

Appendix 1.21. Model Archive Summary for Total Phosphorus Concentration at U.S. Geological Survey site 07143672; Little Arkansas River at Highway 50 near Halstead, Kansas, during March 2017 through December 2019

This model archive summary summarizes the total phosphorus model developed to compute hourly or daily total phosphorus. Model development methods follow U.S. Geological Survey (USGS) guidance from Office of Surface Water/Office of Water Quality Technical Memoranda and USGS Techniques and Methods, book 3, chap. C4 (Rasmussen and others, 2009).

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Site and Model Information

Site Number: 07143672

Site Name: Little Arkansas River at Highway 50 near Halstead, Kansas

Location: Latitude 38°01'43", longitude 97°32'25" referenced to North American Datum of 1927, in NW 1/4 NE 1/4 NE 1/4 sec.28, T.23 S., R.2 W., Harvey County, Kansas, hydrologic unit 11030012.

Equipment: A Sutron Satlink II High Data Rate Collection Platform and a Design Analysis Water Log H350/355 nonsubmersible pressure transducer transfers real-time stage 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 33.396 feet. The orifice tube is enclosed in 1.25-inch steel conduit trenched into the ground down to the edge of water, where the orifice emerges from the bank and culminates in a 2-inch open-end orifice tethered to a steel fencepost near the left edge of water. Gage height was measured during May 1998 through December 2019. A YSI 6600 water-quality monitor equipped with water temperature, specific conductance, pH, dissolved oxygen, and turbidity (a YSI Model 6026 [December 1998 through December 2006] and YSI Model 6136 [July 2004 through December 2017]) sensors collected data during May 1998 through December 2017. A YSI EXO2 water-quality monitor equipped with water temperature, specific conductance, pH, dissolved oxygen, turbidity, and fluorescent dissolved organic matter sensors collected data during January 2017 through December 2019. A Hach Nitratex monitor collected nitrate data during February 2017 through December 2019.

Date model was developed: June 1, 2020

Model calibration data period: March 30, 2017 through December 10, 2019

Model Data

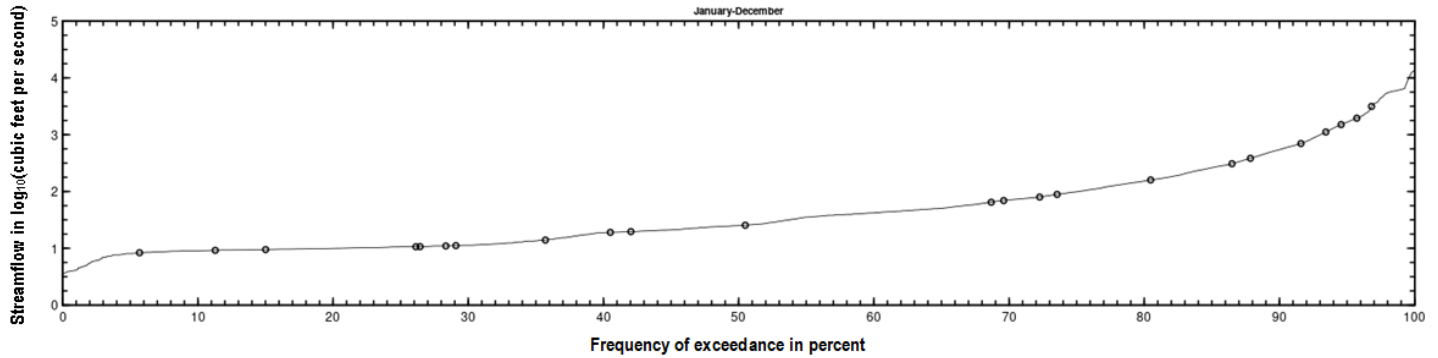
All data were collected using USGS protocols (U.S. Geological Survey, variously dated; Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010) and are stored in the National Water Information System (NWIS) database (U.S. Geological Survey, 2021). Explanatory variables were evaluated individually and in combination. Potential explanatory variables included streamflow, water temperature, specific conductance, pH, dissolved oxygen, YSI EXO2 turbidity, nitrate, and fluorescent dissolved organic matter. Seasonal components (sine and cosine variables) also were evaluated as explanatory variables.

The regression model is based on 23 concomitant values of discretely collected total phosphorus and continuously measured turbidity during March 2017 through December 2019. Discrete samples were collected over a range of streamflow and turbidity conditions. No samples had detections that were below laboratory detection limits. Summary statistics and the complete model-calibration dataset are provided below. Outliers and influential points were identified using studentized residuals, DFITS, Cook's D (Cook, 1977), and leverage. Outliers in previously published versions of this model (Christensen and others, 2003; Rasmussen and others, 2016) 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. One sample (collection date April 29, 2019) was not representative of the dataset and exceeded Cook's D and DFITS outlier criteria and was removed from the model dataset to avoid erroneous inflation of model-computed values at the upper range of surrogate relations. Removing data points based only on outlier criteria may only overestimate the certainty of the model.

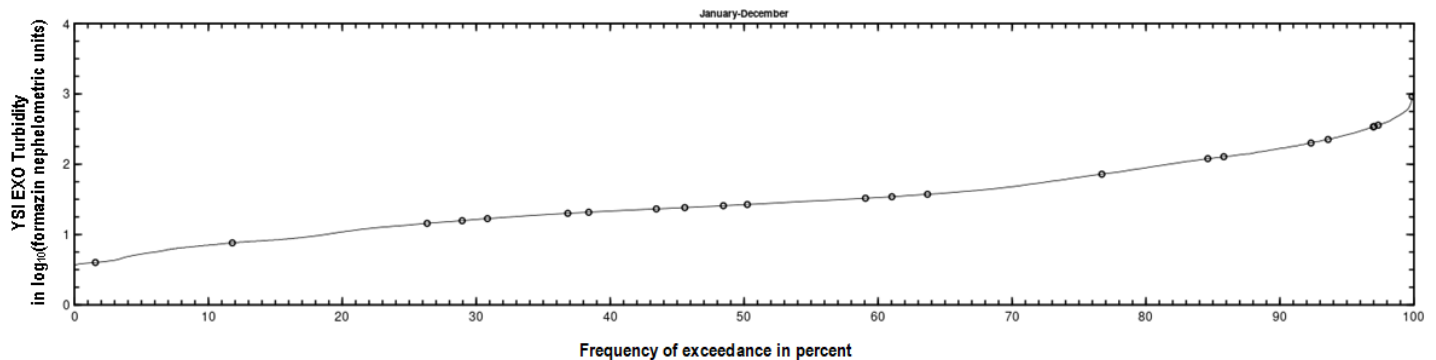
Total Phosphorus

Discrete samples were collected from the downstream side of the bridge or instream within 50 feet of the bridge using equal-width-increment, multi-vertical, single vertical or grab-dip methods following U.S. Geological Survey (variously dated) and Rasmussen and others (2014). Discrete samples were collected on a semifixed to event-based schedule ranging from 6 to 9 samples per year with a FISP US 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 total phosphorus by the USGS National Water Quality Laboratory according to standard methods (American Public Health Association and others, 1995).

Total Phosphorus Samples Plotted on Streamflow Duration Curve



Total Phosphorus Samples Plotted on YSI EXO Turbidity Duration Curve



Continuous Data

Concomitant turbidity values were time interpolated. If no concomitant continuous data were available within 2 hours of sample collection, the sample was not included in the dataset.

Model Development

Ordinary least squares regression analysis was done using R (version 4.0.0) programming language (R Core Team, 2020) to relate discretely collected total phosphorus 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-computed total phosphorus 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) were ultimately selected.

Turbidity was selected as the best predictor of total phosphorus based on residual plots, high coefficient of determination (R^2), and low model standard percentage error (MSPE). Turbidity was positively correlated with total phosphorus because turbidity measures light scattered by particulates in water.

Model Summary

Summary of final total phosphorus regression analysis at USGS site number 07143672:

Total phosphorus-based model:

$$\log_{10}(TP) = 0.378 \times \log_{10}(TBY) - 0.901$$

where,

\log_{10} = logarithm base 10;

TP = total phosphorus, in milligrams per liter (mg/L); and

TBY = turbidity, in formazin nephelometric units (FNU)

The log-transformed model may be retransformed to original units so that TP 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 1.02. The retransformed model, accounting for BCF is:

$$TP = 0.1281 \times TBY^{0.378}$$

Model Statistics, Data, and Plots

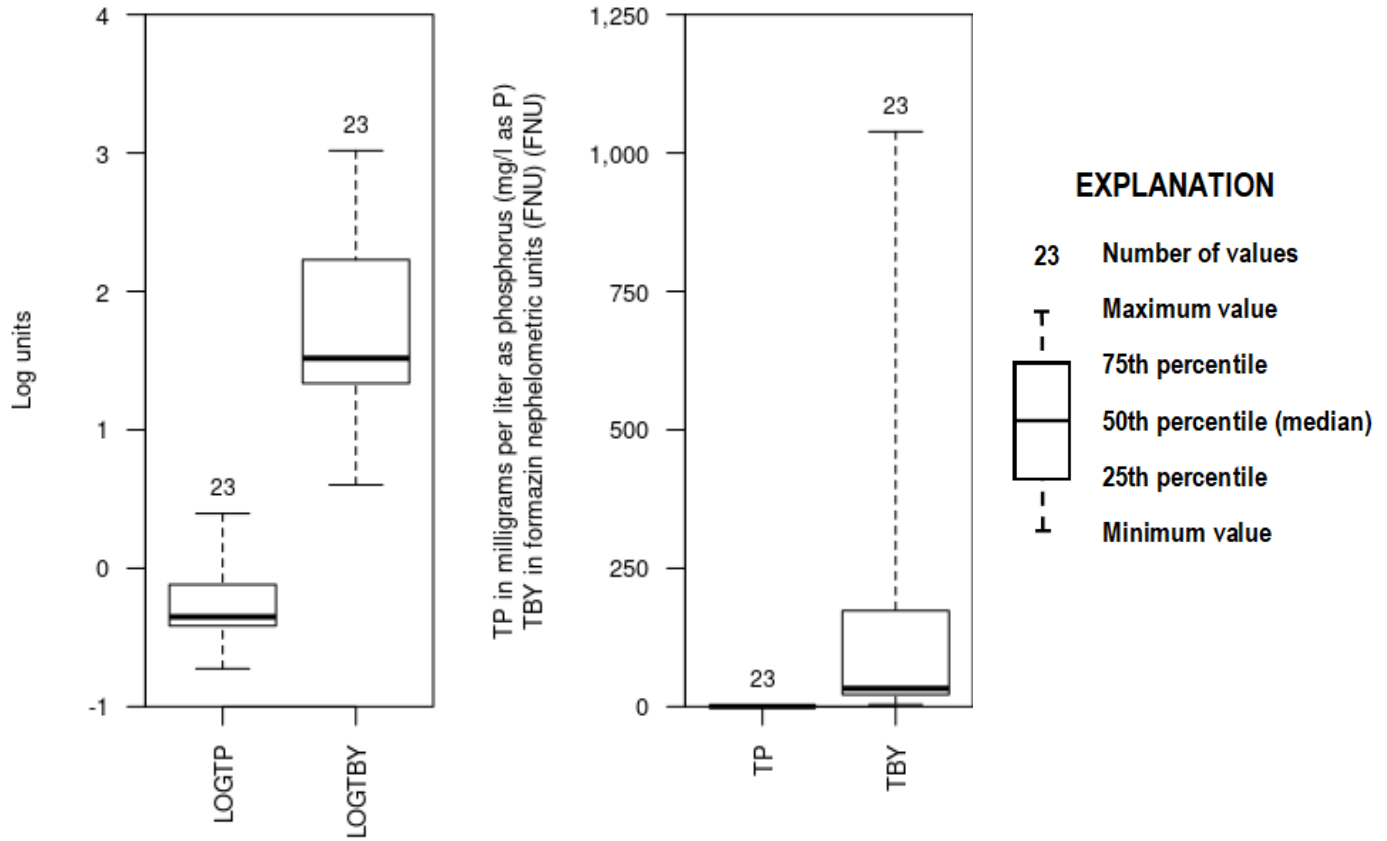
Model

$$\text{LOGTP} = + 0.378 * \text{LOGTBY} - 0.901$$

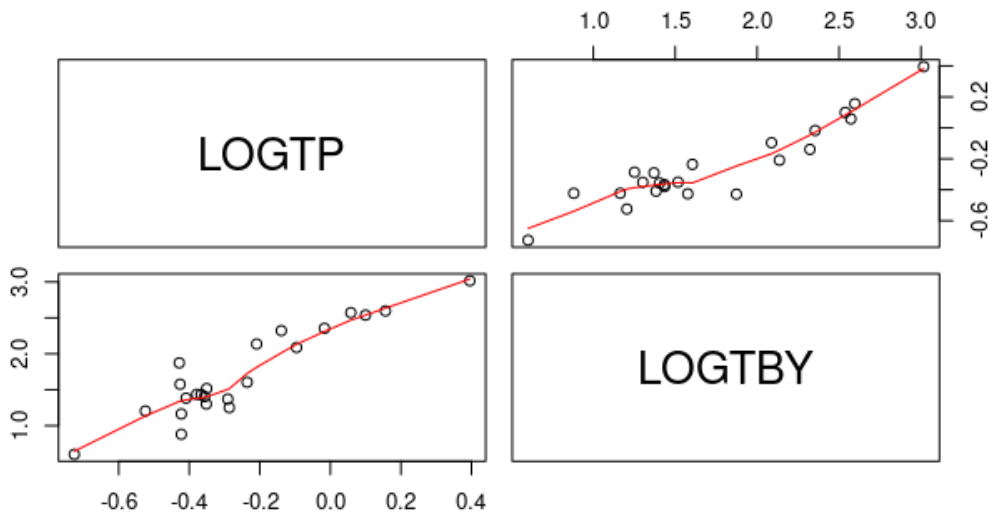
Variable Summary Statistics

	LOGTP	TP	LOGTBY	TBY
Minimum	-0.7260	0.188	0.602	4.0
1st Quartile	-0.4230	0.378	1.300	20.0
Median	-0.3510	0.446	1.520	32.9
Mean	-0.2490	0.678	1.720	141.0
3rd Quartile	-0.0958	0.802	2.320	210.0
Maximum	0.3960	2.490	3.020	1040.0

Box Plots



Exploratory Plots



Basic Model Statistics

Number of Observations	23
Standard error (RMSE)	0.0971
Average Model standard percentage error (MSPE)	22.6
Coefficient of determination (R^2)	0.859
Adjusted Coefficient of Determination (Adj. R^2)	0.852
Bias Correction Factor (BCF)	1.02

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-0.901	0.0611	-14.7	1.50e-12
LOGTBY	0.378	0.0334	11.3	2.15e-10

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.943
E.vars	-0.943	1.000

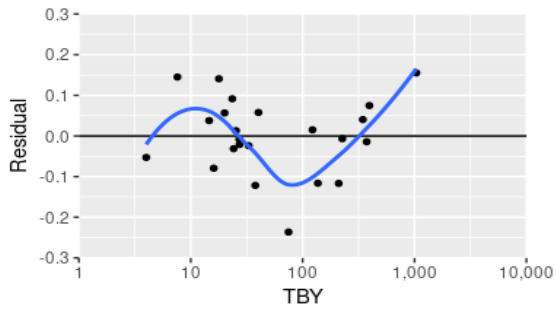
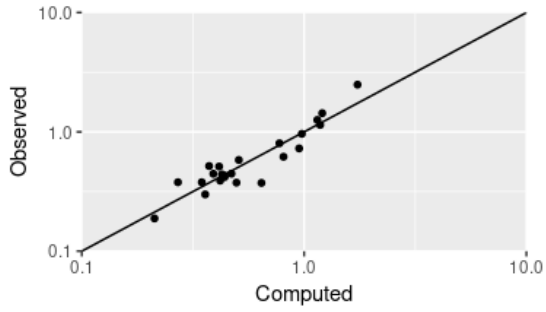
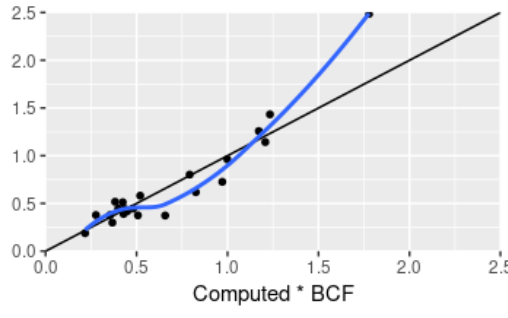
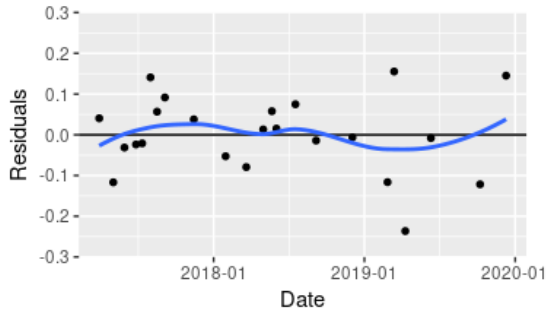
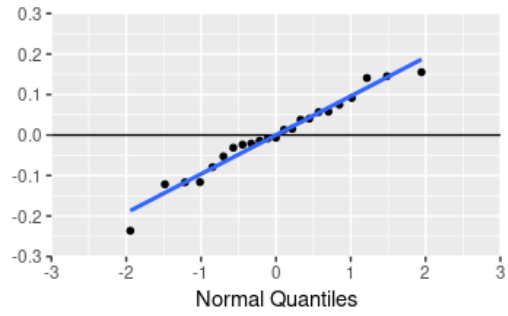
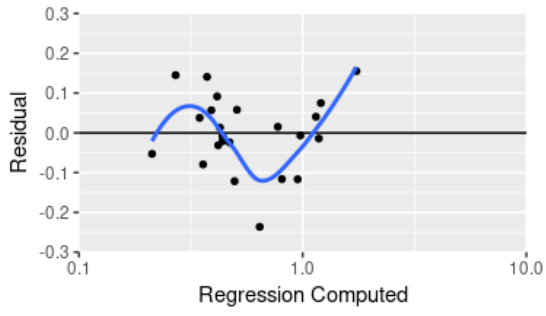
Outlier Test Criteria

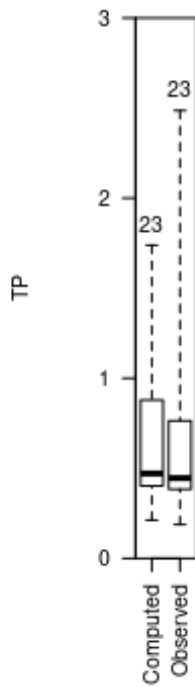
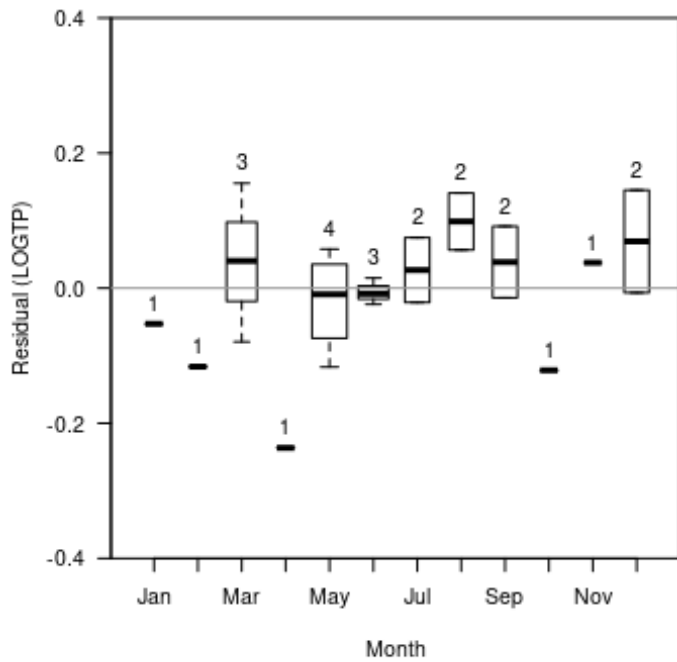
Leverage	Cook's D	DFFITS
0.261	0.193	0.590

Flagged Observations

datetime	LOGTP	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
3/14/2019 10:20	0.396	0.24	0.155	1.84	1.95	0.242	0.537	1.1
4/10/2019 12:00	-0.428	-0.192	-0.236	-2.49	-2.9	0.0462	0.15	-0.637
12/10/2019 11:30	-0.423	-0.568	0.145	1.6	1.67	0.128	0.187	0.637

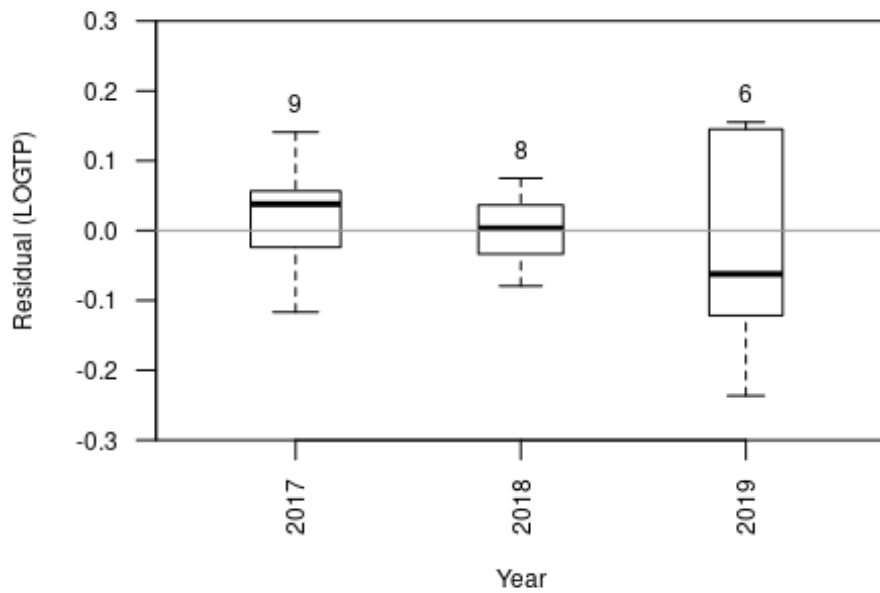
Statistical Plots





EXPLANATION

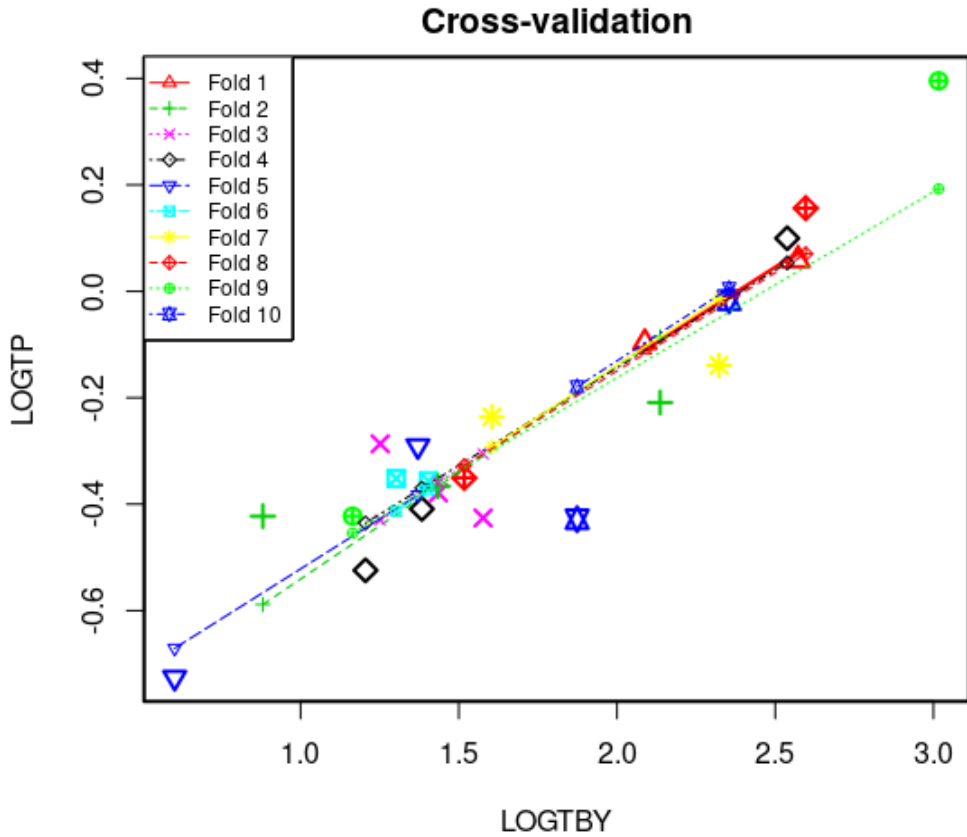
- 23 Number of values
- T Maximum value
- 75th percentile
- 50th percentile (median)
- 25th percentile
- Minimum value



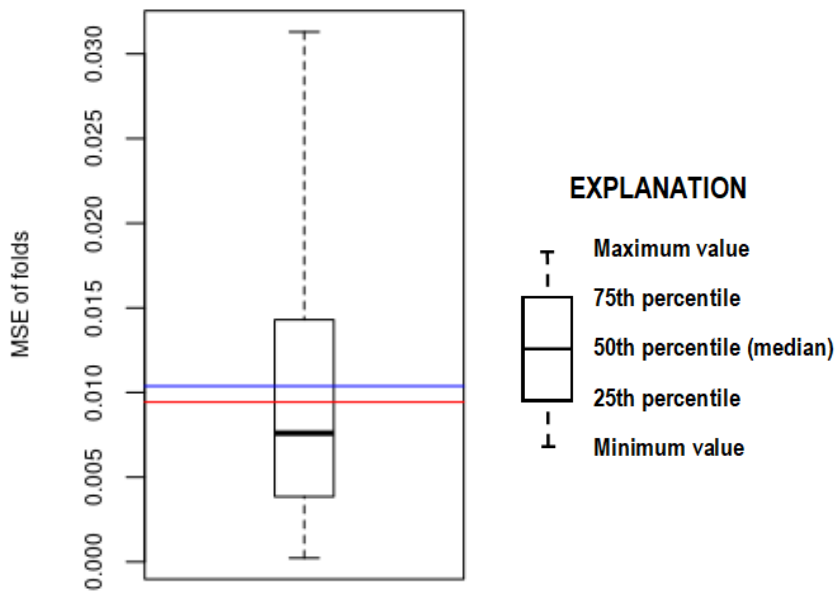
EXPLANATION

- 9 Number of values
- T Maximum value
- 75th percentile
- 50th percentile (median)
- 25th percentile
- Minimum value

Cross Validation



Minimum MSE of folds: 0.000221
 Mean MSE of folds: 0.010400
 Median MSE of folds: 0.007600
 Maximum MSE of folds: 0.031300
 (Mean MSE of folds) / (Model MSE): 1.100000



Red line - Model MSE
 Blue line - Mean MSE of folds

Model-Calibration Dataset

	Date	LOGTP	LOGTBY	TP	TBY	Computed LOGTP	Computed TP	Residual	Normal Quantiles
1	3/30/2017	0.0997	2.54	1.26	345	0.0592	1.17	0.0404	0.447
2	5/3/2017	-0.139	2.32	0.726	210	-0.0223	0.971	-0.117	-1.22
3	5/30/2017	-0.409	1.38	0.39	24.2	-0.378	0.429	-0.0314	-0.57
4	6/27/2017	-0.351	1.52	0.446	32.9	-0.327	0.482	-0.0238	-0.447
5	7/12/2017	-0.379	1.44	0.418	27.3	-0.358	0.449	-0.0211	-0.33
6	8/1/2017	-0.287	1.25	0.517	17.8	-0.427	0.382	0.141	1.22
7	8/17/2017	-0.352	1.3	0.445	20	-0.408	0.399	0.0566	0.57
8	9/5/2017	-0.291	1.37	0.512	23.5	-0.382	0.424	0.0915	1.01
9	11/14/2017	-0.423	1.16	0.378	14.6	-0.46	0.354	0.0378	0.33
10	1/30/2018	-0.726	0.602	0.188	4	-0.673	0.217	-0.0528	-0.702
11	3/21/2018	-0.524	1.21	0.299	16	-0.445	0.367	-0.0794	-0.848
12	5/1/2018	-0.357	1.4	0.44	25.4	-0.37	0.437	0.013	0.108
13	5/22/2018	-0.236	1.6	0.581	40.3	-0.294	0.52	0.0578	0.702
14	6/2/2018	-0.0958	2.09	0.802	122	-0.111	0.792	0.0151	0.218
15	7/18/2018	0.156	2.6	1.43	395	0.0814	1.23	0.0749	0.848
16	9/6/2018	0.058	2.57	1.14	373	0.0722	1.21	-0.0142	-0.218
17	12/3/2018	-0.0168	2.35	0.962	226	-0.0102	0.999	-0.00667	0
18	2/26/2019	-0.209	2.14	0.618	137	-0.0927	0.826	-0.116	-1.01
19	3/14/2019	0.396	3.02	2.49	1040	0.24	1.78	0.155	1.95
20	4/10/2019	-0.428	1.87	0.373	74.8	-0.192	0.657	-0.236	-1.95
21	6/11/2019	-0.367	1.43	0.43	27.2	-0.358	0.448	-0.00812	-0.108
22	10/8/2019	-0.426	1.58	0.375	37.7	-0.304	0.507	-0.122	-1.48
23	12/10/2019	-0.423	0.881	0.378	7.6	-0.568	0.277	0.145	1.48

Definitions

TP: Phosphorus in mg/L as P (00665)

TBY: Turbidity in FNU (63680)

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