Appendix 2. Model Archive Summary for Total Suspended Solids at U.S. Geological Survey Site 07144780, North Fork Ninnescah River above Cheney Reservoir, Kansas, during October 17, 2009, through December 31, 2019

This model archive summary summarizes the total suspended solids (TSS) model developed to compute hourly or daily TSS during October 17, 2009, onward. This model supersedes all prior models used during this period. 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).

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 YSI 6600 Extended Deployment System water-quality monitor equipped with sensors for water temperature, specific conductance, pH, dissolved oxygen, and turbidity (a YSI Model 6026 turbidity sensor [November 9, 1998, to December 1, 2010] and a YSI Model 6136 turbidity sensor [October 17, 2009, to November 12, 2015; March 31, 2017, to June 7, 2017]) (YSI Incorporated, 2007, 2012a). The YSI 6600 water-quality monitor was in operation during November 9, 1998, through November 12, 2015.

A Xylem YSI EXO2 water-quality monitor equipped with sensors for water temperature, specific conductance, dissolved oxygen, pH, and turbidity (YSI Incorporated, 2012b). The YSI EXO2 water-quality monitor began operation on November 13, 2015. Monitors were housed in a 4-inch diameter polyvinyl chloride (PVC) pipe and placed in a location representative of the stream cross section. Monitor readings were recorded and satellite transmitted hourly.

Date model was developed: April 26, 2019

Model calibration data period: April 23, 2010, to May 2, 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 30 concomitant values of discretely collected TSS samples and continuously measured turbidity during April 23, 2010, through May 2, 2017. Discrete samples were collected over a range of streamflows and turbidity conditions. 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.

Total Suspended Solids

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 2 to 7 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 were analyzed for TSS by the Wichita Municipal Water and Wastewater Laboratory in Wichita, Kans., according to standard methods (American Public Health Association and others, 1995).

Continuous Data

Turbidity was measured using a YSI model 6136 sensor installed during October 17, 2009, through November 12, 2015, and March 31, 2017, through June 7, 2017. Concomitant turbidity values were time interpolated. If the continuous data were not available (2 or more hours of turbidity values bracketing the sample collection time were missing) because of fouling, changes in equipment, or unsuitable site conditions, then the field monitor turbidity value measured during sampling was substituted. If no data were 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 TSS to turbidity 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 TSS 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.

Turbidity was selected as the best predictor of logarithm base 10 ($\log_{10}$) (TSS) based on residual plots, relatively high coefficient of determination (R^2), and relatively low model standard percentage error (MSPE).

Model Summary

Summary of final TSS regression analysis at USGS site 07144780:

TSS-based model:

$$\log_{10}(TSS) = 0.964 \times \log_{10}(TBY6136) + 0.26\ ,$$

where,

TSS = total suspended solids, in milligrams per liter, and
TBY6136 = turbidity, YSI model 6136, in formazin nephelometric units.

The use of turbidity as an explanatory variable is appropriate physically and statistically. Turbidity makes sense physically because suspended solids are composed of particles that scatter light in water. The relation between turbidity and suspended-sediment concentration (SSC) can vary given varying concentrations of organic suspended particles that increase turbidity but are not included in the SSC analysis.

The log-transformed model may be retransformed to 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; Duan, 1983). For this model, the calculated BCF is 1.08. The retransformed model, accounting for BCF, is as follows:

$$TSS = (TBY6136^{0.964} \times 10^{0.26}) \times 1.08$$

Model Statistics, Data, and Plots

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

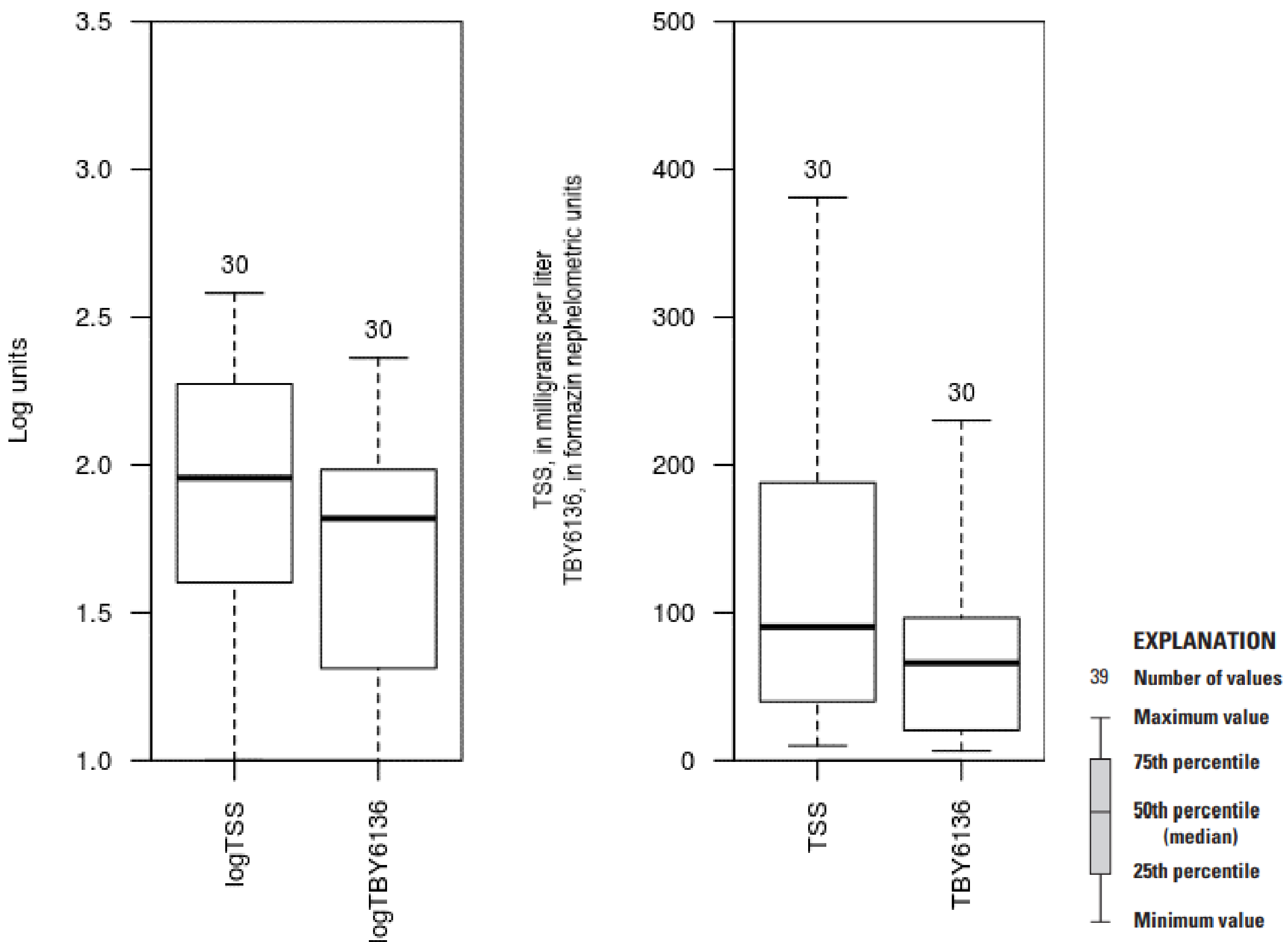
Model

log*TSS* = + 0.964 * log*TBY*6136 + 0.26

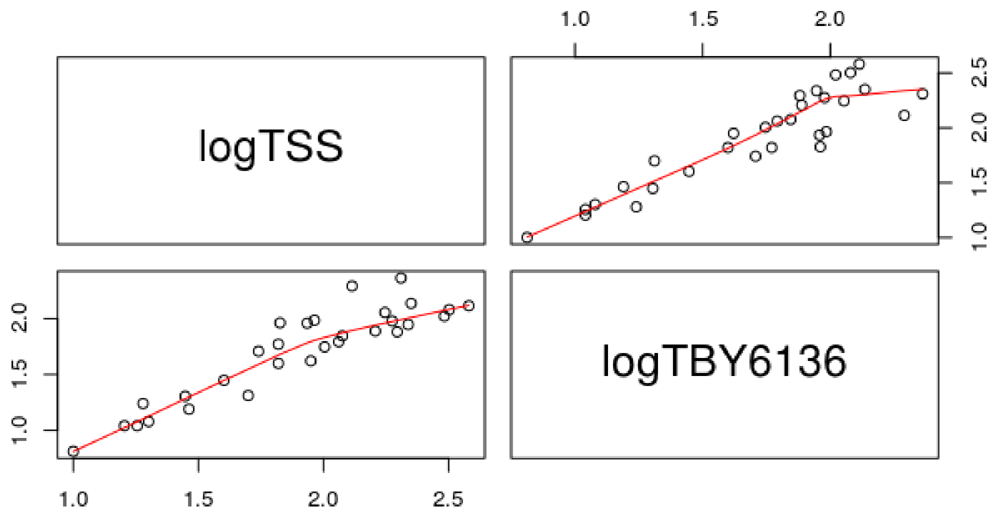
Variable Summary Statistics

	logTSS	TSS	logTBY6136	TBY6136
Minimum	1.00	10.0	0.813	6.5
1st Quartile	1.60	40.0	1.310	20.5
Median	1.96	90.5	1.820	66.0
Mean	1.90	120.0	1.710	72.2
3d Quartile	2.27	188.0	1.980	96.5
Maximum	2.58	381.0	2.360	230.0

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                                  30
Standard error (RMSE)                                0.175
Average Model standard percentage error (MSPE)        41.4
Coefficient of determination (R²)                    0.841
Adjusted Coefficient of Determination (Adj. R²)      0.835
Bias Correction Factor (BCF)                          1.08
```

Explanatory Variables

```
            Coefficients Standard Error t value Pr(>|t|)
(Intercept)        0.260          0.1390    1.87 7.20e-02
logTBY6136         0.964          0.0792   12.20 1.07e-12
```

Correlation Matrix

```
          Intercept E.vars
Intercept     1.000 -0.973
E.vars       -0.973  1.000
```

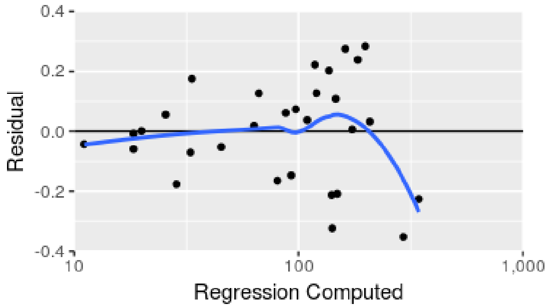
Outlier Test Criteria

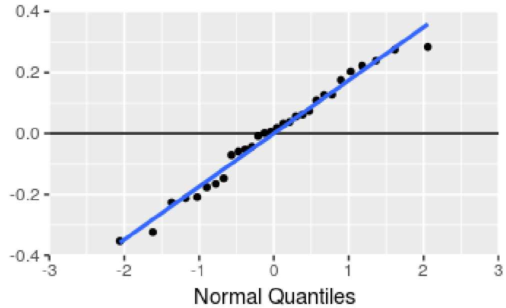
```
Leverage Cook's D   DFFITS
   0.200    0.193    0.516
```

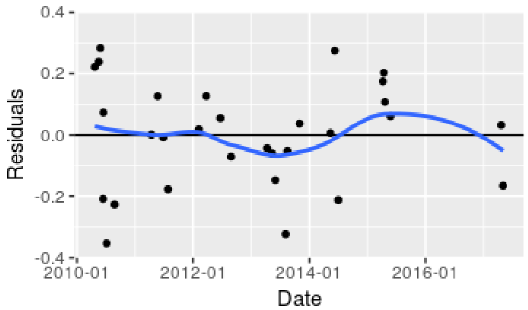
Flagged Observations

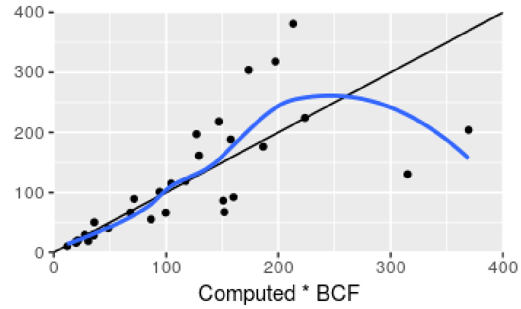
```
               logTSS Estimate Residual Standard Residual Studentized Residual Leverage Cook's D DFFITS
7/6/2010 10:30   2.11     2.47   -0.353             -2.13                -2.29    0.103    0.261 -0.775
8/25/2010 11:00  2.31     2.54   -0.226             -1.38                -1.40    0.121    0.132 -0.522
```

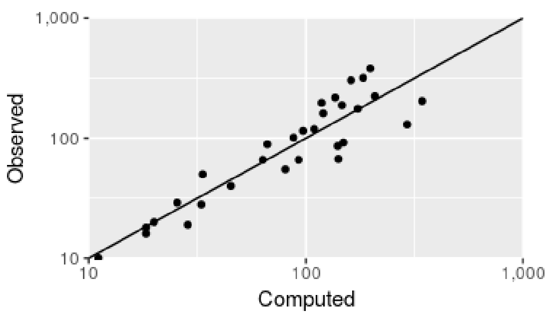
Statistical Plots

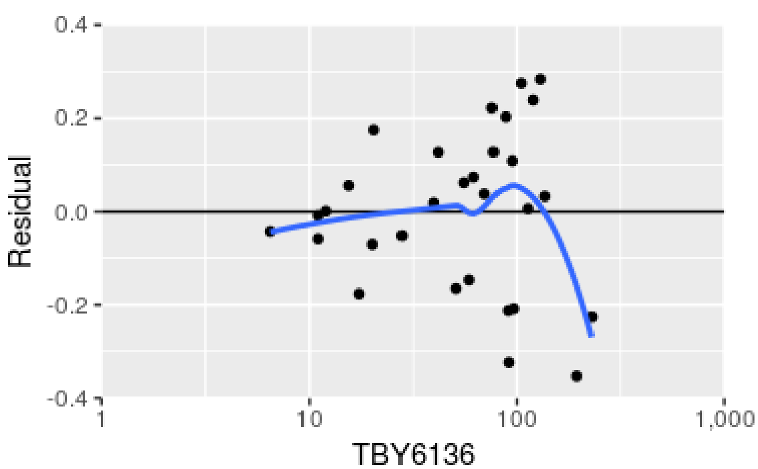


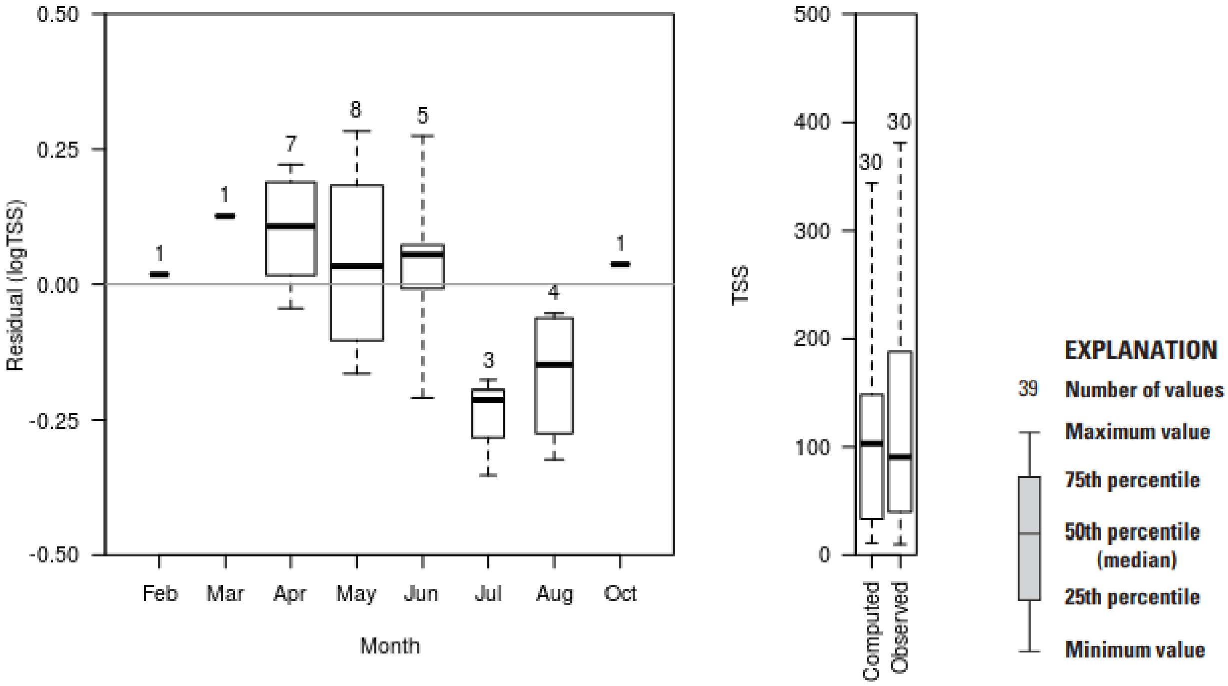




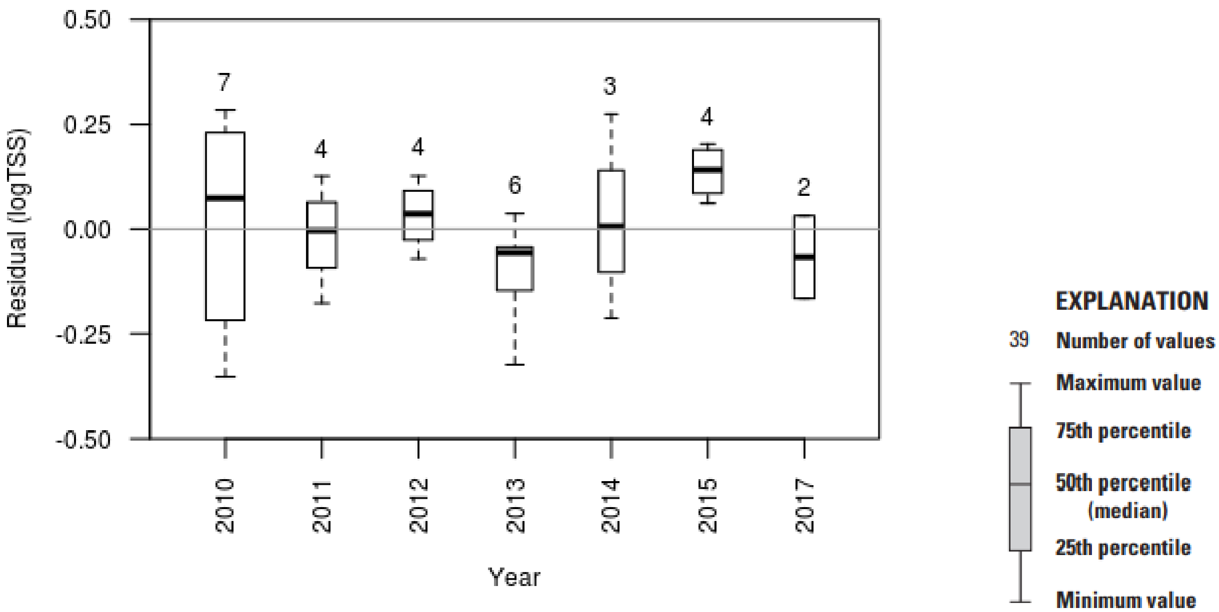






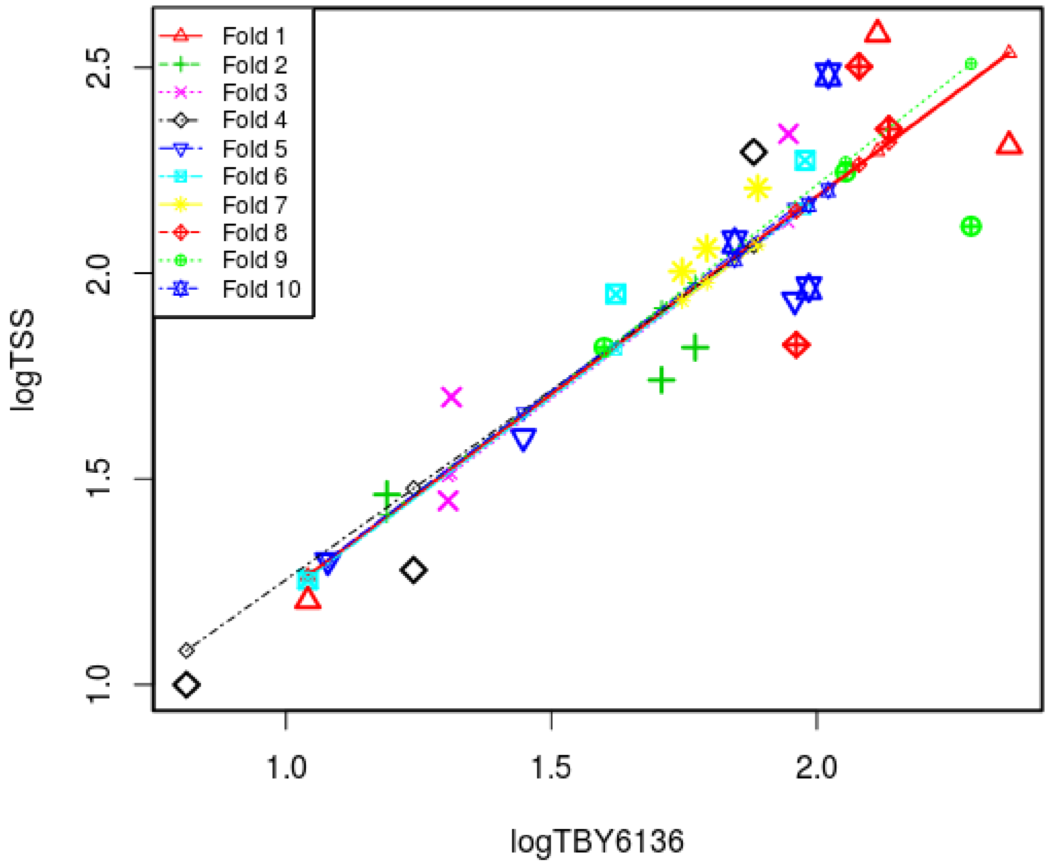


Residual (logTSS)
0.50
0.25
0.00
-0.25
-0.50
Feb
Mar
Apr
May
Jun
Jul
Aug
Oct
Month
1
1
7
8
5
3
4
1
TSS
500
400
300
200
100
0
30
30
Computed
Observed
EXPLANATION
39 Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value



Residual (logTSS)
0.50
0.25
0.00
-0.25
-0.50
2010
2011
2012
2013
2014
2015
2017
Year
7
4
4
6
3
4
2
EXPLANATION
39 Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value

Cross Validation



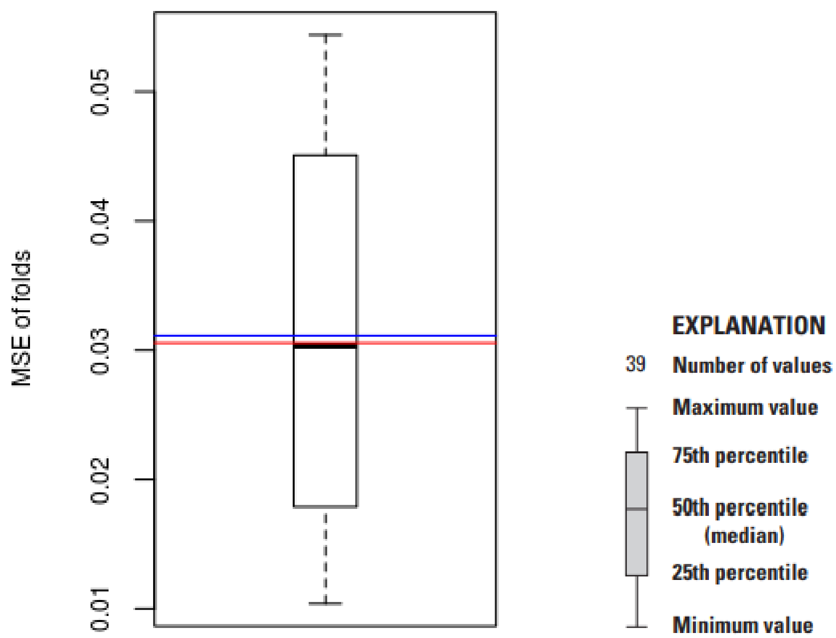

```
Fold – equal partition of the data (10 percent of the data)

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:  0.0104
                 Mean MSE of folds:  0.0311
               Median MSE of folds:  0.0304
              Maximum MSE of folds:  0.0544
 (Mean MSE of folds) / (Model MSE):  1.0200
```




```
Red line - Model MSE

Blue line - Mean MSE of folds
```

Model-Calibration Data Set

0	Date	logTSS	logTBY6136	TSS	TBY6136	Computed logTSS	Computed TSS	Residual	Normal Quantiles	Censored Values
1	2010-04-23	2.29	1.88	197	76	2.07	127	0.222	1.18	--
2	2010-05-17	2.5	2.08	318	120	2.26	197	0.239	1.37	--
3	2010-05-27	2.58	2.11	381	130	2.3	213	0.284	2.06	--
4	2010-06-14	1.96	1.98	92	96.5	2.17	160	-0.209	-1.03	--
5	2010-06-16	2.06	1.79	115	62	1.99	104	0.0735	0.474	--
6	2010-07-06	2.11	2.29	130	195	2.47	315	-0.353	-2.06	--
7	2010-08-25	2.31	2.36	204	230	2.54	369	-0.226	-1.37	--
8	2011-04-13	1.3	1.08	20	12	1.3	21.5	0.00118	-0.125	--
9	2011-05-23	1.95	1.62	89	41.8	1.82	71.5	0.127	0.669	--
10	2011-06-28	1.26	1.04	18	11	1.26	19.7	-0.00816	-0.209	--
11	2011-07-27	1.28	1.24	19	17.4	1.46	30.7	-0.177	-0.895	--
12	2012-02-06	1.82	1.6	66	39.8	1.8	68	0.0184	0.0415	--
13	2012-03-23	2.21	1.89	161	77.3	2.08	129	0.127	0.777	--
14	2012-06-20	1.46	1.19	29	15.5	1.41	27.5	0.0554	0.295	--
15	2012-08-27	1.45	1.31	28	20.2	1.52	35.4	-0.0707	-0.569	--
16	2013-04-11	1	0.813	10	6.5	1.04	11.9	-0.0432	-0.295	--
17	2013-05-10	1.2	1.04	16	11	1.26	19.7	-0.0593	-0.474	--
18	2013-05-31	1.82	1.77	66	59	1.97	99.6	-0.147	-0.669	--
19	2013-08-05	1.83	1.96	67	91.4	2.15	152	-0.324	-1.62	--
20	2013-08-16	1.6	1.45	40	28	1.65	48.5	-0.0524	-0.383	--
21	2013-10-31	2.08	1.85	119	70	2.04	117	0.0375	0.209	--
22	2014-05-13	2.25	2.05	176	113	2.24	187	0.0063	-0.0415	--
23	2014-06-10	2.48	2.02	304	105	2.21	174	0.275	1.62	--
24	2014-07-02	1.93	1.96	86	90.8	2.15	151	-0.212	-1.18	--
25	2015-04-08	1.7	1.31	50	20.5	1.52	35.9	0.175	0.895	--
26	2015-04-14	2.34	1.95	218	88.3	2.14	147	0.203	1.03	--
27	2015-04-21	2.27	1.98	188	95	2.17	158	0.108	0.569	--

```
 28 2015-05-26      2        1.75 101    55.8      1.94       94.3   0.0616      0.383        --
 29 2017-04-20   2.35        2.14 224     137      2.32        224   0.0324      0.125        --
 30 2017-05-02   1.74        1.71  55      51      1.91       86.5   -0.165     -0.777        --
```

Definitions

```
TSS: total suspended solids, in milligrams per liter (00530)
TBY6136: turbidity, YSI model 6136, in formazin nephelometric units (63680)
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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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