Appendix 12. Model Archive Summary for Orthophosphate at U.S. Geological Survey Site 07144780, North Fork Ninnescah River above Cheney Reservoir, Kansas, during January 1, 1999, through December 31, 2019

This model archive summary summarizes the orthophosphate (OP) model developed to compute hourly or daily OP from January 1, 1999, through December 31, 2019. This model is used concomitantly with other models during this period to calculate concentrations when other explanatory variables are not available for the purposes of load and concentration model calculations. 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), and other standard USGS methods (Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010).

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 Sutron Satlink 2 High Data Rate Collection Platform and a Design Analysis Water Log H350/355 nonsubmersible pressure transducer transfers real-time stage, precipitation, 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 21.804 feet. The orifice is enclosed in 1 1/4-inch pipe, which runs from the gage house, under the bridge, and along an I-beam where it is attached to the concrete pier closest to the left edge of water.

Date model was developed: April 26, 2019

Model calibration data period: January 26, 1999, to September 28, 2017

Model Data

All data were collected using U.S. Geological Survey (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 nine concomitant values of discretely collected OP samples and continuously measured streamflow during January 26, 1999, through September 28, 2017. Discrete samples were collected over a range of streamflows. A total of 34 samples were below the minimum reporting level (less than [<] 0.01 milligram per liter [mg/L], <0.02 mg/L, <0.04 mg/L); therefore, a Tobit regression model was developed to compute estimates of OP using the absolute maximum likelihood estimation approach (Hald, 1949; Cohen, 1950; Tobin, 1958; Helsel and others, 2020). Summary statistics and the complete model-calibration data are provided below. Potential outliers were identified using the methods described in Rasmussen and others (2009). Additionally, outlier test criteria, including leverage and Cook's distance (Cook's D), were used to estimate potential outlier influence on the final Tobit regression model (Cook, 1977). None of the samples in this dataset were deemed outliers or removed from the model calibration dataset.

Orthophosphate

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 the 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 1 to 16 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 sampling location. Samples are analyzed for OP by the Wichita Municipal Water and Wastewater Laboratory in Wichita, Kans., according to standard methods (American Public Health Association and others, 1995).

Continuous Data

The streamflow data used in this analysis were measured using a nonsubmersible pressure transducer from January 1, 1991, through December 31, 2019. The surrogate data used were time interpolated values from the continuous time series. If the continuous data were not available, the sample was not included in the dataset.

Model Development

Stepwise regression analysis was done using R programming language (R Core Team, 2019) to relate discretely collected OP to streamflow 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 OP were examined for homoscedasticity (departures from zero did not change substantially over the range of model calculated values).

A total of 34.3 percent of the model-calibration dataset consisted of censored results (less than minimum reporting level). Tobit regression models were developed using absolute maximum likelihood estimation methods using the *smwrQW* (v.0.7.9) package in R programming language (R Core Team, 2019).

Streamflow was selected as a good predictor of OP based on residual plots, a higher pseudocoefficient of determination (pseudo-R^2), and relatively low estimated standard residual error (RSE). This model was developed with the sole purpose to fill in gaps of missing data of the primary model for concentration and load estimations.

Model Summary

Summary of final OP regression analysis at USGS site 07144780.

OP-based model:

$$\log_{10}(OP) = 0.8036 \times \log_{10}(Q) - 3.346,$$

where,

OP = orthophosphate, in milligrams per liter as phosphorus, and
Q = streamflow, in cubic feet per second.

The log-transformed model may be retransformed to original units so that OP 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 1.323. The retransformed model, accounting for BCF, is as follows:

$$OP = (Q^{0.8036} \times 10^{-3.346}) \times 1.323$$

Model Statistics and Data

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

Model

$\log_{10}(OP) = 0.8036 \times \log_{10}(Q) - 3.346$

Computation method: Absolute Maximum Likelihood Estimation (AMLE)

Explanatory Variables

```
Coefficients:
            Estimate Std. Error z-score p-value
```

```
(Intercept)  -3.3456     0.1621  -20.63       0
logQ          0.8036     0.0638   12.60       0
```

Basic Model Statistics

For a detailed definition and explanation of the terms used below, refer to Helsel and others (2020).

```
Estimated residual standard error (Unbiased) = 0.3488
Distribution: normal
Number of observations = 99, number censored = 34 (34.3 percent)

Log-likelihood (model) = -43.11
Log-likelihood (intercept only) = -105.1
  Chi-square = 124
  degrees of freedom = 1
  p-value = <0.0001

Computation method: AMLE

Pseudo-R-squared: 0.6984

  Akaike Information Criterion: 92.23
  Bayesian Information Criterion: 100
```

Outlier Test Criteria

```
leverage   cooksD
  0.0303   0.6981
```

Flagged Observations

```
    Observations exceeding at least one test criterion
   logOrthoP  ycen    yhat    resids leverage    cooksD
18   -0.8697 FALSE -0.4699 -0.399739  0.04679 3.382e-02
23   -2.0000  TRUE -2.5672 -0.039113  0.05402 3.796e-04
24   -2.0000  TRUE -2.3088 -0.115788  0.03575 2.119e-03
25   -0.7447 FALSE -0.5893 -0.155456  0.03857 4.144e-03
26   -0.7447 FALSE -0.7248 -0.019892  0.03049 5.276e-05
27   -2.0000  TRUE -2.3368 -0.104827  0.03749 1.828e-03
33   -0.8239 FALSE -0.7013 -0.122653  0.03180 2.097e-03
41   -0.7959 FALSE -0.5342 -0.261705  0.04224 1.296e-02
47   -2.0000  TRUE -2.4183 -0.076615  0.04289 1.130e-03
49   -2.0000  TRUE -2.2512 -0.140463  0.03234 2.801e-03
50   -2.0000  TRUE -2.2512 -0.140463  0.03234 2.801e-03
57   -0.6778 FALSE -0.4757 -0.202123  0.04637 8.562e-03
61   -0.7959 FALSE -0.5386 -0.257280  0.04193 1.243e-02
66   -0.8861 FALSE -0.6628 -0.223238  0.03402 7.467e-03
73   -0.6990 FALSE -0.3318 -0.367180  0.05761 3.595e-02
74   -0.7696 FALSE -0.6474 -0.122121  0.03494 2.299e-03
75   -0.7696 FALSE -0.1996 -0.569995  0.06928 1.068e-01
79   -1.6990  TRUE -2.3054 -0.032005  0.03554 1.609e-04
80   -1.6990  TRUE -2.7641 -0.001315  0.07122 5.868e-07
88   -0.7447 FALSE -0.5505 -0.194186  0.04112 6.932e-03
```

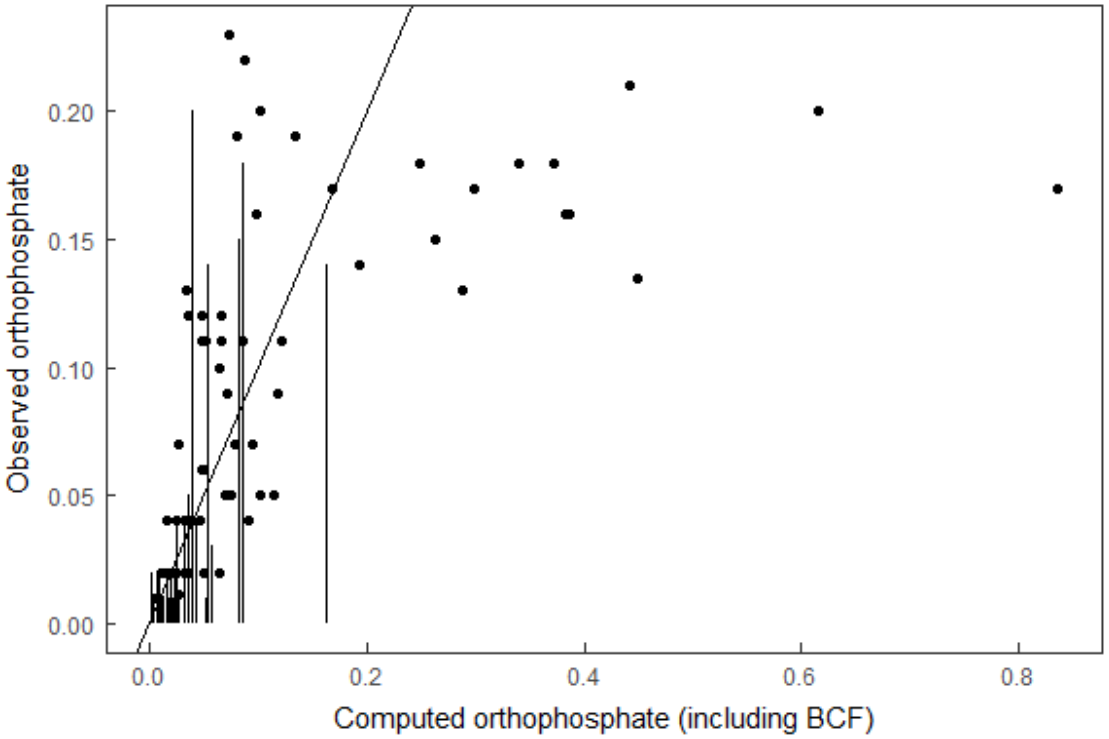
Bias correction factor

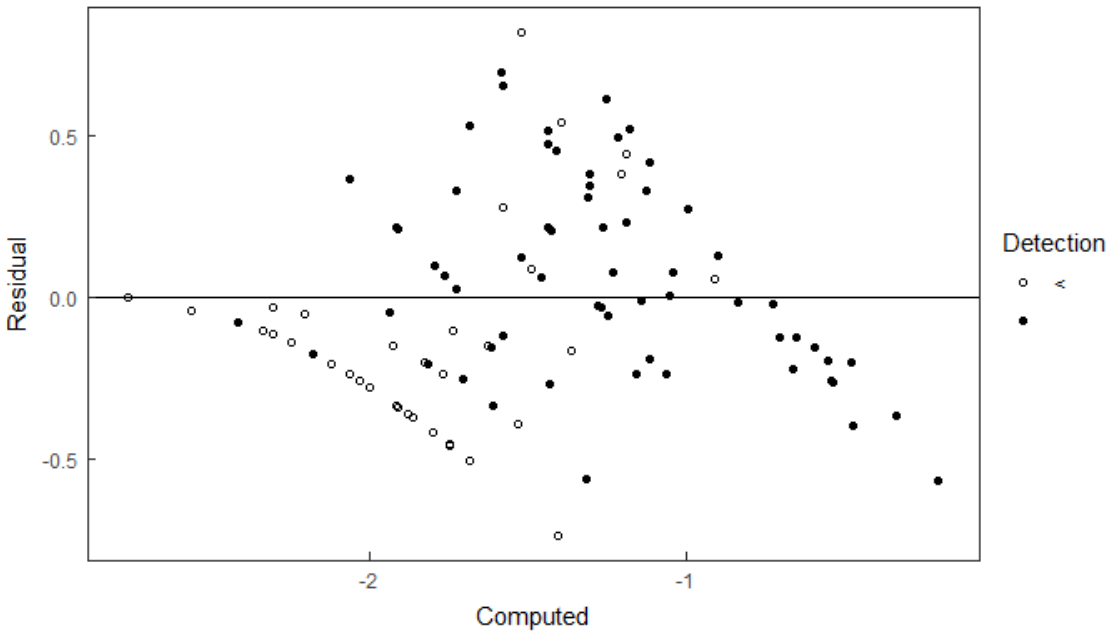
```
[1] 1.323394
```

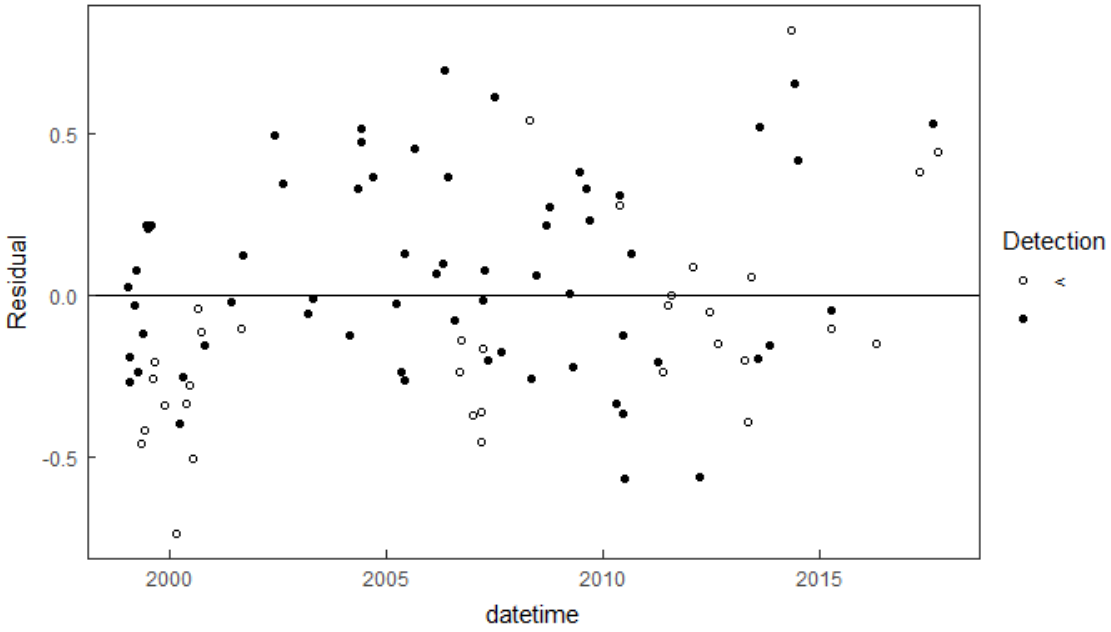
95% Confidence Intervals

```
                 2.5 %     97.5 %
(Intercept) -3.6633322 -3.0277723
logQ         0.6785882  0.9286889
```

Plots







Variable Summary Statistics

Independent Variable (xvar) - Specific Conductance

```
    Min.  1st Qu.   Median     Mean   3d Qu.      Max.
   5.291   78.989  223.226  654.116  512.975 8,216.570
```

Standard Deviation

```
[1] 1240.962
```

Dependent Variable (yvar) - Orthophosphate

```
    Min.  1st Qu.   Median     Mean     3d Qu.     Max.
   <0.01    <0.01     0.04    0.053      0.135     0.23
```

Standard Deviation

```
[1] 0.0939
```

Model-Calibration Data Set

	datetime	logOrthoP	logQ	OrthoP	Q	Computed_logOP	Computed_OP	residuals
1	1999-01-26 11:50:00	-1.7	2.017	0.02	104.00	-1.725	0.02494	0.02562
2	1999-01-31 14:25:00	-1.3	2.779	0.05	601.50	-1.112	0.10221	-0.18898
3	1999-02-03 10:45:00	-1.7	2.382	0.02	241.00	-1.431	0.04901	-0.26770
4	1999-03-17 11:40:00	-1.3	2.584	0.05	384.00	-1.269	0.07126	-0.03235
5	1999-04-06 13:55:00	-1.15	2.632	0.07	428.25	-1.231	0.07779	0.07572
6	1999-04-16 12:55:00	-1.3	2.843	0.05	696.50	-1.061	0.11499	-0.24016
7	1999-05-13 10:25:00	<-2	1.990	<0.01	97.75	-1.746	0.02373	-0.45747
8	1999-05-24 10:45:00	-1.7	2.199	0.02	158.00	-1.579	0.03491	-0.12034
9	1999-06-10 12:00:00	<-2	1.924	<0.01	84.00	-1.799	0.02101	-0.41753
10	1999-06-25 11:15:00	-1.22	2.375	0.06	237.25	-1.437	0.04840	0.21490
11	1999-07-02 10:15:00	-1.22	2.386	0.06	243.25	-1.428	0.04938	0.20618
12	1999-07-14 11:20:00	-1.7	1.788	0.02	61.33	-1.909	0.01632	0.20992
13	1999-07-29 09:55:00	-1.7	1.778	0.02	60.00	-1.917	0.01603	0.21759
14	1999-08-12 10:35:00	<-2	1.633	<0.01	43.00	-2.033	0.01227	-0.25774
15	1999-08-26 10:50:00	<-2	1.521	<0.01	33.17	-2.124	0.00996	-0.20476
16	1999-12-02 10:35:00	<-2	1.787	<0.01	61.25	-1.909	0.01630	-0.33845
17	2000-02-25 10:40:00	<-2	2.414	<0.01	259.33	-1.406	0.05198	-0.73726
18	2000-03-24 13:50:00	-0.87	3.578	0.135	3786.67	-0.470	0.44831	-0.39974
19	2000-04-27 10:45:00	-1.96	2.040	0.011	109.75	-1.706	0.02605	-0.25280
20	2000-05-25 10:20:00	<-2	1.778	<0.01	60.00	-1.917	0.01603	-0.33350
21	2000-06-21 12:00:00	<-2	1.672	<0.01	47.00	-2.002	0.01318	-0.27716
22	2000-07-26 11:50:00	<-2	2.068	<0.01	117.00	-1.684	0.02742	-0.50629
23	2000-08-29 11:00:00	<-2	0.968	<0.01	9.30	-2.567	0.00358	-0.03911
24	2000-09-28 10:30:00	<-2	1.290	<0.01	19.50	-2.309	0.00650	-0.11579
25	2000-10-26 10:50:00	-0.745	3.430	0.18	2690.00	-0.589	0.34059	-0.15546
26	2001-06-06 11:35:00	-0.745	3.261	0.18	1824.17	-0.725	0.24928	-0.01989
27	2001-09-04 11:05:00	<-2	1.255	<0.01	18.00	-2.337	0.00609	-0.10483
28	2001-09-19 10:25:00	-1.4	2.273	0.04	187.33	-1.519	0.04003	0.12125
29	2002-06-12 11:10:00	-0.721	2.650	0.19	446.33	-1.216	0.08042	0.49494
30	2002-08-14 11:35:00	-0.959	2.539	0.11	346.08	-1.305	0.06555	0.34636
31	2003-03-18 12:00:00	-1.3	2.615	0.05	412.00	-1.244	0.07541	-0.05691
32	2003-04-21 11:30:00	-1.15	2.741	0.07	551.00	-1.143	0.09525	-0.01224
33	2004-03-05 12:10:00	-0.824	3.290	0.15	1951.67	-0.701	0.26318	-0.12265
34	2004-05-14 10:35:00	-0.796	2.760	0.16	575.83	-1.127	0.09869	0.33139
35	2004-06-14 09:45:00	-0.921	2.377	0.12	238.00	-1.436	0.04852	0.51482
36	2004-06-14 09:50:00	-0.959	2.377	0.11	238.00	-1.436	0.04852	0.47704
37	2004-09-08 10:25:00	-1.7	1.591	0.02	39.00	-2.067	0.01134	0.36794
38	2005-03-24 10:15:00	-1.3	2.576	0.05	376.75	-1.275	0.07018	-0.02569
39	2005-05-16 11:40:00	-1.4	2.721	0.04	526.00	-1.159	0.09176	-0.23908
40	2005-06-10 10:55:00	-0.77	3.048	0.17	1116.67	-0.896	0.16804	0.12657
41	2005-06-13 09:25:00	-0.796	3.498	0.16	3150.00	-0.534	0.38666	-0.26170
42	2005-08-29 09:35:00	-0.959	2.407	0.11	255.17	-1.411	0.05131	0.45273
43	2006-03-02 09:50:00	-1.7	1.967	0.02	92.67	-1.765	0.02274	0.06589
44	2006-05-01 11:15:00	-1.7	1.928	0.02	84.75	-1.796	0.02116	0.09705
45	2006-05-12 10:30:00	-0.886	2.192	0.13	155.50	-1.584	0.03446	0.69814
46	2006-06-05 10:15:00	-1.7	1.591	0.02	39.00	-2.067	0.01134	0.36794
47	2006-07-31 10:30:00	<-2	1.154	<0.01	14.25	-2.418	0.00505	-0.07662
48	2006-09-07 10:50:00	<-2	1.591	<0.01	39.00	-2.067	0.01134	-0.23715
49	2006-09-21 10:00:00	<-2	1.362	<0.01	23.00	-2.251	0.00742	-0.14046
50	2006-09-21 10:05:00	<-2	1.362	<0.01	23.00	-2.251	0.00742	-0.14046
51	2007-01-09 10:30:00	<-2	1.845	<0.01	70.00	-1.863	0.01815	-0.37115
52	2007-03-14 10:20:00	<-2	1.824	<0.01	66.67	-1.880	0.01745	-0.35907
53	2007-03-22 10:00:00	<-2	1.987	<0.01	97.00	-1.749	0.02359	-0.45541
54	2007-03-26 10:40:00	-1.52	2.471	0.03	295.67	-1.360	0.05776	-0.16296
55	2007-03-31 12:30:00	-0.854	3.122	0.14	1325.00	-0.837	0.19280	-0.01745
56	2007-04-16 12:15:00	-0.959	2.871	0.11	743.50	-1.038	0.12119	0.07947

57	2007-05-07 10:30:00	-0.678	3.571	0.21	3725.00	-0.476	0.44243	-0.20212
58	2007-06-29 10:25:00	-0.638	2.603	0.23	401.00	-1.254	0.07379	0.61529
59	2007-09-04 11:25:00	<-2	1.447	<0.01	28.00	-2.183	0.00869	-0.17342
60	2008-04-24 11:40:00	-0.854	2.426	0.14	266.60	-1.396	0.05315	0.54216
61	2008-05-09 11:35:00	-0.796	3.493	0.16	3110.31	-0.539	0.38274	-0.25728
62	2008-06-19 09:45:00	-1.4	2.349	0.04	223.23	-1.458	0.04608	0.06007
63	2008-09-15 10:55:00	-1.05	2.591	0.09	389.55	-1.264	0.07209	0.21792
64	2008-10-16 10:10:00	-0.721	2.928	0.19	848.02	-0.992	0.13470	0.27093
65	2009-03-31 11:20:00	-1.05	2.853	0.09	713.40	-1.053	0.11723	0.00675
66	2009-04-27 12:15:00	-0.886	3.338	0.13	2178.89	-0.663	0.28754	-0.22324
67	2009-06-17 10:40:00	-0.921	2.543	0.12	349.14	-1.302	0.06602	0.38108
68	2009-08-20 10:50:00	-1.4	2.014	0.04	103.19	-1.727	0.02479	0.32936
69	2009-09-10 11:30:00	-0.959	2.682	0.11	481.29	-1.190	0.08544	0.23126
70	2010-04-23 10:00:00	<-1.7	2.159	<0.02	144.33	-1.610	0.03246	-0.33715
71	2010-05-17 16:40:00	-1.3	2.197	0.05	157.26	-1.580	0.03478	0.27925
72	2010-05-27 10:00:00	-1	2.533	0.1	341.23	-1.310	0.06481	0.30990
73	2010-06-14 11:30:00	-0.699	3.750	0.2	5625.32	-0.332	0.61618	-0.36718
74	2010-06-16 10:15:00	-0.77	3.357	0.17	2277.10	-0.648	0.29791	-0.12212
75	2010-07-06 10:30:00	-0.77	3.915	0.17	8216.57	-0.200	0.83548	-0.56999
76	2010-08-25 11:00:00	-0.77	3.047	0.17	1114.21	-0.897	0.16774	0.12734
77	2011-04-13 10:00:00	<-1.7	1.904	<0.02	80.15	-1.816	0.02023	-0.20861
78	2011-05-23 10:20:00	<-1.7	1.965	<0.02	92.25	-1.767	0.02265	-0.23681
79	2011-06-28 10:00:00	<-1.7	1.294	<0.02	19.69	-2.306	0.00655	-0.03200
80	2011-07-27 11:20:00	<-1.7	0.724	<0.02	5.29	-2.764	0.00228	-0.00132
81	2012-02-06 09:45:00	-1.4	2.313	0.04	205.38	-1.487	0.04310	0.08916
82	2012-03-23 10:15:00	<-1.7	2.529	<0.02	337.76	-1.314	0.06428	-0.56158
83	2012-06-20 09:15:00	<-1.7	1.414	<0.02	25.93	-2.209	0.00817	-0.05139
84	2012-08-27 09:30:00	<-1.7	1.762	<0.02	57.83	-1.930	0.01557	-0.15004
85	2013-04-11 10:10:00	<-1.7	1.891	<0.02	77.82	-1.826	0.01976	-0.20291
86	2013-05-10 10:00:00	<-1.7	2.258	<0.02	180.98	-1.531	0.03893	-0.39314
87	2013-05-31 10:00:00	-0.854	3.033	0.14	1078.66	-0.908	0.16342	0.05434
88	2013-08-05 10:05:00	-0.745	3.478	0.18	3005.69	-0.551	0.37236	-0.19419
89	2013-08-16 08:30:00	-0.658	2.699	0.22	499.95	-1.177	0.08809	0.51901
90	2013-10-31 10:00:00	<-1.4	2.153	<0.04	142.12	-1.616	0.03206	-0.15610
91	2014-05-13 10:00:00	-0.699	2.272	0.2	186.89	-1.520	0.03995	0.82105
92	2014-06-10 10:30:00	-0.921	2.199	0.12	157.96	-1.579	0.03490	0.65791
93	2014-07-02 09:10:00	-0.699	2.776	0.2	597.26	-1.115	0.10163	0.41555
94	2015-04-08 09:45:00	<-1.4	1.754	<0.04	56.75	-1.936	0.01533	-0.04512
95	2015-04-14 09:55:00	<-1.4	1.999	<0.04	99.67	-1.740	0.02411	-0.10304
96	2016-04-19 10:25:00	<-1.4	2.138	<0.04	137.55	-1.627	0.03123	-0.15068
97	2017-04-20 12:00:00	-0.824	2.666	0.15	463.31	-1.203	0.08287	0.37925
98	2017-08-11 11:00:00	-1.15	2.066	0.07	116.31	-1.686	0.02729	0.53065
99	2017-09-28 10:30:00	-0.745	2.686	0.18	484.79	-1.187	0.08594	0.44261

Definitions

OP: orthophosphate, in milligrams per liter as phosphorus (00671)
Q: streamflow, instantaneous, in cubic feet per second (00061)
Leverage: an outlier’s measure in the x-direction (Helsel and others, 2020).
p-value: the probability that the independent variable has no effect on the dependent variable (Helsel and others, 2020).
Pseudo-R-squared: pseudocoefficient of determination. An estimation of the proportion of variance in the response variable explained by the model (McKelvey and Zavoina, 1975).
z-score: the estimated coefficient divided by its associated standard error (Helsel and others, 2020).

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