	-0.112	-1.12	--
80	2014-07-28	3.08	2.3	1190	200	2.55	386	0.521	2.12	--
81	2014-07-28	2.95	2.23	892	170	2.49	331	0.464	1.78	--
82	2015-06-15	1.95	1.74	90	55	2.02	112	-0.0627	-0.585	--
83	2015-06-15	1.79	1.89	61	77	2.16	155	-0.372	-1.92	--
84	2016-02-16	3	2.72	999	530	2.96	983	0.0398	0.377	--
85	2016-02-25	3.45	2.75	2800	560	2.98	1040	0.465	1.92	--
86	2016-06-24	2.47	2.41	295	260	2.66	497	-0.194	-1.66	--
87	2016-07-28	2.65	2.51	447	320	2.75	606	-0.0995	-0.897	--

88	2017-03-31	2.59	2.38	391	240	2.63	460	-0.0379	-0.435	--
89	2017-06-24	2.69	2.3	487	200	2.55	386	0.133	1.48	--
90	2018-02-11	2.2	1.91	158	82	2.18	164	0.0155	0.239	--
91	2018-05-17	2.12	1.79	131	62	2.07	126	0.0504	0.554	--
92	2018-07-23	2.28	2.04	191	110	2.31	218	-0.0244	-0.266	--
93	2018-09-28	2.44	2.64	277	440	2.88	822	-0.44	-2.12	--
94	2019-03-21	2.41	2.04	258	110	2.31	218	0.106	0.897	--
95	2019-03-22	3.18	2.34	1530	220	2.59	423	0.591	2.49	--

Definitions

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

TURB: Turbidity in FNU (63680)