Appendix 2.3. Model Archive Summary for Hardness Concentration at U.S. Geological Survey site 07144100; Little Arkansas River near Sedgwick, Kansas, during May 1998 through December 2019

This model archive summary summarizes the hardness model developed to compute hourly or daily hardness. 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: 07144100

Site Name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick 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 handrail. Check-bar elevation is 33.614 feet. The orifice is enclosed in a well-screen and attached to a concrete pier on the left downstream side of the bridge. 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 [September 1998 through December 2006] and YSI Model 6136 [July 2004 through March 2015]) sensors collected data during April 1998 through March 2015. 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 September 2014 through December 2019. A Hach Nitratax monitor collected nitrate data during March 2012 through December 2019.

Date model was developed: June 1, 2020

Model calibration data period: May 1, 1998 through December 11, 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.

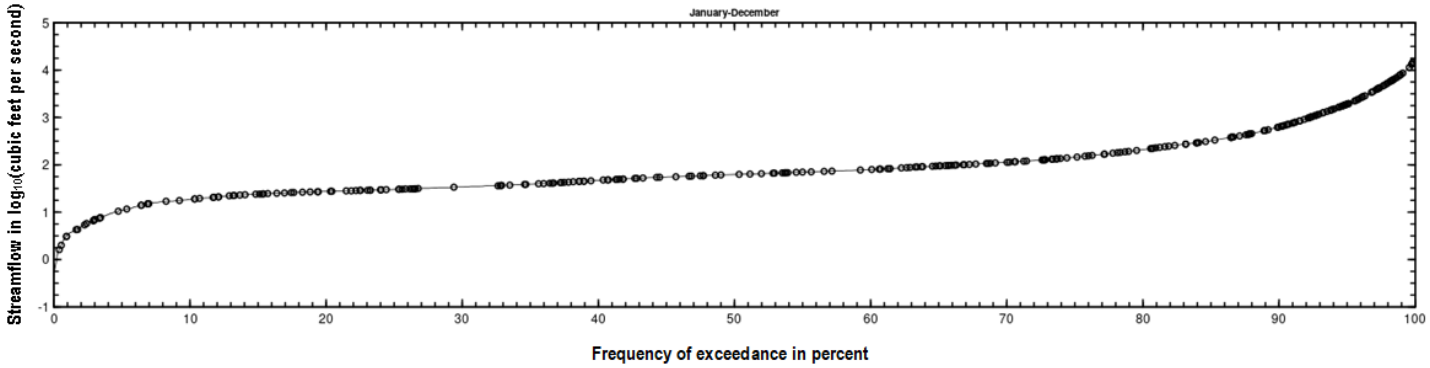
The regression model is based on 320 concomitant values of discretely collected hardness and continuously measured specific conductance during May 1998 through December 2019. Discrete samples were collected over a range of streamflow and specific conductance conditions. No samples had concentrations 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. All samples were retained in the dataset.

Hardness

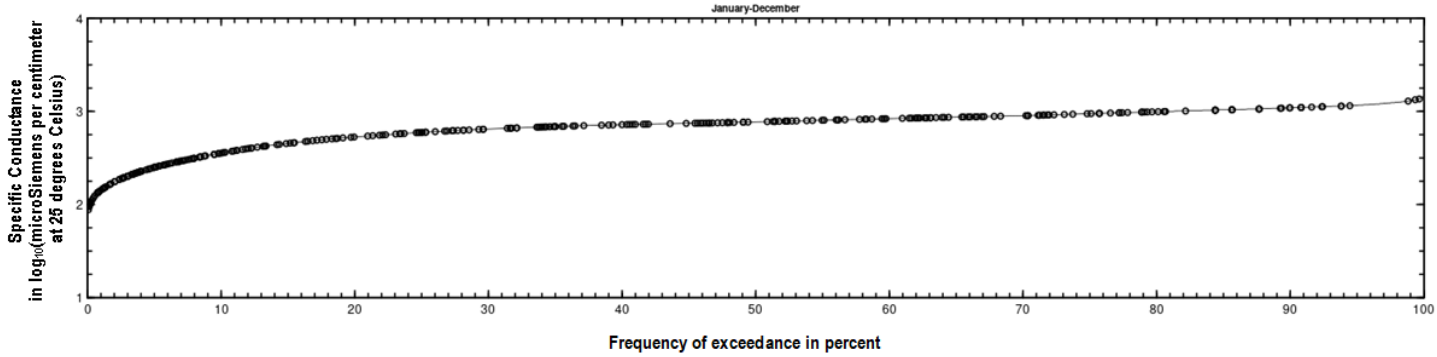
Discrete samples were collected from the downstream side of the bridge or instream within 50 feet of the bridge using equal-width-increment, multi-vertical, single vertical or grab-dip methods following U.S. Geological Survey (variously dated) and Rasmussen and others (2014). Discrete samples were collected on a semifixed to event-based schedule ranging

from 4 to 24 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 hardness 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).

Hardness Samples Plotted on Streamflow Duration Curve



Hardness Samples Plotted on Specific Conductance Duration Curve



Continuous Data

Concomitant specific conductance 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 hardness to specific conductance 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 hardness 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.

Specific conductance was selected as the best predictor of hardness based on residual plots, high coefficient of determination (R^2), and low model standard percentage error (MSPE). Specific conductance was positively related to hardness because it measures water's capacity to conduct an electrical current and is related to the concentration of ionized substances in water (Hem, 1992).

Model Summary

Summary of final hardness regression analysis at USGS site number 07144100:

Hardness-based model:

$$\log_{10}(HD) = 1.05 \times \log_{10}(SC) - 0.611$$

where,

$\log_{10}$ = logarithm base 10;
HD = hardness, in milligrams per liter as calcium carbonate (mg/L $CaCO_3$); and
SC = specific conductance, in microsiemens per centimeter at 25 degrees Celsius (µS/cm)

The log-transformed model may be retransformed to original units so that HD 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 1.01. The retransformed model, accounting for BCF is:

$$HD = 0.2474 \times SC^{1.05}$$

Model Statistics, Data, and Plots

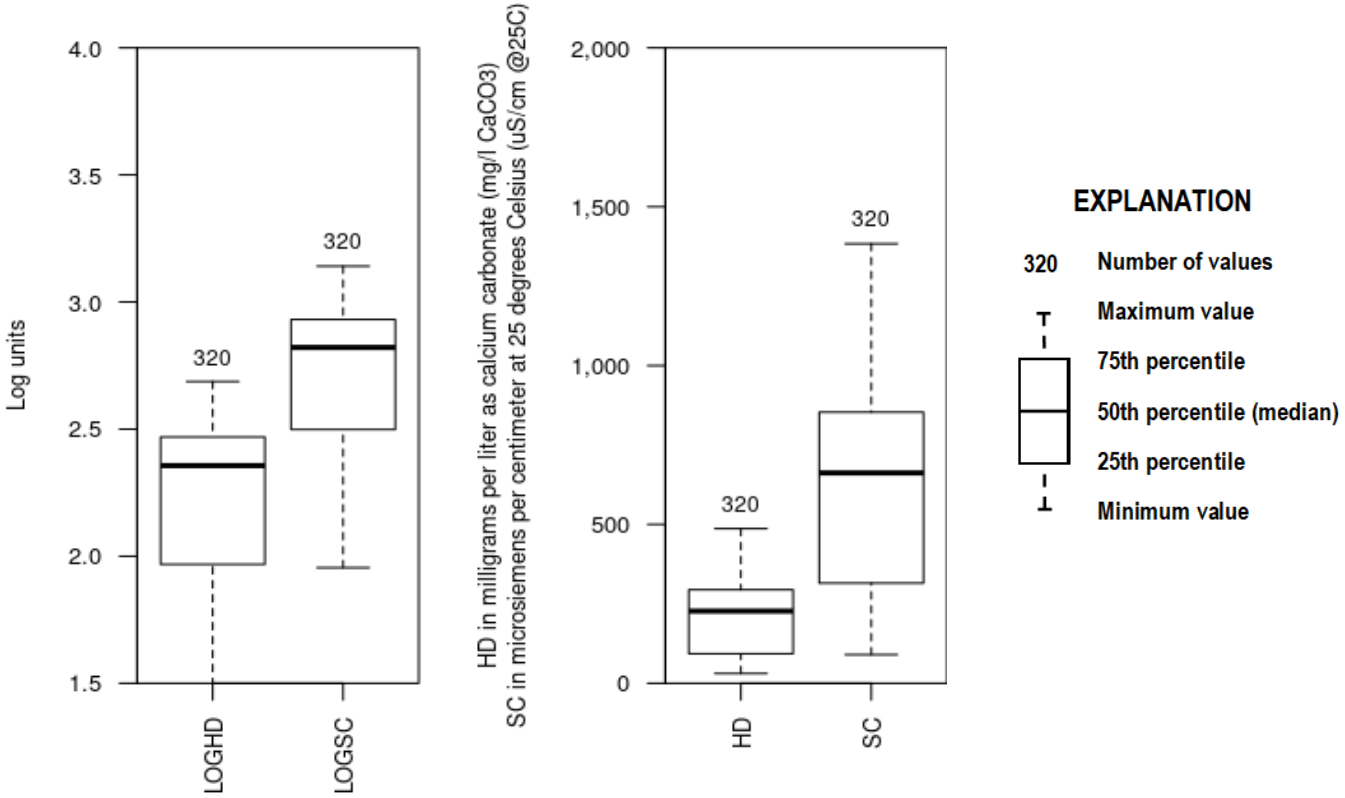
Model

LOGHD = + 1.05 * LOGSC - 0.611

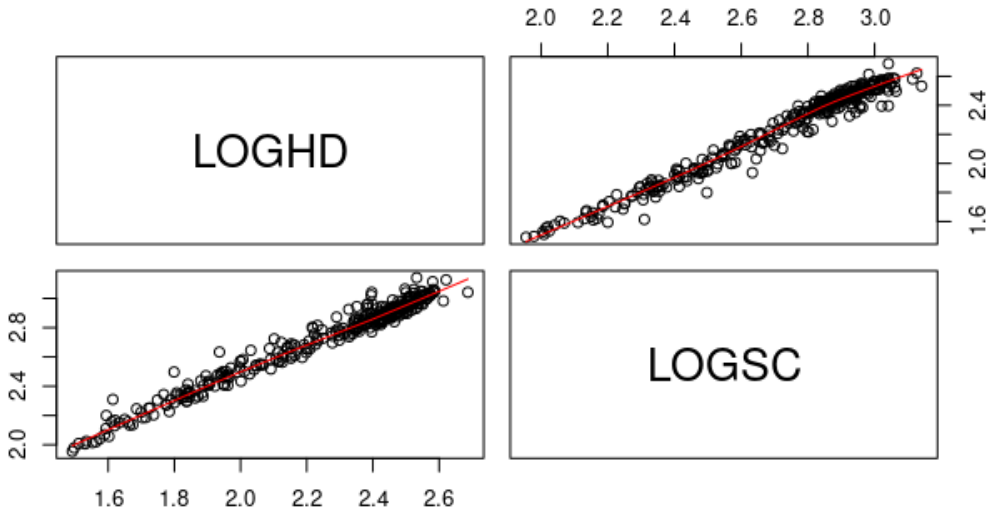
Variable Summary Statistics

	LOGHD	HD	LOGSC	SC
Minimum	1.49	31.0	1.96	90.2
1st Quartile	1.97	92.9	2.50	315.0
Median	2.36	227.0	2.82	662.0
Mean	2.23	206.0	2.71	610.0
3rd Quartile	2.47	294.0	2.93	853.0
Maximum	2.69	487.0	3.14	1380.0

Box Plots



Exploratory Plots



Basic Model Statistics

Number of Observations	320
Standard error (RMSE)	0.0519
Average Model standard percentage error (MSPE)	12
Coefficient of determination (R^2)	0.97
Adjusted Coefficient of Determination (Adj. R^2)	0.97
Bias Correction Factor (BCF)	1.01

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(>|t|)
(Intercept)	-0.611	0.0282	-21.7	1.36e-64
LOGSC	1.050	0.0103	101.0	4.35e-244

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.995
E.vars	-0.995	1.000

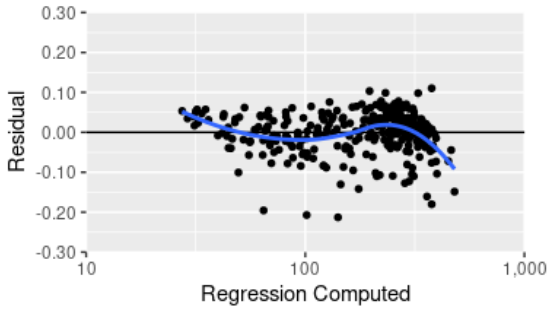
Outlier Test Criteria

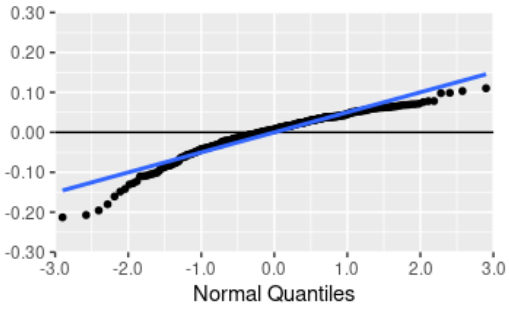
Leverage	Cook's D	DFFITS
0.0187	0.1947	0.1581

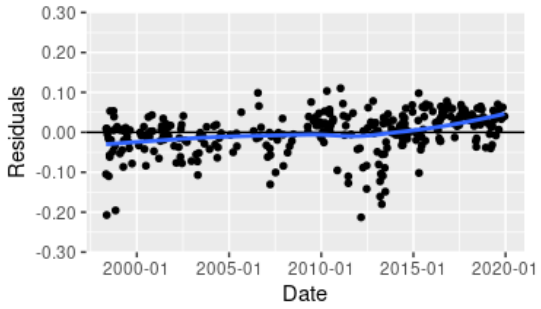
Flagged Observations

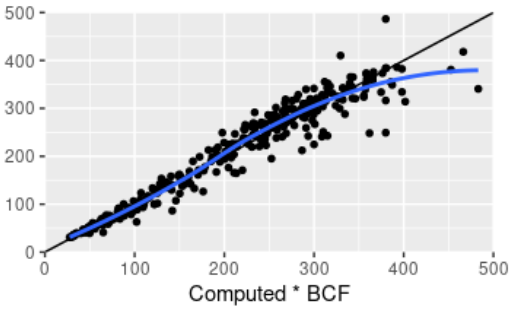
	LOGHD	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
5/14/1998 9:25	1.8	2.01	-0.207	-4	-4.1	0.00493	0.0396	-0.288
9/25/1998 10:10	1.49	1.44	0.0535	1.04	1.04	0.0258	0.0144	0.17
10/5/1998 10:20	1.53	1.49	0.0392	0.763	0.762	0.0228	0.0068	0.117
11/5/1998 13:40	1.61	1.81	-0.196	-3.79	-3.87	0.0095	0.0687	-0.379
6/6/2001 10:10	1.5	1.46	0.0346	0.675	0.674	0.0244	0.00569	0.107
7/11/2007 12:10	1.59	1.69	-0.101	-1.95	-1.96	0.0135	0.026	-0.229
6/13/2010 15:20	1.55	1.5	0.0523	1.02	1.02	0.0224	0.0119	0.154
6/13/2010 19:20	1.56	1.51	0.0572	1.11	1.11	0.0221	0.014	0.167
6/14/2010 9:40	1.57	1.53	0.047	0.914	0.914	0.021	0.00895	0.134
7/6/2010 9:00	1.51	1.49	0.0168	0.327	0.327	0.0227	0.00124	0.0498
1/19/2011 11:40	2.69	2.58	0.11	2.13	2.14	0.00747	0.0171	0.186
6/21/2011 10:00	2.39	2.5	-0.11	-2.13	-2.14	0.00567	0.0129	-0.162
6/22/2011 10:20	2.33	2.45	-0.127	-2.46	-2.48	0.00494	0.015	-0.175
3/1/2012 12:00	1.94	2.15	-0.213	-4.11	-4.21	0.00336	0.0284	-0.245
3/12/2013 11:00	2.35	2.47	-0.123	-2.37	-2.39	0.00528	0.0149	-0.174
3/13/2013 9:15	2.39	2.56	-0.161	-3.11	-3.15	0.00696	0.0338	-0.264
3/27/2013 11:35	2.5	2.6	-0.104	-2.01	-2.02	0.0081	0.0165	-0.182
4/15/2013 9:00	2.4	2.58	-0.18	-3.48	-3.55	0.00747	0.0457	-0.308
6/24/2013 9:40	2.53	2.68	-0.149	-2.88	-2.91	0.0105	0.0439	-0.3
8/7/2013 9:45	1.53	1.51	0.0236	0.459	0.458	0.0218	0.00235	0.0684
9/6/2018 12:00	1.6	1.54	0.0573	1.11	1.11	0.0201	0.0127	0.159
5/23/2019 12:20	1.59	1.56	0.0312	0.608	0.607	0.0194	0.00366	0.0855

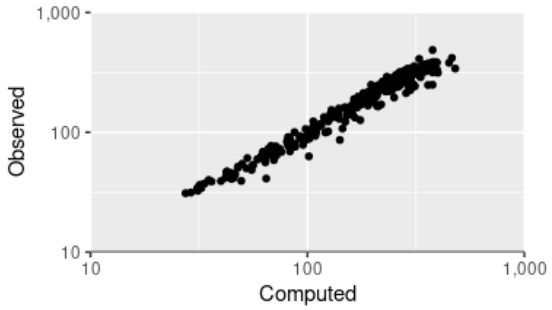
Statistical Plots

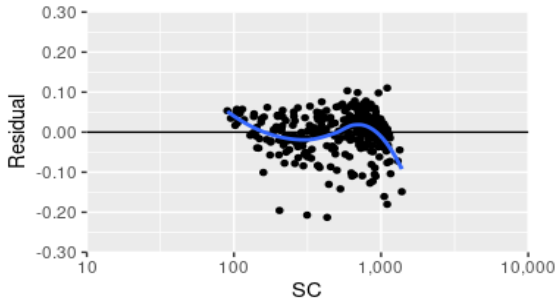


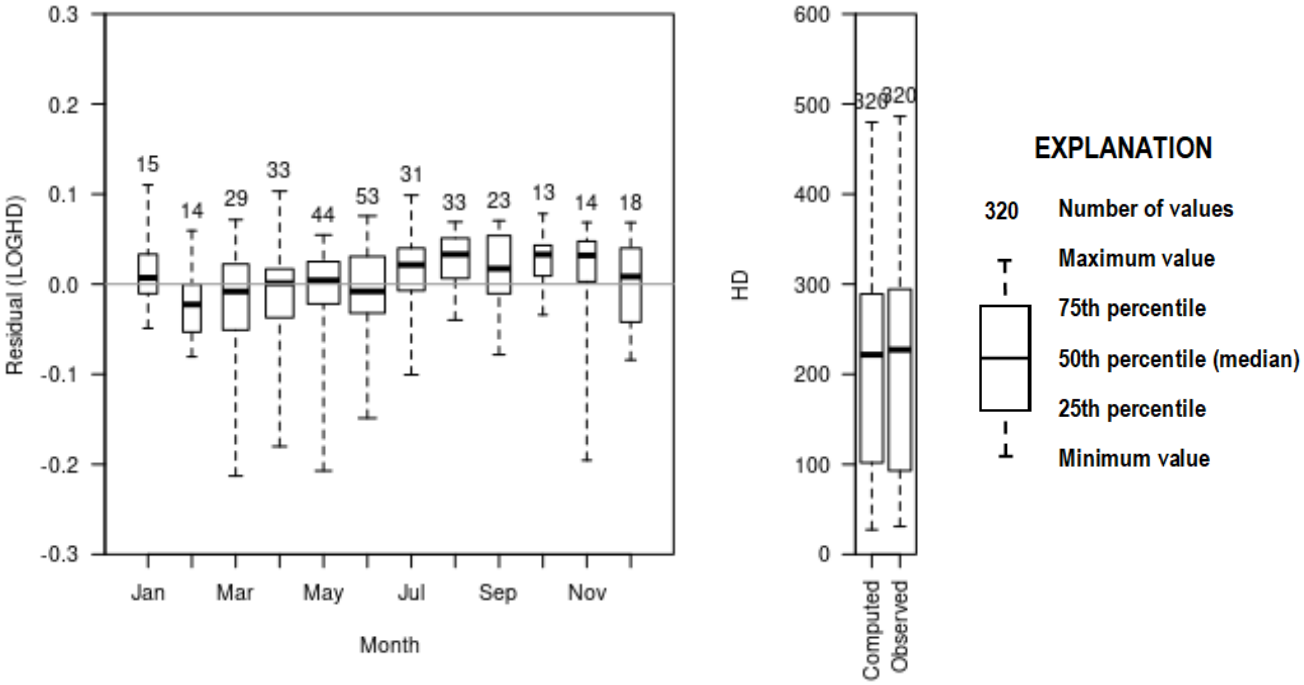


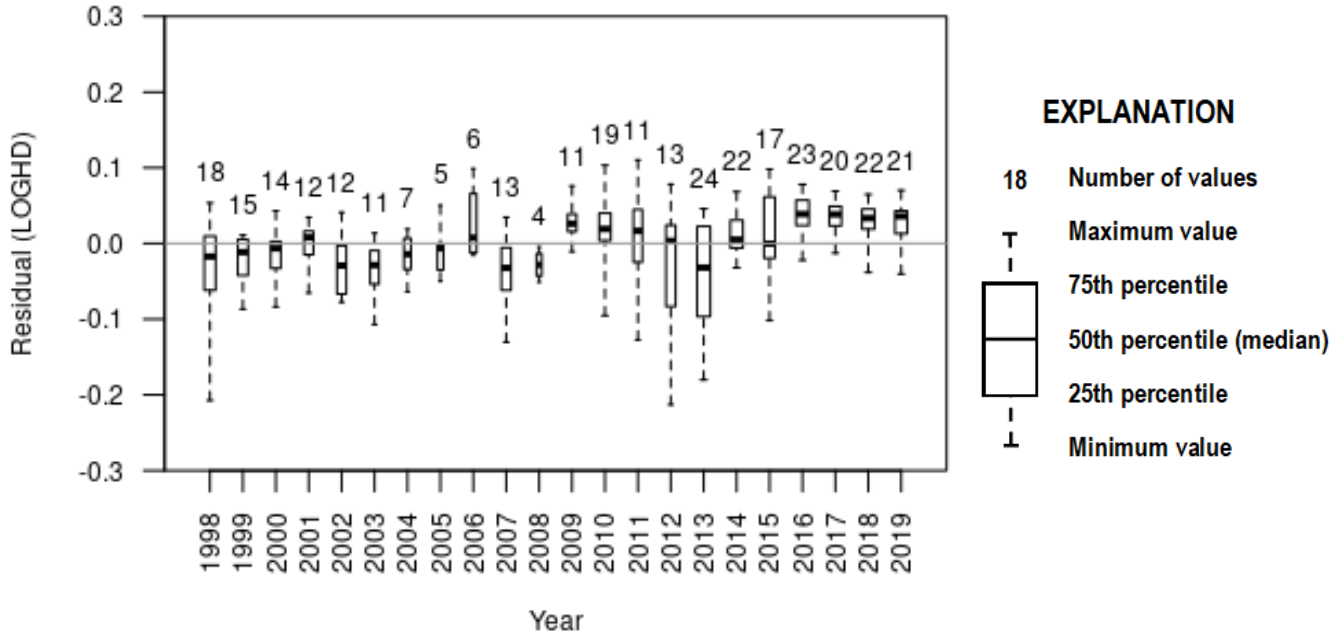









Residual (LOGHD)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
15
14
29
33
44
53
31
33
23
13
14
18
Jan
Mar
May
Jul
Sep
Nov
Month
HD
600
500
400
300
200
100
0
320
320
Computed
Observed
EXPLANATION
320
Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value


Residual (LOGHD)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
18
15
14
12
12
11
7
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22
17
23
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22
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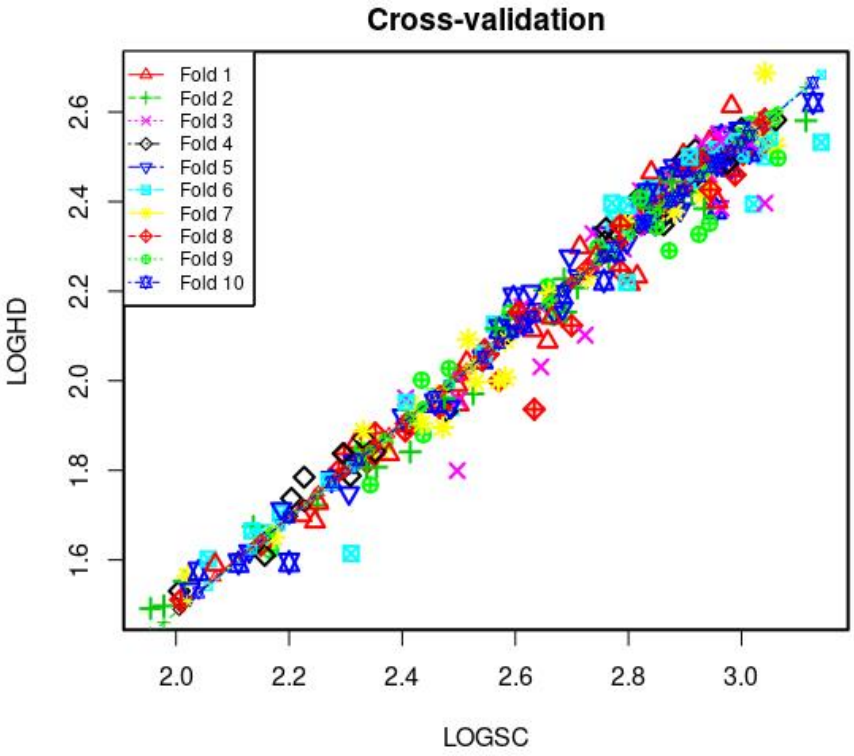
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year
EXPLANATION
18
Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value

Cross Validation

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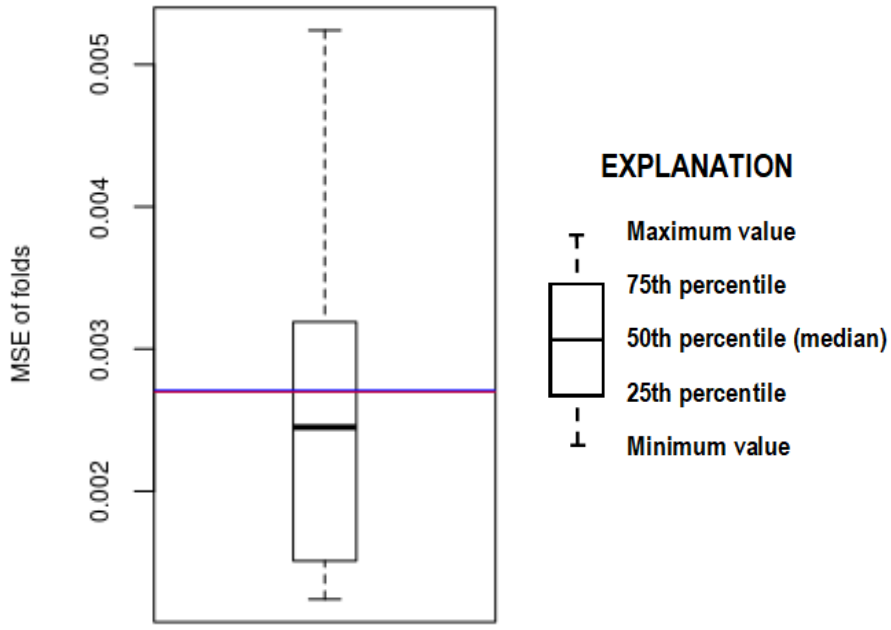
             Minimum MSE of folds:  0.00124
                Mean MSE of folds:  0.00271
              Median MSE of folds:  0.00245
             Maximum MSE of folds:  0.00524
(Mean MSE of folds) / (Model MSE):  1.00000
```




```
Red line - Model MSE

Blue line - Mean MSE of folds
```

Model-Calibration Dataset

	Date	LOGHD	LOGSC	HD	SC	Computed LOGHD	Computed HD	Residual	Normal Quantiles
1	5/1/1998	2.38	2.96	241	903	2.49	309	-0.105	-1.69
2	5/6/1998	2.45	2.91	280	811	2.44	276	0.00878	0.0352
3	5/11/1998	2.5	2.96	318	914	2.49	313	0.0097	0.0509
4	5/14/1998	1.8	2.5	63	314	2.01	102	-0.207	-2.58
5	5/27/1998	2.45	2.93	282	843	2.46	287	-0.00478	-0.29
6	6/16/1998	2.46	2.94	287	877	2.47	300	-0.0154	-0.547
7	6/24/1998	2.22	2.8	165	634	2.33	213	-0.11	-1.8
8	7/10/1998	1.75	2.31	56.1	202	1.81	64.4	-0.0569	-1.19
9	7/13/1998	1.95	2.5	88.6	316	2.01	103	-0.0618	-1.24
10	7/20/1998	2.33	2.75	213	568	2.28	190	0.0532	1.17
11	8/6/1998	2.42	2.91	264	817	2.44	278	-0.0191	-0.593
12	9/15/1998	2.41	2.93	259	853	2.46	291	-0.0473	-1.04
13	9/22/1998	1.83	2.32	67.5	210	1.82	67.1	0.00504	-0.0509
14	9/25/1998	1.49	1.96	31	90.2	1.44	27.6	0.0535	1.19
15	10/5/1998	1.53	2.01	33.9	101	1.49	31.2	0.0392	0.803
16	10/22/1998	2.11	2.63	130	428	2.15	141	-0.034	-0.824
17	11/5/1998	1.61	2.31	41.1	204	1.81	65	-0.196	-2.4
18	12/4/1998	2.4	2.86	253	728	2.39	247	0.0139	0.13
19	1/12/1999	2.58	3.04	384	1100	2.58	380	0.00708	-0.00391
20	2/1/1999	1.94	2.49	87.3	306	1.99	99.4	-0.0532	-1.13
21	2/19/1999	2.56	3.02	361	1040	2.55	359	0.00547	-0.0274
22	3/16/1999	2.62	3.13	418	1340	2.67	466	-0.0445	-1.03
23	3/23/1999	2.58	3.04	384	1100	2.58	380	0.0073	0.0117
24	4/7/1999	2.09	2.66	122	454	2.17	150	-0.0867	-1.49
25	4/16/1999	1.79	2.31	61.4	203	1.81	64.7	-0.0202	-0.621
26	5/5/1999	2.44	2.91	274	806	2.44	274	0.00224	-0.145
27	5/24/1999	1.84	2.32	68.7	211	1.83	67.3	0.0114	0.0666
28	6/18/1999	2.01	2.5	103	316	2.01	103	0.00258	-0.13
29	6/21/1999	1.84	2.35	69	223	1.85	71.3	-0.0114	-0.44
30	7/20/1999	1.72	2.25	52.7	178	1.75	56.2	-0.025	-0.719
31	8/3/1999	1.62	2.17	41.8	147	1.66	46.1	-0.0399	-0.928
32	8/19/1999	2.5	2.96	315	914	2.49	313	0.00533	-0.0352
33	9/28/1999	1.84	2.41	69.3	259	1.92	83.6	-0.0783	-1.38
34	2/9/2000	2.55	3.05	355	1120	2.58	385	-0.0329	-0.813
35	3/7/2000	1.97	2.46	92.3	287	1.97	93	-0.00046	-0.185
36	3/28/2000	1.9	2.41	80.2	255	1.91	82.3	-0.00814	-0.372
37	5/19/2000	2.57	3.03	376	1060	2.56	366	0.014	0.137
38	5/31/2000	2.14	2.67	139	464	2.18	154	-0.0421	-0.977
39	6/28/2000	2	2.57	100	372	2.08	122	-0.0838	-1.45
40	7/20/2000	2.37	2.86	236	725	2.39	245	-0.0144	-0.493
41	7/28/2000	2.06	2.55	115	356	2.06	117	-0.00465	-0.282
42	8/16/2000	2.44	2.87	274	745	2.4	253	0.0382	0.75
43	9/8/2000	2.45	2.93	280	849	2.46	290	-0.0117	-0.458
44	9/25/2000	2.47	2.93	292	857	2.46	292	0.00241	-0.137
45	10/26/2000	1.86	2.32	72.9	208	1.82	66.5	0.0432	0.965
46	11/8/2000	2.23	2.71	171	515	2.23	171	0.00281	-0.122
47	12/4/2000	2.52	3.04	334	1090	2.57	375	-0.0474	-1.06
48	3/14/2001	1.97	2.53	93.5	335	2.04	109	-0.0653	-1.29
49	4/13/2001	2.21	2.71	161	513	2.23	171	-0.0217	-0.64
50	4/26/2001	2.53	3	341	989	2.53	340	0.00494	-0.0587
51	5/8/2001	2.36	2.82	231	666	2.35	225	0.0158	0.185
52	6/4/2001	1.96	2.46	90.3	288	1.97	93.3	-0.0113	-0.432
53	6/6/2001	1.5	1.98	31.4	95.2	1.46	29.2	0.0346	0.64

54	6/23/2001	1.7	2.22	50.1	167	1.72	52.6	-0.0184	-0.574
55	7/11/2001	2.45	2.91	283	815	2.44	277	0.0122	0.0901
56	8/2/2001	2.44	2.89	273	769	2.41	261	0.0213	0.306
57	8/28/2001	2.44	2.9	273	790	2.43	268	0.0109	0.0587
58	9/20/2001	1.63	2.15	43	141	1.64	44.2	-0.00948	-0.389
59	10/31/2001	2.48	2.93	301	853	2.46	291	0.017	0.225
60	1/10/2002	2.51	3.01	326	1030	2.55	356	-0.0342	-0.835
61	2/21/2002	2.5	3.04	316	1100	2.58	380	-0.0765	-1.34
62	4/9/2002	2.48	2.98	300	958	2.51	329	-0.0371	-0.881
63	4/22/2002	1.9	2.41	80.2	259	1.92	83.4	-0.0144	-0.502
64	5/13/2002	2.25	2.78	176	610	2.31	205	-0.0615	-1.22
65	5/22/2002	2.15	2.63	142	425	2.14	140	0.00841	0.0274
66	6/6/2002	2.13	2.59	134	393	2.11	129	0.0192	0.282
67	6/13/2002	1.77	2.34	58.6	221	1.85	70.5	-0.0775	-1.36
68	7/9/2002	2.42	2.86	265	717	2.38	242	0.041	0.881
69	8/15/2002	2.29	2.79	197	618	2.31	208	-0.0202	-0.611
70	9/19/2002	2.36	2.86	228	717	2.38	242	-0.0243	-0.699
71	12/18/2002	2.58	3.11	381	1300	2.65	453	-0.0721	-1.31
72	3/20/2003	1.93	2.48	85.5	301	1.99	97.8	-0.0555	-1.17
73	4/17/2003	2.52	3.06	334	1150	2.6	398	-0.073	-1.33
74	4/23/2003	2.23	2.82	171	654	2.34	220	-0.107	-1.72
75	5/14/2003	1.96	2.5	90.6	316	2.01	103	-0.0519	-1.11
76	5/29/2003	2.19	2.68	156	482	2.2	160	-0.00916	-0.381
77	6/11/2003	2.35	2.83	225	673	2.35	227	-0.00087	-0.201
78	6/24/2003	2.5	2.99	318	967	2.52	332	-0.0156	-0.556
79	7/30/2003	2.47	2.95	295	889	2.48	304	-0.00952	-0.398
80	9/3/2003	1.9	2.43	80.2	267	1.93	86.3	-0.0286	-0.739
81	10/14/2003	1.8	2.29	63.2	194	1.79	61.6	0.0136	0.122
82	12/11/2003	2.54	3.05	349	1120	2.58	387	-0.0421	-0.99
83	3/9/2004	1.84	2.33	69.9	213	1.83	67.9	0.0155	0.177
84	3/30/2004	2.51	3	320	1010	2.54	346	-0.0307	-0.75
85	4/26/2004	2.55	3	353	989	2.53	340	0.019	0.273
86	5/13/2004	1.88	2.44	75.8	274	1.94	88.4	-0.0638	-1.27
87	5/26/2004	2.51	3.01	324	1030	2.55	356	-0.0378	-0.892
88	6/22/2004	1.9	2.41	80.3	259	1.92	83.6	-0.0142	-0.484
89	7/27/2004	1.62	2.13	41.6	135	1.62	42.1	-0.00183	-0.225
90	1/27/2005	2.05	2.54	111	349	2.05	114	-0.00649	-0.339
91	3/23/2005	1.81	2.35	64.2	226	1.86	72.4	-0.0499	-1.08
92	5/27/2005	1.96	2.46	92.2	288	1.97	93.4	-0.0026	-0.241
93	6/6/2005	1.94	2.47	86.9	293	1.97	94.9	-0.0349	-0.858
94	8/31/2005	2.13	2.56	134	366	2.08	120	0.0503	1.06
95	5/2/2006	2.39	2.86	248	732	2.39	248	0.0032	-0.106
96	6/26/2006	1.95	2.46	89.1	287	1.97	92.9	-0.0154	-0.529
97	7/27/2006	2.46	2.84	292	692	2.37	234	0.0988	2.4
98	8/15/2006	2.41	2.82	256	658	2.34	222	0.0658	1.69
99	8/23/2006	2.27	2.77	188	582	2.29	195	-0.0123	-0.467
100	9/27/2006	2.41	2.88	260	750	2.4	254	0.0122	0.098
101	1/10/2007	2.44	2.94	275	873	2.47	298	-0.0323	-0.792
102	2/5/2007	2.46	2.99	288	974	2.52	334	-0.0618	-1.25
103	3/12/2007	2.38	2.85	237	708	2.38	239	-0.0008	-0.193
104	3/21/2007	2.35	2.86	223	728	2.39	247	-0.0406	-0.965
105	3/27/2007	2.03	2.65	107	442	2.16	146	-0.13	-1.98
106	4/2/2007	1.69	2.25	48.5	176	1.74	55.7	-0.0571	-1.2
107	4/18/2007	1.86	2.37	72.8	234	1.87	75	-0.0102	-0.406
108	7/11/2007	1.59	2.2	39.3	159	1.69	49.9	-0.101	-1.6
109	8/16/2007	2.34	2.83	219	684	2.36	231	-0.019	-0.583

110	9/6/2007	2.51	2.98	324	954	2.51	327	-0.00104	-0.217
111	11/26/2007	2.47	2.91	298	815	2.44	277	0.0346	0.63
112	12/6/2007	2.48	2.96	304	906	2.49	310	-0.00575	-0.323
113	12/13/2007	1.9	2.47	78.6	296	1.98	96.1	-0.0842	-1.47
114	3/6/2008	1.94	2.48	87.5	305	1.99	99	-0.051	-1.1
115	4/14/2008	2.15	2.67	142	467	2.19	155	-0.0348	-0.847
116	5/29/2008	1.82	2.34	65.7	218	1.84	69.6	-0.0218	-0.65
117	6/30/2008	2.05	2.54	111	347	2.05	113	-0.00481	-0.298
118	4/6/2009	2.37	2.83	232	670	2.35	226	0.0142	0.145
119	4/13/2009	2.25	2.73	178	535	2.25	178	0.00107	-0.161
120	4/28/2009	1.84	2.3	68.7	198	1.8	63.1	0.0393	0.813
121	6/16/2009	2.19	2.6	154	395	2.11	130	0.0758	2.04
122	7/30/2009	1.95	2.41	88.6	259	1.92	83.6	0.0283	0.467
123	9/9/2009	1.74	2.2	54.6	160	1.7	50.4	0.0381	0.739
124	9/24/2009	1.92	2.4	83.6	251	1.91	80.9	0.0173	0.241
125	11/3/2009	2.04	2.51	110	327	2.02	106	0.0173	0.249
126	11/19/2009	2.47	2.89	294	780	2.42	265	0.0476	1.03
127	12/1/2009	2.52	2.96	333	921	2.5	315	0.0262	0.432
128	12/17/2009	2.54	3.02	347	1040	2.55	358	-0.0108	-0.423
129	1/6/2010	2.58	3.06	382	1150	2.6	398	-0.0146	-0.511
130	1/19/2010	2.57	3.02	372	1040	2.55	358	0.0192	0.29
131	2/4/2010	2.51	2.98	324	949	2.51	325	0.00184	-0.153
132	2/23/2010	2.51	3	321	997	2.53	343	-0.0254	-0.729
133	3/10/2010	2.43	2.85	271	713	2.38	241	0.0527	1.16
134	3/11/2010	2.34	2.79	218	619	2.31	208	0.0235	0.364
135	4/14/2010	2.57	3.02	373	1040	2.55	358	0.0211	0.298
136	4/23/2010	2.4	2.77	249	590	2.29	198	0.103	2.58
137	5/13/2010	2.07	2.55	117	351	2.06	115	0.0115	0.0744
138	6/9/2010	1.66	2.16	45.7	143	1.65	44.8	0.0123	0.106
139	6/13/2010	1.55	2.01	35.7	103	1.5	31.9	0.0523	1.13
140	6/14/2010	1.56	2.02	36.6	105	1.51	32.3	0.0572	1.27
141	6/14/2010	1.57	2.04	37.5	110	1.53	33.9	0.047	1.02
142	6/15/2010	1.78	2.27	59.8	188	1.77	59.8	0.0035	-0.0901
143	6/16/2010	1.82	2.31	65.9	206	1.81	65.8	0.00418	-0.0744
144	7/6/2010	1.51	2.01	32.4	102	1.49	31.4	0.0168	0.209
145	8/19/2010	2.36	2.8	226	637	2.33	214	0.0272	0.449
146	8/25/2010	2.2	2.65	159	449	2.17	149	0.0331	0.593
147	11/16/2010	2.12	2.7	133	501	2.22	166	-0.0953	-1.57
148	1/19/2011	2.69	3.04	487	1100	2.58	380	0.11	2.9
149	3/7/2011	2.48	2.88	302	759	2.41	258	0.0716	1.98
150	3/16/2011	2.48	2.91	300	808	2.44	275	0.0415	0.892
151	4/6/2011	2.51	2.98	321	956	2.51	328	-0.00692	-0.347
152	5/2/2011	2.52	2.97	331	936	2.5	321	0.0166	0.201
153	6/7/2011	2.4	2.84	253	692	2.37	234	0.0375	0.709
154	6/21/2011	2.39	2.96	243	920	2.5	315	-0.11	-1.84
155	6/22/2011	2.33	2.92	212	841	2.45	287	-0.127	-1.93
156	8/15/2011	2.09	2.58	123	382	2.1	125	-0.00507	-0.306
157	9/22/2011	2.15	2.59	142	390	2.1	128	0.0481	1.04
158	12/20/2011	2	2.53	99.5	338	2.04	110	-0.0427	-1
159	2/6/2012	2.14	2.66	138	461	2.18	153	-0.0399	-0.94
160	3/1/2012	1.94	2.63	86.4	430	2.15	142	-0.213	-2.9
161	4/7/2012	2.01	2.58	102	382	2.1	126	-0.0885	-1.52
162	4/17/2012	2.39	2.86	246	725	2.39	245	0.00342	-0.098
163	6/18/2012	2	2.57	99.9	372	2.08	122	-0.0833	-1.43
164	6/19/2012	2.1	2.72	126	529	2.24	176	-0.142	-2.04
165	7/12/2012	2.43	2.89	271	781	2.42	266	0.0115	0.0823

166	7/19/2012	2.42	2.83	264	683	2.36	231	0.0618	1.45
167	9/11/2012	2.39	2.84	244	685	2.36	231	0.0255	0.423
168	10/24/2012	2.42	2.82	266	663	2.35	223	0.0783	2.19
169	11/7/2012	2.46	2.92	291	826	2.45	281	0.0172	0.233
170	11/14/2012	2.46	2.93	290	860	2.46	293	-0.00229	-0.233
171	12/12/2012	2.49	2.93	306	854	2.46	291	0.0242	0.398
172	1/16/2013	2.43	2.94	267	880	2.48	301	-0.0489	-1.07
173	1/29/2013	2.43	2.9	270	791	2.43	269	0.00424	-0.0666
174	2/13/2013	2.38	2.93	242	860	2.46	294	-0.0805	-1.41
175	3/12/2013	2.35	2.94	225	878	2.47	300	-0.123	-1.88
176	3/13/2013	2.39	3.02	248	1050	2.56	362	-0.161	-2.19
177	3/27/2013	2.5	3.06	314	1160	2.6	402	-0.104	-1.66
178	4/15/2013	2.4	3.04	249	1100	2.58	380	-0.18	-2.28
179	4/24/2013	2.22	2.76	167	571	2.28	191	-0.0553	-1.16
180	5/6/2013	2.29	2.87	195	745	2.4	253	-0.109	-1.76
181	5/15/2013	2.32	2.78	210	599	2.3	201	0.0216	0.323
182	5/21/2013	2.21	2.66	162	453	2.17	150	0.0371	0.689
183	5/28/2013	2.42	2.86	262	718	2.38	243	0.0353	0.65
184	6/5/2013	2.15	2.69	142	489	2.21	162	-0.0545	-1.14
185	6/13/2013	2.4	2.96	251	907	2.49	310	-0.0891	-1.54
186	6/24/2013	2.53	3.14	341	1380	2.68	483	-0.149	-2.11
187	7/9/2013	2.36	2.86	229	721	2.38	244	-0.0244	-0.709
188	7/29/2013	1.61	2.16	40.8	143	1.65	44.9	-0.0392	-0.916
189	8/7/2013	1.53	2.02	34.2	106	1.51	32.6	0.0236	0.381
190	8/15/2013	1.67	2.14	47.3	137	1.63	42.8	0.0458	1
191	8/29/2013	2.37	2.82	237	665	2.35	224	0.0265	0.44
192	10/24/2013	2.48	2.94	304	878	2.47	300	0.00919	0.0431
193	10/30/2013	2.13	2.61	134	411	2.13	135	-0.00102	-0.209
194	11/25/2013	2.5	2.94	314	863	2.47	295	0.0302	0.52
195	12/11/2013	2.56	3.03	365	1060	2.56	365	0.00288	-0.114
196	1/14/2014	2.55	3.03	358	1060	2.56	365	-0.00612	-0.331
197	2/20/2014	2.55	3.02	351	1040	2.55	358	-0.00566	-0.314
198	3/17/2014	2.54	3	344	998	2.53	343	0.00373	-0.0823
199	4/9/2014	2.54	2.99	349	989	2.53	340	0.0142	0.153
200	4/14/2014	2.53	2.99	343	967	2.52	332	0.0168	0.217
201	5/14/2014	2.29	2.78	194	597	2.3	200	-0.0105	-0.415
202	5/15/2014	2.39	2.9	248	791	2.43	269	-0.0322	-0.781
203	5/29/2014	2.47	2.94	292	869	2.47	297	-0.00419	-0.257
204	6/3/2014	2.35	2.79	225	612	2.31	205	0.0418	0.904
205	6/5/2014	2.34	2.85	221	707	2.38	239	-0.0321	-0.771
206	6/9/2014	1.84	2.36	69.7	231	1.87	73.8	-0.022	-0.669
207	6/12/2014	1.7	2.18	50.5	153	1.68	48.1	0.0245	0.406
208	6/24/2014	2.31	2.76	204	573	2.28	192	0.0308	0.538
209	7/10/2014	2.38	2.82	239	657	2.34	221	0.0359	0.659
210	7/15/2014	2.43	2.88	269	760	2.41	258	0.0215	0.314
211	7/24/2014	2.42	2.89	262	783	2.42	266	-0.00381	-0.249
212	8/4/2014	2.5	2.92	320	823	2.44	280	0.06	1.36
213	8/7/2014	2.43	2.9	269	786	2.42	267	0.00658	-0.0196
214	9/3/2014	1.65	2.17	44.7	149	1.67	46.7	-0.0164	-0.565
215	10/16/2014	2.3	2.78	199	598	2.3	201	0.000617	-0.169
216	12/9/2014	2.52	2.92	328	829	2.45	282	0.0684	1.76
217	12/15/2014	2.55	2.96	352	921	2.5	315	0.0509	1.1
218	2/11/2015	2.57	3.04	373	1090	2.57	376	-0.0003	-0.177
219	2/25/2015	2.53	3.02	339	1040	2.55	357	-0.0196	-0.602
220	4/6/2015	2.56	3	365	999	2.53	343	0.0296	0.511
221	4/16/2015	2.61	2.98	410	960	2.51	330	0.0981	2.28

222	4/22/2015	2.22	2.8	166	627	2.32	211	-0.102	-1.63
223	5/5/2015	2.41	2.88	255	763	2.41	259	-0.00428	-0.265
224	5/20/2015	1.85	2.35	70.6	226	1.86	72.4	-0.00786	-0.356
225	5/27/2015	1.84	2.38	68.6	238	1.88	76.4	-0.0438	-1.02
226	6/10/2015	2.31	2.8	204	627	2.32	211	-0.0117	-0.449
227	6/17/2015	1.81	2.34	64	217	1.84	69.4	-0.0325	-0.803
228	6/29/2015	2.46	2.87	286	735	2.39	249	0.0637	1.6
229	7/13/2015	2.11	2.59	128	385	2.1	127	0.00739	0.0196
230	8/3/2015	2.45	2.88	282	763	2.41	259	0.0391	0.792
231	8/17/2015	2.36	2.77	228	596	2.3	200	0.0615	1.43
232	8/27/2015	1.96	2.47	91.6	298	1.98	96.8	-0.0211	-0.63
233	9/8/2015	2.33	2.74	213	546	2.26	182	0.0705	1.93
234	11/17/2015	2.43	2.84	269	687	2.36	232	0.0671	1.72
235	1/19/2016	2.46	2.88	287	755	2.41	256	0.0526	1.14
236	3/16/2016	2.5	2.94	315	878	2.47	300	0.0242	0.389
237	4/20/2016	2.45	2.9	282	793	2.43	269	0.0234	0.356
238	4/21/2016	2.42	2.88	263	767	2.41	260	0.00717	0.00391
239	5/3/2016	2.06	2.54	115	350	2.06	114	0.00519	-0.0431
240	5/18/2016	2.37	2.82	233	654	2.34	220	0.0284	0.475
241	5/26/2016	1.99	2.5	97.9	314	2.01	102	-0.0154	-0.538
242	5/31/2016	1.88	2.35	76.4	225	1.85	72	0.0289	0.484
243	6/7/2016	2.3	2.75	199	558	2.27	186	0.0308	0.529
244	6/17/2016	1.73	2.25	53.3	178	1.75	56.5	-0.022	-0.659
245	6/21/2016	1.89	2.41	77.3	254	1.91	81.9	-0.022	-0.679
246	6/28/2016	2.3	2.71	199	518	2.23	172	0.0648	1.63
247	7/6/2016	1.66	2.13	46.2	136	1.63	42.6	0.0389	0.781
248	7/13/2016	2.16	2.61	146	409	2.13	135	0.0385	0.771
249	7/25/2016	2.42	2.84	263	698	2.37	236	0.0504	1.07
250	8/11/2016	1.96	2.41	91.5	255	1.91	82	0.0506	1.08
251	8/16/2016	2.28	2.7	189	497	2.21	165	0.0629	1.57
252	8/29/2016	1.84	2.3	68.8	198	1.8	62.8	0.0424	0.928
253	9/7/2016	2.2	2.63	158	426	2.14	140	0.0543	1.2
254	9/13/2016	2	2.43	100	272	1.94	87.8	0.061	1.41
255	10/24/2016	2.5	2.9	319	789	2.43	268	0.078	2.11
256	11/15/2016	2.49	2.9	311	787	2.42	267	0.0686	1.8
257	12/14/2016	2.55	2.96	355	911	2.49	312	0.0599	1.34
258	1/10/2017	2.54	2.97	346	928	2.5	318	0.0396	0.824
259	2/14/2017	2.53	2.94	341	878	2.47	300	0.0594	1.33
260	3/14/2017	2.5	2.95	318	890	2.48	304	0.0223	0.339
261	3/30/2017	1.84	2.35	69.4	225	1.85	72	-0.0128	-0.475
262	4/11/2017	2.23	2.69	169	485	2.2	161	0.0228	0.347
263	5/1/2017	2.12	2.57	131	373	2.08	122	0.0311	0.547
264	5/15/2017	2.34	2.8	220	637	2.33	214	0.0152	0.169
265	5/31/2017	2.46	2.9	285	786	2.42	267	0.0314	0.565
266	6/5/2017	2.39	2.84	243	687	2.36	232	0.0235	0.372
267	6/13/2017	2.51	2.95	321	886	2.48	303	0.0282	0.458
268	6/28/2017	2.48	2.94	305	862	2.47	294	0.0184	0.257
269	7/13/2017	2.43	2.86	269	725	2.39	246	0.0422	0.916
270	7/31/2017	2.36	2.79	227	623	2.32	209	0.0375	0.699
271	8/2/2017	2.39	2.8	247	630	2.32	212	0.0691	1.84
272	8/16/2017	2.43	2.84	268	692	2.37	234	0.0622	1.49
273	8/30/2017	2.46	2.87	286	748	2.4	254	0.0547	1.24
274	9/6/2017	2.44	2.87	279	749	2.4	254	0.0431	0.94
275	10/17/2017	2.45	2.87	283	740	2.4	251	0.056	1.25
276	11/15/2017	2.43	2.86	266	722	2.39	244	0.04	0.858
277	12/12/2017	2.45	2.87	279	749	2.4	254	0.0436	0.977

278	1/18/2018	2.5	2.94	320	866	2.47	296	0.0369	0.679
279	1/31/2018	2.44	2.88	276	765	2.41	260	0.0296	0.502
280	3/6/2018	2.45	2.88	282	754	2.41	256	0.0455	0.99
281	3/22/2018	2.44	2.88	278	753	2.4	255	0.0396	0.835
282	4/18/2018	2.48	2.93	301	856	2.46	292	0.016	0.193
283	5/2/2018	2.49	2.93	309	844	2.46	288	0.0345	0.621
284	5/9/2018	2.52	2.96	328	904	2.49	309	0.029	0.493
285	5/23/2018	2.49	2.98	306	945	2.51	324	-0.0222	-0.689
286	6/1/2018	1.9	2.43	80.3	272	1.94	87.9	-0.0365	-0.869
287	6/6/2018	2.23	2.73	170	531	2.25	177	-0.015	-0.52
288	6/20/2018	2.42	2.83	263	681	2.36	230	0.0603	1.38
289	6/26/2018	2.15	2.61	142	404	2.12	133	0.0321	0.574
290	7/19/2018	1.71	2.19	51.7	154	1.68	48.2	0.0334	0.602
291	7/31/2018	1.78	2.23	60.9	168	1.72	53.2	0.0619	1.47
292	8/16/2018	2.2	2.66	157	457	2.18	151	0.0189	0.265
293	8/28/2018	2.09	2.52	124	329	2.03	107	0.0648	1.66
294	9/6/2018	1.6	2.06	40	114	1.54	35.3	0.0573	1.29
295	9/18/2018	2.34	2.76	219	576	2.28	193	0.0578	1.31
296	10/16/2018	1.87	2.33	74.3	215	1.83	68.5	0.0385	0.76
297	11/19/2018	2.56	3	365	991	2.53	341	0.0336	0.611
298	12/4/2018	2.38	2.89	241	779	2.42	265	-0.0383	-0.904
299	12/17/2018	2.49	2.93	309	859	2.46	293	0.0251	0.415
300	1/29/2019	2.47	2.92	298	837	2.45	285	0.0223	0.331
301	2/19/2019	2.59	3.05	386	1130	2.59	392	-0.00444	-0.273
302	3/14/2019	2.16	2.68	145	483	2.2	160	-0.0403	-0.952
303	3/19/2019	2.28	2.74	189	554	2.26	185	0.0131	0.114
304	4/11/2019	2.38	2.88	238	760	2.41	258	-0.0314	-0.76
305	4/16/2019	2.53	2.99	342	968	2.52	332	0.0149	0.161
306	5/1/2019	1.89	2.33	77.1	214	1.83	68.4	0.0546	1.22
307	5/15/2019	2.03	2.48	107	304	1.99	98.7	0.036	0.669
308	5/23/2019	1.59	2.07	38.8	117	1.56	36.4	0.0312	0.556
309	6/5/2019	2.35	2.79	222	610	2.31	205	0.0376	0.719
310	6/12/2019	2.47	2.9	298	799	2.43	272	0.0431	0.952
311	6/24/2019	1.59	2.11	39.2	129	1.6	40.2	-0.00801	-0.364
312	7/10/2019	2.12	2.57	131	368	2.08	121	0.0379	0.729
313	7/30/2019	2.53	2.93	340	853	2.46	291	0.0702	1.88
314	8/7/2019	2.48	2.9	299	787	2.42	268	0.0511	1.11
315	8/20/2019	1.78	2.27	59.6	186	1.77	59.1	0.00664	-0.0117
316	8/26/2019	1.95	2.41	89.5	255	1.91	82.2	0.0397	0.847
317	9/11/2019	2.41	2.82	256	662	2.35	223	0.0626	1.54
318	10/9/2019	2.49	2.93	310	847	2.46	289	0.033	0.583
319	11/6/2019	2.5	2.91	316	810	2.44	276	0.0625	1.52
320	12/11/2019	2.53	2.96	343	919	2.49	315	0.04	0.869

Definitions

HD: Total hardness -- SDWA NPDWR in mg/L CaCO3 (00900)
SC: Specific conductance in µS/cm @25C (00095)

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