Appendix 1.27. Model Archive Summary for Dissolved Arsenic Concentration at U.S. Geological Survey site 07143672; Little Arkansas River at Highway 50 near Halstead, Kansas, during June 1998 through December 2019

This model archive summary summarizes the dissolved arsenic model developed to compute hourly or daily dissolved arsenic. 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 Nitratax monitor collected nitrate data during February 2017 through December 2019.

Date model was developed: June 1, 2020

Model calibration data period: June 25, 1998 through December 10, 2019

Model Data

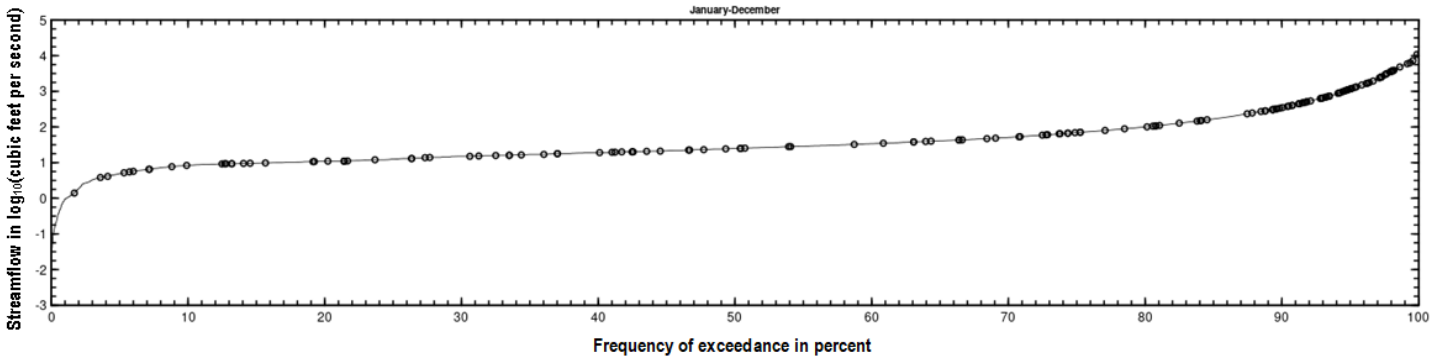
All data were collected using USGS protocols (U.S. Geological Survey, variously dated; Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010) and are stored in the National Water Information System (NWIS) database (U.S. Geological Survey, 2021). Explanatory variables were evaluated 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 163 concomitant values of discretely collected dissolved arsenic and continuously measured streamflow and water temperature during June 1998 through December 2019. Discrete samples were collected over a range of streamflow and water temperature conditions. Four samples had concentrations that were below the minimum reporting level (<1 to <2.9 µg/L) and and a Tobit regression model was developed to compute estimates of dissolved arsenic using the absolute maximum likelihood estimation approach (Hald, 1949; Cohen, 1950; Tobin, 1958; Helsel and others, 2020). Summary statistics and the complete model-calibration dataset are provided below. Outliers and influential points were identified using methods described in Rasmussen and others (2009), including leverage and Cook's distance (Cook's D; Cook, 1977) values. 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. All samples were retained in the dataset.

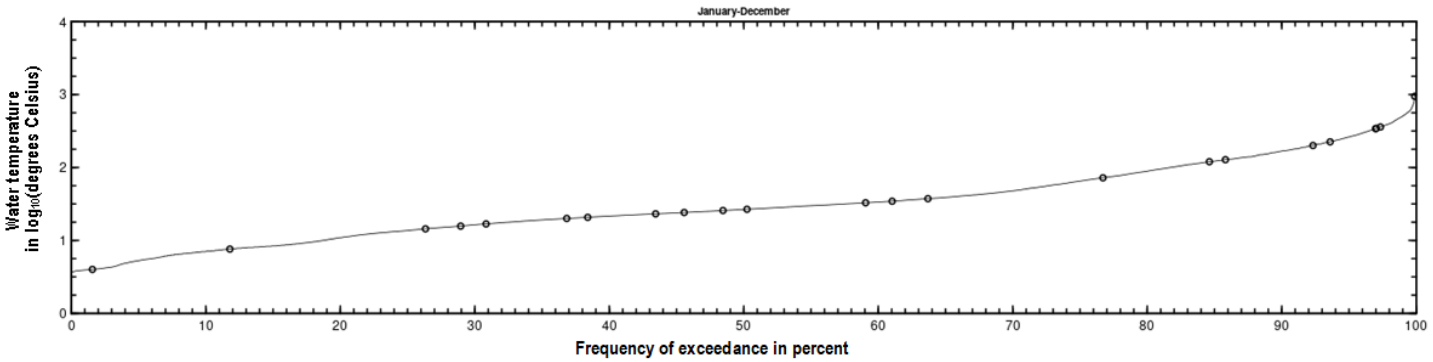
Dissolved Arsenic

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 3 to 12 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 dissolved arsenic by the Wichita Municipal Water and Wastewater Laboratory in Wichita, Kansas, or the USGS National Water Quality Laboratory according to standard methods (American Public Health Association and others, 1995).

Dissolved Arsenic Samples Plotted on Streamflow Duration Curve



Dissolved Arsenic Samples Plotted on Water Temperature Duration Curve



Continuous Data

Concomitant streamflow and water temperature 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

Tobit regression models were developed using absolute maximum likelihood estimation methods using the *smwrQW* (v.0.7.9) package in R (version 4.0.0) programming language (R Core Team, 2020).

Streamflow and water temperature were selected as the best predictors of dissolved arsenic based on residual plots, a larger pseudo coefficient of determination (pseudo R^2) and a low estimated residual standard error (*RSE*).

Model Summary

Summary of final dissolved arsenic regression analysis at USGS site number 07143672:

Dissolved arsenic-based model:

$$\log_{10}(AS) = -0.22085 \times \log_{10}(Q) + 0.01336 \times (\mathrm{T}) + 0.90451$$

where,

$\log_{10}$ = logarithm base 10;
AS = dissolved arsenic, in micrograms per liter (µg/L);
Q = streamflow, in cubic feet per second (ft3/s); and
T = water temperature, in degrees Celsius (˚C)

The log-transformed model may be retransformed to original units so that AS 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). Extracted model residuals used for BCF computation included censored residuals that were replaced by their expected values. For this model, the calculated BCF is 1.04. The retransformed model, accounting for BCF is:

$$\boldsymbol{AS = \frac{8.347 \times 10^{0.01336 \times T}}{Q^{0.22085}}}$$

Model Statistics, Data, and Plots

Model

LOGAS = - 0.22085 * LOGQ + 0.01336 * T + 0.90451

Variable Summary Statistics

	AS	Q	T
Minimum	<1	1.4	0.1
1st Quartile	3.09	19.84	11.85
Median	4.8	83.77	18.07
Mean	5.392	772.75	16.67
3rd Quartile	6.6	696	22.96
Maximum	16.2	10933.33	27.99

Explanatory Variables

```
Coefficients:
            Estimate Std. Error z-score p-value
(Intercept)  0.90451   0.029725   30.43       0
logQ        -0.22085   0.010040  -22.00       0
T            0.01336   0.001175   11.37       0
```

Basic Model Statistics

```
Estimated residual standard error (Unbiased) = 0.1163
Distribution: normal
Number of observations = 163, number censored = 4 (2.5 percent)

Loglik(model) = 113.2 Loglik(intercept only) = -14.11
  Chi-square = 254.5, degrees of freedom = 2, p-value = <0.0001

Computation method: AMLE

Pseudo R-squared: 0.7917

  AIC: -218.3
  BIC: -205.9


Variance inflation factors
logQ 1
   T 1
```

Outlier Test Criteria

```
leverage   cooksD
 0.03681  0.79201
```

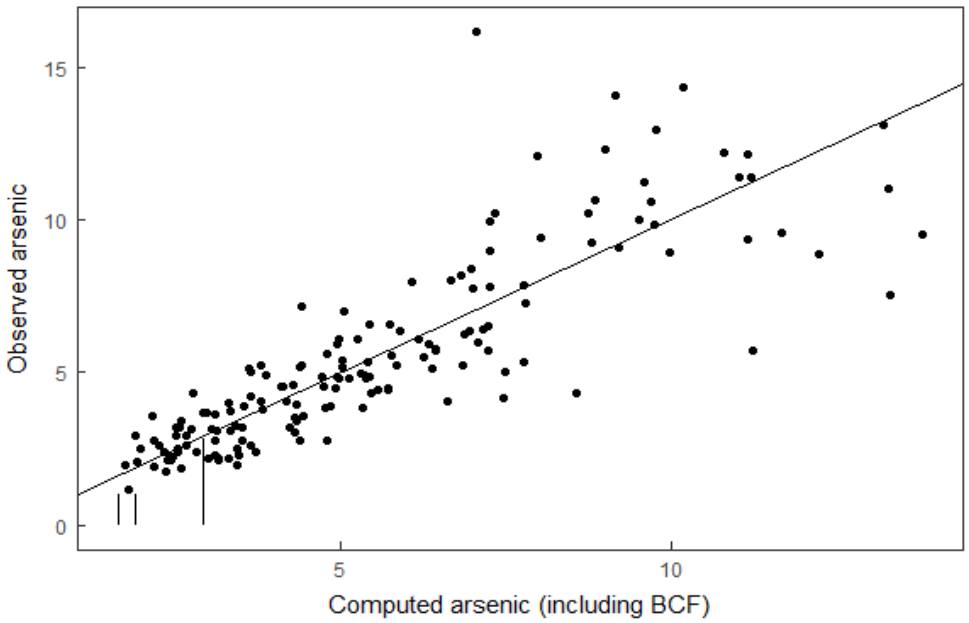
Flagged Observations

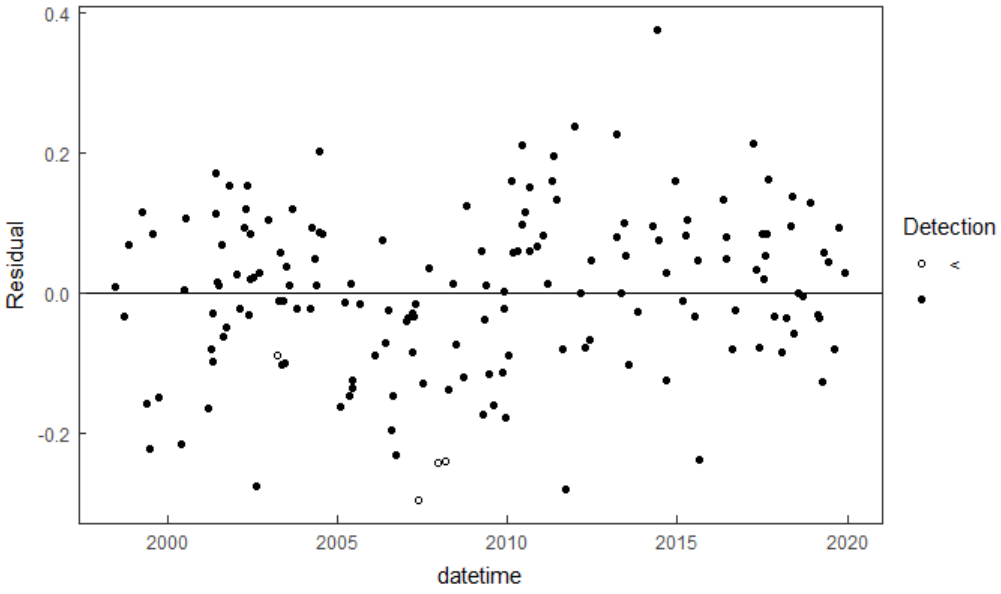
	logAS	ycen	yhat	resids	leverage	cooksD
67	0.7404	FALSE	0.7814	-0.04106	0.03815	0.001713
76	0	TRUE	0.1948	-0.24295	0.04412	0.07019
77	0	TRUE	0.1922	-0.2407	0.03853	0.059466

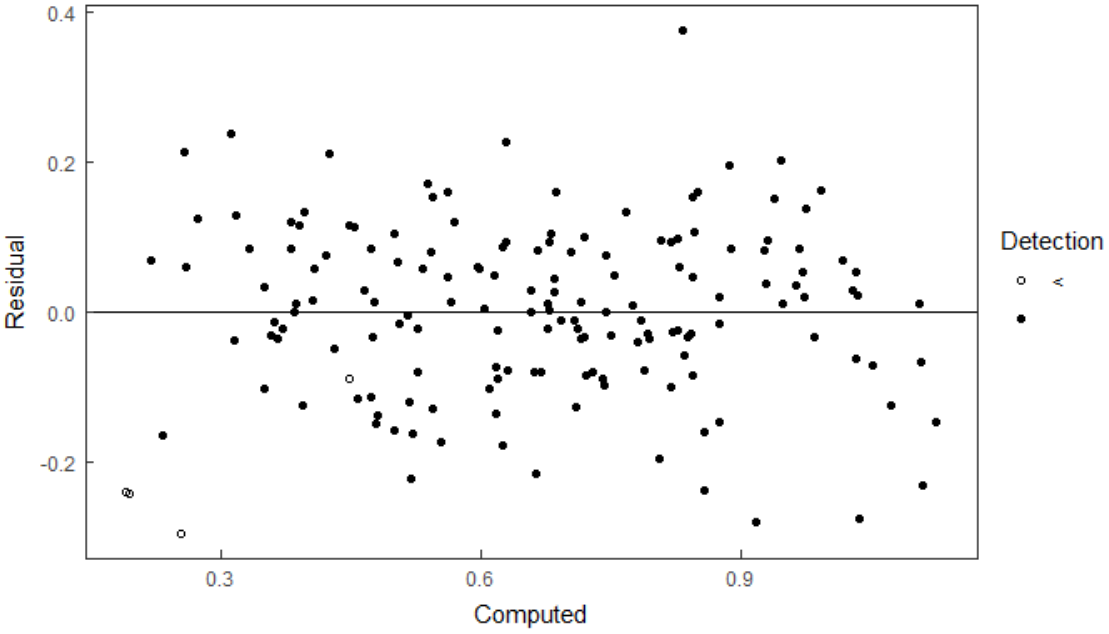
95% Confidence Intervals

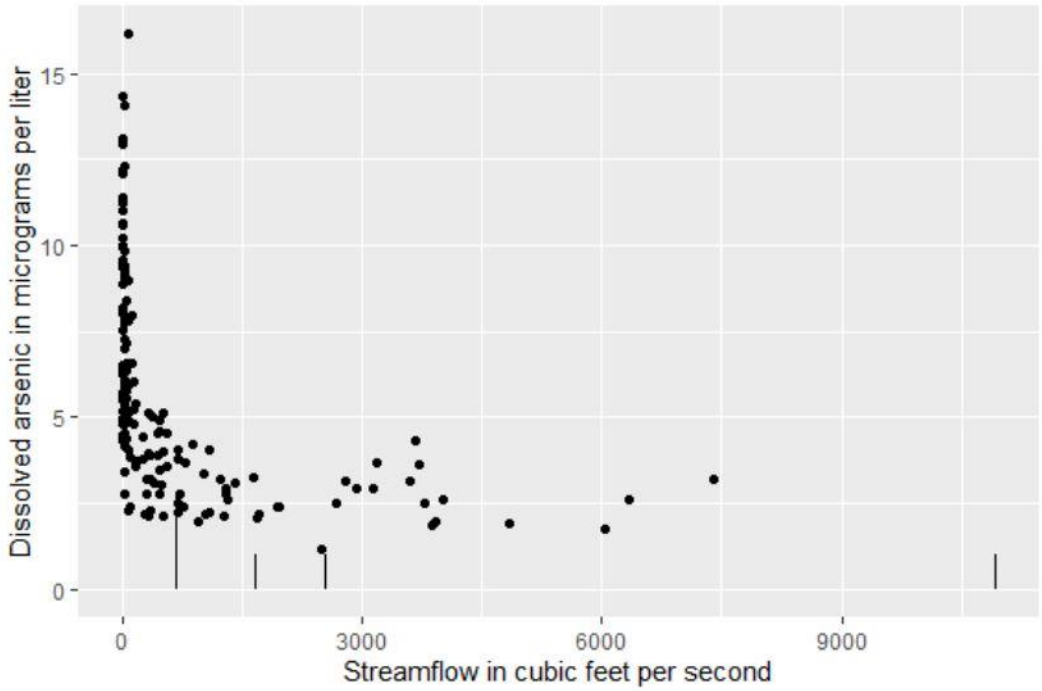
```
                 2.5 %     97.5 %
(Intercept)  0.84625413  0.9627741
logQ        -0.24052390 -0.2011684
T            0.01105417  0.0156590
```

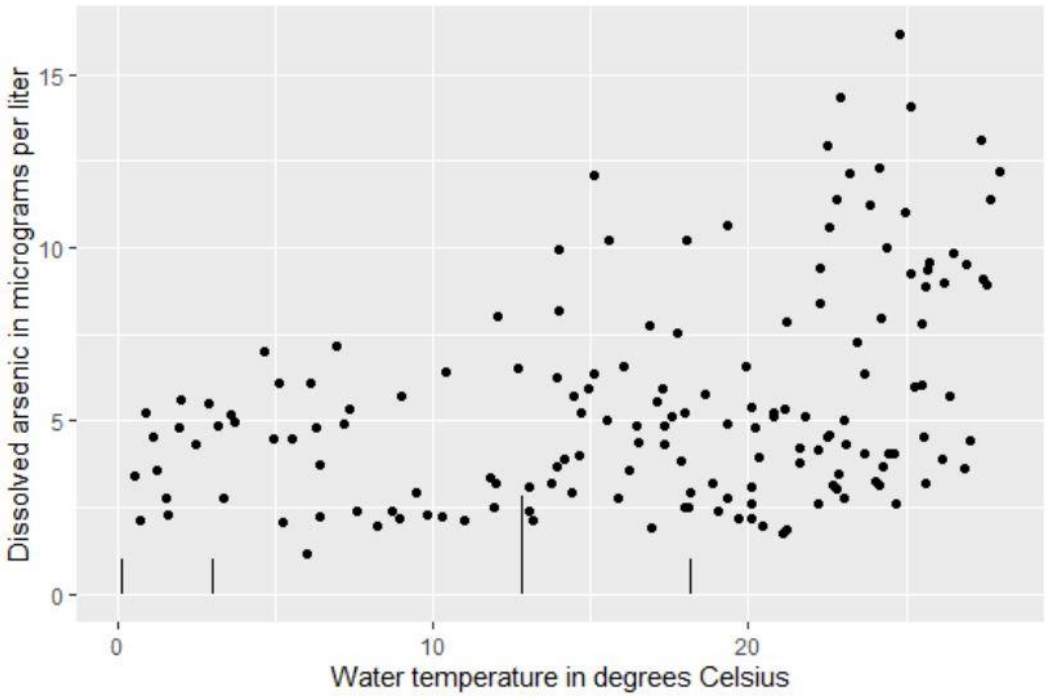
Plots


Observed arsenic
15
10
5
0
5
10
Computed arsenic (including BCF)


Residual
0.4
0.2
0.0
-0.2
2000
2005
2010
2015
2020
datetime
Detection
<


0.4
0.2
0.0
-0.2
Residual
0.3
0.6
0.9
Computed
Detection
<


15
10
5
0
Dissolved arsenic in micrograms per liter
0
3000
6000
9000
Streamflow in cubic feet per second



Model-Calibration Dataset

	datetime	logAS	logQ	T	AS	Q	Computed logAS	Computed AS
1	6/25/1998 10:30	0.783	2.125	25.495	6.07	133.5	0.776	6.18
2	10/1/1998 11:20	0.441	3.114	19.347	2.76	1300	0.475	3.09
3	11/6/1998 11:30	0.29	3.594	8.225	1.95	3925	0.221	1.72
4	4/7/1999 10:55	0.566	2.903	13.939	3.68	799.92	0.45	2.91
5	5/24/1999 10:05	0.342	3.016	19.688	2.2	1037.5	0.501	3.28
6	6/21/1999 10:30	0.297	2.978	20.44	1.98	951.5	0.52	3.43
7	7/19/1999 13:05	0.559	3.571	26.826	3.62	3723.33	0.474	3.09
8	9/28/1999 10:30	0.33	2.716	13.15	2.14	520	0.48	3.13
9	5/30/2000 10:25	0.447	2.48	23.027	2.8	302.17	0.664	4.78
10	6/26/2000 10:30	0.607	2.839	24.445	4.05	690.5	0.604	4.16
11	7/19/2000 10:45	0.953	1.851	26.212	8.97	71	0.846	7.26
12	3/13/2001 11:15	0.0682	3.398	5.978	1.17	2497.5	0.234	1.77
13	4/12/2001 11:50	0.447	2.667	15.843	2.8	464	0.527	3.49
14	4/26/2001 10:10	0.644	1.732	16.49	4.41	54	0.742	5.72
15	5/9/2001 9:55	0.763	1.633	18.634	5.8	43	0.793	6.42
16	6/1/2001 10:25	0.711	2.714	17.568	5.14	517.25	0.54	3.59
17	6/11/2001 10:55	0.568	3.504	24.288	3.7	3192.5	0.455	2.95
18	6/22/2001 10:35	0.42	3.602	22.233	2.63	4003.33	0.406	2.64
19	7/12/2001 9:15	0.959	1.459	27.438	9.09	28.75	0.949	9.2
20	8/1/2001 10:00	1.09	1.176	27.99	12.2	15	1.019	10.81
21	8/30/2001 9:45	0.971	0.973	25.677	9.35	9.4	1.033	11.16
22	9/18/2001 12:05	0.384	3.29	19.041	2.42	1948.33	0.432	2.8
23	10/30/2001 10:55	0.997	1.114	13.967	9.94	13	0.845	7.25
24	1/9/2002 9:50	0.713	1.204	3.567	5.17	16	0.686	5.03
25	2/20/2002 10:55	0.691	1.301	7.175	4.91	20	0.713	5.35
26	4/10/2002 9:55	0.912	1.23	13.967	8.16	17	0.819	6.83
27	4/22/2002 11:35	0.502	3.088	11.975	3.18	1223.33	0.383	2.5
28	5/14/2002 10:05	0.699	2.566	15.525	5	368.17	0.545	3.63
29	5/23/2002 10:30	0.72	1.778	17.95	5.25	60	0.752	5.84

30	6/6/2002 12:00	0.895	1.415	21.2	7.86	26	0.875	7.77
31	6/17/2002 9:15	0.465	3.466	18.175	2.92	2922.5	0.382	2.49
32	7/9/2002 9:30	1.06	1.079	27.65	11.4	12	1.036	11.24
33	8/20/2002 10:10	0.759	0.997	26.35	5.74	9.93	1.036	11.26
34	9/18/2002 10:15	1.06	0.818	22.8	11.4	6.58	1.028	11.05
35	12/17/2002 10:10	0.786	1.319	5.133	6.11	20.83	0.682	4.98
36	3/24/2003 10:05	<0.455	2.836	12.817	<2.85	685.25	0.449	2.91
37	4/16/2003 11:30	0.775	1.58	17.25	5.96	38	0.786	6.33
38	4/22/2003 10:10	0.591	2.538	14.15	3.9	345.5	0.533	3.53
39	5/15/2003 10:30	0.507	2.473	18.85	3.21	297	0.61	4.22
40	5/28/2003 10:30	0.681	2.178	20.2	4.8	150.5	0.693	5.11
41	6/10/2003 10:35	0.719	1.643	20.817	5.23	44	0.82	6.83
42	6/24/2003 9:25	0.967	1.408	25.125	9.27	25.58	0.929	8.8
43	7/30/2003 9:20	1.12	0.74	27.367	13.1	5.5	1.107	13.23
44	9/2/2003 11:30	0.69	2.68	19.3	4.9	478.5	0.571	3.85
45	10/15/2003 10:50	0.504	2.539	13.767	3.19	346.33	0.528	3.49
46	3/9/2004 12:00	0.348	3.037	10.3	2.23	1090	0.371	2.43
47	3/29/2004 10:00	0.721	2.137	14.7	5.26	137	0.629	4.41
48	4/26/2004 10:30	0.803	1.591	15.1	6.35	39	0.755	5.89
49	5/13/2004 11:15	0.688	2.018	16.45	4.88	104.25	0.679	4.94
50	6/16/2004 9:45	1.15	1.327	25.125	14.1	21.25	0.947	9.16
51	6/21/2004 9:10	0.713	2.522	20.817	5.16	332.83	0.626	4.37
52	7/26/2004 10:20	0.417	3.802	20.1	2.61	6336.67	0.333	2.23
53	1/28/2005 10:45	0.36	1.828	1.6	2.29	67.25	0.522	3.45
54	3/25/2005 10:00	0.348	2.843	6.4	2.23	696	0.362	2.38
55	5/11/2005 9:40	0.728	1.409	21.15	5.34	25.67	0.876	7.78
56	5/26/2005 12:00	0.577	2.843	21.6	3.78	696	0.565	3.8
57	6/7/2005 9:15	0.48	2.68	22.8	3.02	479	0.617	4.29
58	6/14/2005 8:40	0.27	3.587	21.2	1.86	3866.67	0.395	2.57
59	8/31/2005 9:10	0.861	1.544	23.433	7.26	35	0.877	7.79
60	2/7/2006 11:15	0.652	1.041	4.95	4.49	11	0.741	5.7
61	5/2/2006 10:35	0.82	1.698	16.05	6.6	49.83	0.744	5.74
62	6/8/2006 9:35	0.981	0.886	25.733	9.57	7.7	1.053	11.68
63	6/26/2006 10:30	0.802	1.785	23.7	6.34	61	0.827	6.95
64	7/28/2006 9:25	0.611	1.878	23.683	4.08	75.5	0.806	6.63
65	8/23/2006 11:10	0.979	0.623	26.883	9.52	4.2	1.126	13.84
66	9/27/2006 9:40	0.878	0.146	17.767	7.55	1.4	1.11	13.32
67	1/10/2007 9:55	0.74	0.732	2.883	5.5	5.39	0.781	6.26
68	1/30/2007 13:50	0.681	0.968	1.917	4.8	9.3	0.716	5.39
69	3/12/2007 10:15	0.815	1.041	12.675	6.53	11	0.844	7.23
70	3/21/2007 10:05	0.759	1.144	14.425	5.74	13.92	0.845	7.24
71	3/27/2007 10:05	0.687	1.88	17.308	4.86	75.83	0.721	5.44
72	4/18/2007 10:20	0.49	2.593	13.033	3.09	392	0.506	3.32
73	5/25/2007 10:20	<0	4.039	18.133	<1	10933.33	0.255	1.86
74	7/11/2007 10:10	0.415	3.123	24.683	2.6	1326.67	0.545	3.63
75	9/5/2007 10:15	1	1.204	24.35	10	16	0.964	9.53
76	12/12/2007 11:30	<0	3.22	0.1	<1	1658.19	0.195	1.62
77	3/4/2008 10:15	<0	3.407	3	<1	2551.48	0.192	1.61
78	4/14/2008 10:00	0.342	2.454	8.9	2.2	284.73	0.481	3.14
79	5/29/2008 9:40	0.491	3.149	20.1	3.1	1408.96	0.478	3.11
80	6/30/2008 9:50	0.544	2.679	22.867	3.5	477.24	0.618	4.3
81	9/16/2008 9:40	0.398	2.841	18.067	2.5	692.67	0.519	3.42
82	10/17/2008 9:50	0.398	3.577	11.9	2.5	3777.14	0.273	1.94
83	4/1/2009 11:10	0.322	3.227	5.217	2.1	1687.51	0.261	1.89
84	4/6/2009 10:40	0.38	2.042	7.567	2.4	110.2	0.555	3.71
85	4/30/2009 10:05	0.279	3.685	16.9	1.9	4840.49	0.316	2.15

86	5/12/2009 10:15	0.398	3.429	17.975	2.5	2687.73	0.387	2.53
87	6/16/2009 10:20	0.342	3.233	20.067	2.2	1710.44	0.459	2.98
88	7/30/2009 12:30	0.699	1.597	23	5	39.58	0.859	7.48
89	11/2/2009 10:10	0.362	2.542	9.833	2.3	348.19	0.475	3.09
90	11/19/2009 10:00	0.681	1.396	6.3	4.8	24.91	0.68	4.96
91	12/1/2009 9:55	0.653	1.363	5.5	4.5	23.08	0.677	4.92
92	12/17/2009 10:00	0.447	1.352	1.5	2.8	22.48	0.626	4.38
93	1/6/2010 10:10	0.531	1.317	0.517	3.4	20.73	0.621	4.32
94	2/11/2010 10:30	0.721	1.606	0.9	5.26	40.32	0.562	3.78
95	2/23/2010 10:25	0.658	1.449	1.125	4.55	28.09	0.6	4.12
96	4/13/2010 9:20	0.889	1.36	16.867	7.74	22.88	0.83	6.99
97	6/1/2010 9:50	0.925	1.693	22.283	8.42	49.28	0.828	6.97
98	6/15/2010 10:00	0.637	3.566	23.1	4.34	3679.68	0.426	2.76
99	7/7/2010 10:00	0.508	3.869	25.6	3.22	7399.65	0.392	2.55
100	8/19/2010 9:20	1.09	1.302	24.133	12.3	20.07	0.939	9
101	8/25/2010 9:10	0.656	2.753	22.5	4.53	566.07	0.597	4.09
102	11/16/2010 9:55	0.571	2.195	6.392	3.72	156.53	0.505	3.31
103	1/19/2011 9:45	0.748	1.204	2	5.6	15.98	0.665	4.79
104	3/7/2011 9:40	0.73	1.294	7.333	5.37	19.7	0.717	5.39
105	4/18/2011 9:50	1.01	1.188	15.55	10.2	15.42	0.85	7.33
106	5/16/2011 9:20	1.08	0.991	15.1	12.1	9.8	0.887	7.99
107	6/20/2011 10:00	0.901	2.08	24.2	7.97	120.36	0.768	6.07
108	8/11/2011 9:45	0.582	2.404	21.625	3.82	253.59	0.662	4.76
109	9/22/2011 10:30	0.637	0.992	17.35	4.34	9.81	0.917	8.56
110	12/21/2011 12:05	0.551	2.751	1.208	3.56	563.21	0.313	2.13
111	3/1/2012 10:00	0.384	2.88	8.7	2.42	758.82	0.385	2.51
112	4/18/2012 10:30	0.553	2.215	16.2	3.57	164.06	0.632	4.43
113	5/29/2012 11:05	1.04	0.583	24.942	11	3.83	1.109	13.3
114	6/18/2012 9:30	0.892	1.811	25.5	7.8	64.72	0.845	7.25
115	3/12/2013 9:30	0.856	1.666	6.9	7.18	46.35	0.629	4.4
116	3/13/2013 11:50	0.785	1.27	6.083	6.09	18.63	0.705	5.25
117	4/29/2013 11:00	0.745	1.754	17.1	5.56	56.75	0.746	5.76
118	6/3/2013 10:00	0.82	2.044	19.9	6.6	110.59	0.719	5.42
119	7/1/2013 9:40	1.08	0.822	23.2	12.2	6.64	1.033	11.17
120	7/30/2013 10:15	0.248	3.781	21.1	1.77	6045.22	0.351	2.32
121	10/30/2013 9:10	0.795	1.215	13.9	6.24	16.4	0.822	6.87
122	4/9/2014 9:20	0.904	1.159	12.033	8.01	14.43	0.809	6.67
123	6/4/2014 9:20	1.21	1.824	24.8	16.2	66.66	0.833	7.05
124	6/12/2014 9:30	0.497	3.556	22.65	3.14	3600.96	0.422	2.73
125	8/28/2014 8:20	0.948	0.784	25.6	8.88	6.09	1.073	12.26
126	9/4/2014 11:30	0.496	3.445	24.15	3.13	2787.27	0.466	3.03
127	12/10/2014 10:15	0.846	1.267	4.625	7.02	18.51	0.686	5.03
128	2/25/2015 9:35	0.696	1.112	3.704	4.97	12.93	0.708	5.29
129	4/7/2015 9:55	1.01	0.991	18.058	10.2	9.8	0.927	8.75
130	4/20/2015 11:25	0.605	2.71	14.642	4.03	512.63	0.502	3.29
131	7/14/2015 11:05	0.952	1.301	27.525	8.95	19.99	0.985	10
132	8/6/2015 10:20	0.609	3.041	24.633	4.06	1097.95	0.562	3.78
133	8/27/2015 9:00	0.62	1.551	22.2	4.17	35.6	0.858	7.47
134	5/2/2016 11:00	0.53	3.013	11.8	3.39	1031.11	0.397	2.58
135	6/1/2016 10:20	0.623	2.946	21.633	4.2	882.22	0.543	3.61
136	6/16/2016 10:05	0.665	2.668	22.542	4.62	466.05	0.616	4.28
137	8/10/2016 13:15	0.649	2.429	27.025	4.46	268.65	0.729	5.55
138	9/12/2016 10:05	0.594	2.517	20.325	3.93	328.79	0.62	4.32
139	3/30/2017 10:30	0.471	3.498	9.45	2.96	3149.87	0.258	1.88
140	5/3/2017 10:15	0.384	3.294	13.025	2.42	1966.21	0.351	2.32
141	5/30/2017 12:10	0.711	1.84	21.793	5.14	69.2	0.789	6.37

142	6/27/2017 10:35	0.973	1.415	22.255	9.4	26	0.889	8.02
143	7/12/2017 9:40	0.993	1.291	26.52	9.83	19.54	0.974	9.74
144	8/1/2017 10:25	1.02	1.062	22.56	10.6	11.53	0.971	9.69
145	8/17/2017 10:05	1.05	1.157	23.86	11.3	14.35	0.968	9.61
146	9/5/2017 9:50	1.16	0.983	22.923	14.3	9.62	0.994	10.2
147	11/14/2017 10:30	0.807	0.922	10.4	6.41	8.35	0.84	7.16
148	1/30/2018 10:00	0.637	0.978	2.46	4.33	9.52	0.721	5.45
149	3/21/2018 10:10	0.759	1.043	8.975	5.74	11.03	0.794	6.44
150	5/1/2018 11:10	1.03	1.045	19.34	10.7	11.1	0.932	8.85
151	5/22/2018 9:35	1.11	1.041	22.512	13	10.98	0.975	9.78
152	6/2/2018 9:20	0.777	1.845	25.25	5.98	69.91	0.834	7.07
153	7/18/2018 10:20	0.658	2.657	25.543	4.55	453.69	0.659	4.72
154	9/6/2018 10:00	0.511	3.216	24.05	3.25	1644.91	0.516	3.39
155	12/3/2018 11:05	0.445	2.861	3.357	2.79	725.69	0.318	2.15
156	2/26/2019 11:40	0.327	2.511	0.717	2.12	324.56	0.359	2.37
157	3/14/2019 10:20	0.33	3.102	10.963	2.14	1263.33	0.366	2.4
158	4/10/2019 12:00	0.583	1.959	17.87	3.83	90.98	0.711	5.32
159	4/29/2019 13:05	0.466	3.112	14.373	2.93	1293.99	0.409	2.66
160	6/11/2019 10:10	0.731	2.204	20.08	5.38	160.03	0.686	5.02
161	8/21/2019 11:20	0.588	2.645	26.147	3.88	441.77	0.67	4.84
162	10/8/2019 10:10	0.772	1.923	14.928	5.91	83.77	0.679	4.95
163	12/10/2019 11:30	0.688	1.306	3.17	4.88	20.22	0.658	4.72

Definitions

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AS: Arsenic in g/L (01000)
Q: Streamflow in cubic feet per second (00060)
T: Temperature, water in deg C (00010)
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