Model Archival Summary for Suspended-Sediment Concentration at U.S. Geological Survey streamflow-gaging station 08067252 Trinity River at Wallisville, Texas.

This model archive summary documents the suspended-sediment concentration model developed to compute 15-minute suspended-sediment concentration from May 16, 2014 at U.S. Geological Survey (USGS) station 08067252 Trinity River at Wallisville, Tex. The methods follow USGS guidance documented in USGS Techniques and Methods, book 2, chapter C5 (Landers and others, 2016).

Site and model information

Site Number: 08067252
Site Name: Trinity River at Wallisville, Tex.
Location: Latitude 29°49'52.71", Longitude 94°45'14.89"W NAD 27
Chambers County, Tex., Hydrologic Unit 12030203, at the Index Velocity gage approximately 2.5 miles upstream of the stage gage at the Trinity River Dam at the U.S. Army Corps of Engineers river lock which is located 3.0 miles west along Interstate Highway 10 from the Interstate overpass over Farm Road 563, 2.0 miles below Wallisville and 3.9 river miles from mouth.
Drainage area: 17,796 square miles
Contributing drainage area: 17,796 square mile

Date rating model was created: 05/18/2016
Model calibration data period: 05/16/2014–12/09/2015
Model application date: Starting 05/16/2014
Computed by: Zulimar Lucena, USGS, Houston, Tex. (zlucena@usgs.gov)
Reviewed by: Mark Landers, USGS, OSW, Atlanta, Ga.
Approved by: Robert Joseph, USGS, TXWSC Director, Austin, Tex.

PHYSICAL SAMPLING EQUIPMENT AND SAMPLING DETAILS

Suspended-sediment samples were collected bi-monthly during the first year of model development, monthly during the second year of model development, and quarterly after the second year of model development during base flow conditions. During high flow events samples are collected at higher frequency depending on the duration of the event. Samples are collected within each of five vertical sections in a cross-section. The location of each vertical section is determined based on discharge and water velocity. When water velocities exceed 1.5 feet per second, the cross section is divided using the equal discharge increment (EDI) method and samples are collected using a US DH-2 sampler. When water velocities are below 1.5 feet per second grab samples are collected along the cross section using weighted bottle sampler. Samples are analyzed for suspended-sediment concentrations (SSC) in the USGS Kentucky Water Science Center Sediment Laboratory.

SURROGATE EQUIPMENT AND SETUP DETAILS

A 1.5-megahertz (MHz) SonTek Argonaut-SL (Side-Looker) ADVM is installed at the site to compute discharge in cubic feet per second (ft^3/s) and obtain sediment backscatter data. The ADVM is bolted to a Cupronickel 2" diameter pipe that is pinned in place to a steel bracket welded onto the stream bulkhead on the right bank of the river. The beams are horizontal and perpendicular to flow. The gage house, containing a battery, solar panel, Data Collection Platform, and regulator is located on the right bank, approximately 10 feet from the ADVM. The ADVM characteristics and configuration are below:

ADVM Characteristics

Make	Model	Frequency (MHz)	Serial Number	Effective Transducer Diameter (m)	Slant beam angle (degrees)	Echo Intensity factor
SonTek	Argonaut SL	1.5	E3902	0.03	25	0.43

ADVM Configuration

Blanking Distance (meter)	Number of cells	Cell Size (meter)	Measurement averaging period (seconds)	Measurement Interval (seconds)	Date Installed
3.05	5	3.05	600 (from 5/16/2014 to 1/15/2015) 60 (from 1/16/2015 to 8/5/2015)	900 (from 5/16/2014 to 1/15/2015) 60 (from 1/16/2015 to 8/5/2015)	5/16/2014

MODEL CALIBRATION DATASET

All data were collected using USGS protocols and are available on the National Water Information System (NWIS) database. The dataset used to develop the regression model consisted of 35 measurements of suspended sediment concentration (EDI and grab samples) and ADVM data collected from May 16, 2014 to December 9, 2016. Two samples were excluded due to missing acoustic backscatter data. Two samples were removed based on outlier diagnostic indicators and further evaluation of the data. From the 35 samples, 31 were used in the model calibration dataset.

The 31 samples were collected over the range of continuously observed streamflow conditions as shown in the duration curves below. The duration curves were developed for streamflow and sediment corrected backscatter (SCB) data collected in May 2014 – December 2015.

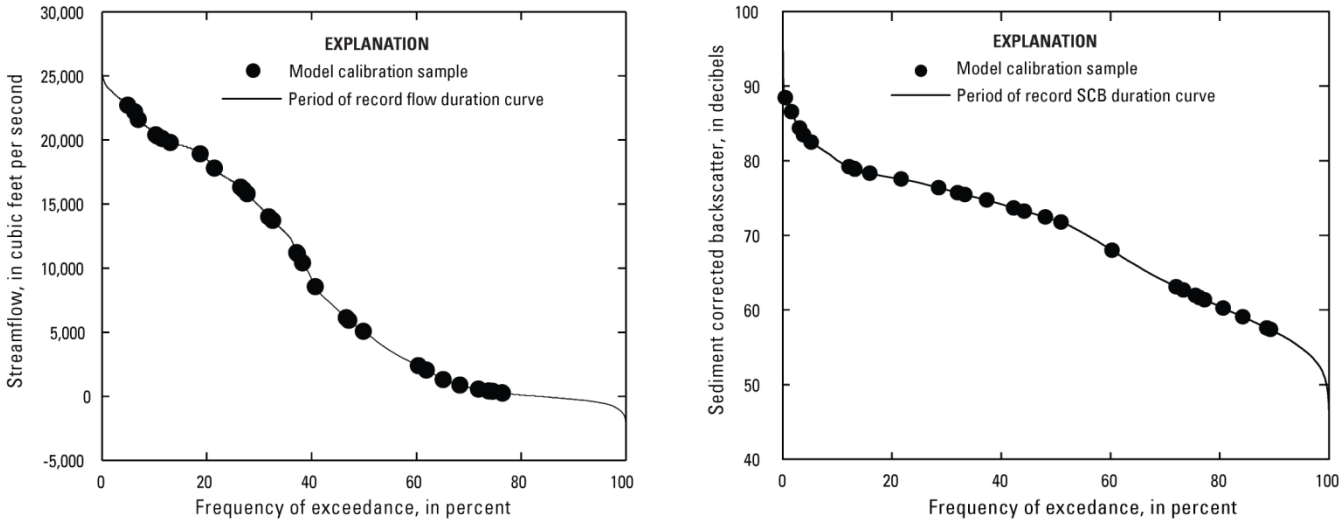


Figure 1. Streamflow and sediment corrected backscatter duration curves at USGS station 08067252 Trinity River at Wallisville, Tex., May 2014-December 2015.

The table below shows summary statistics of suspended sediment concentration data used in the model calibration dataset:

Statistical Parameter	Suspended Sediment Concentration (mg/L)
Minimum	5
Maximum	453
Median	65
Mean	11.3
Count	31

Suspended-sediment finer than 0.0625 mm was measured for 27 samples and ranged from 37 to 100 percent, with a median of 85.5. Percent fines decreased as discharged increased. Full-size analysis was also performed for 6 samples between May 4, 2015 and June 10, 2015 (table 4). For these samples, the fraction of sediment particles smaller than fine sand (<0.25 mm) ranged from 96 to 100 percent.

MODEL DEVELOPMENT:

Suspended sediment concentrations at the site are computed from a calibrated regression model between streamflow, suspended sediment concentrations, and continuously measured surrogates. The model was developed by evaluating mean sediment corrected backscatter ($\overline{SCB}$), sediment attenuation coefficient (SAC), and streamflow as explanatory variables for suspended-sediment concentration (SSC).

By using the Surrogate Analysis and Index Developer (SAID) tool (version 1.0), $\overline{SCB}$ was calculated from measured backscatter following the methods described in Techniques and Methods 3C5 (Landers and others, 2016). The processing settings used in the SAID tool are shown in the table below.

ADVM Processing

[Avg, average calculated from two beams; SNR, signal-to-noise ratio; WCB, water corrected backscatter]

Beam Used	Moving Average Span	Backscatter Values	Cells Used	Near Field Correction	WCB Profile Adjustment
Avg	1	SNR	2-5	Yes	Yes

The SAID tool was also used to develop an ordinary least squares (OLS) linear regression analysis which examined streamflow, SAC, and $\overline{SCB}$ as explanatory variables for estimating SSC. Combinations of these three variables were evaluated to determine the best explanatory variables for SSC. A multiple linear regression model with a combination of streamflow and $\overline{SCB}$ as explanatory variables was determined to be the best model based on adjusted R^2, significance tests, model root mean square error, residual plots, and correlation of explanatory variables. All considered models were evaluated using these statistical measures and are included in a table below. Statistical results and additional detailed statistical information for the selected model are included in the table below titled "Detailed Regression Model Results".

MODEL SUMMARY

The model of SSC for USGS station 08067252 Trinity River at Wallisville, Tex., is shown below:

Linear Regression Model	Adjusted coefficient of determination
$log_{10}SSC = -1.57 + 0.0416\,\overline{SCB} + 0.00003\,Q$	0.92

where,

SSC is the suspended-sediment concentration, in milligrams per liter,
$\overline{SCB}$ is the mean sediment corrected backscatter, in decibels, and
Q is the computed discharge, in cubic feet per second

SSC was transformed before regression analysis and the predicted mean of the variable may be biased. To account for this bias, a non-parametric smearing bias correction factor (BCF) was applied to the predicted variable. BCF was calculated to be 1.09.

Start date	End date	Linear Regression Model	BCF
05/16/2014	--	$SSC = 0.0269\ x\ 10^{0.0416\overline{SCB}}\ x\ 10^{0.00003Q}\ x\ BCF$	1.09

Detailed Regression Model Results

[SSC, suspended-sediment-concentration; SCB, sediment corrected backscatter; Q, discharge; SCB, sediment corrected backscatter]

Rating Equation Form

$\log_{10}SSC = -1.57 + 0.00003Q + 0.0416MeanSCB$

Explanatory and response variable summary statistics

	Q (ft^3/s)	MeanSCB	$\log_{10}SSC$	SSC
Minimum	-691	55.1	0.699	5
1st Quartile	1050	62.3	1.089	12.5
Median	10,600	74.7	1.813	65
Mean	9,730	71.8	1.711	113
3rd Quartile	17,000	78.7	2.257	181
Maximum	23,700	86.5	2.656	453

Rating calibration

Number of observations	31
Error degrees of freedom	28
Root Mean Square Error	0.181
R-squared	0.92
Adjusted R-Squared	0.92
F-statistic vs. constant model	163
p-value	3.87E-16
Variance Inflation Factor (Q, SCB)	2.41, 2.41

Estimated Coefficients

	Estimate	Standard error of coefficients	Student's t-value	p-value	Lower value of 90% confidence interval	Upper value of 90% confidence interval
(Intercept)	-1.57	0.410	-3.8206	0.0007	-2.26	-0.870
Q	3.01E-05	7.11E-06	4.2374	0.0002	0.0000	0.0000
Mean SCB	0.0416	0.00650	6.4312	0.0000	0.0306	0.0526

Non-parametric smearing bias correction factor 1.088

Probability plot correlation coefficient 0.983

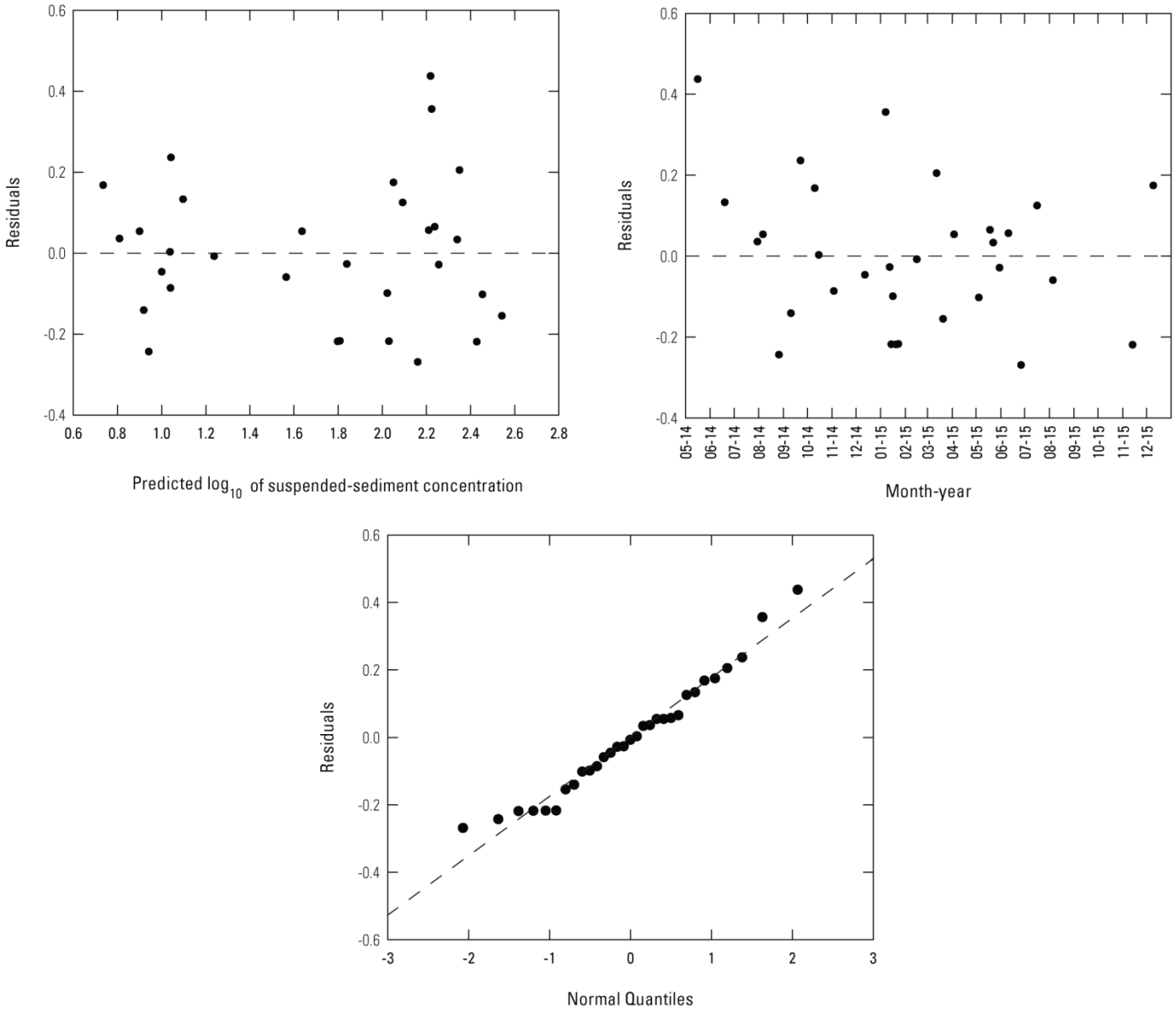
Variance-covariance matrix

	(Intercept)	Discharge	MeanSCB
(Intercept)	0.168	2.23E-06	-0.00260
Discharge	2.23E-06	5.06E-11	-3.79E-08
MeanSCB	-0.00260	-3.79E-08	4.18E-05

Test Criteria

High leverage	0.290
Extreme outlier (Standardized residual)	3 (absolute value)
High influence (Cook's D)	2.12
High influence (DFFITS)	0.622

Residual plots showing distribution of residuals throughout the period of the calibration dataset and the range of predicted log transformed SSC concentrations and a normal quantile plot are shown in figure 2. A scatter plot showing observed and computed SSC is shown in figure 3.



igure 2. Diagnostics plots for selected regression model.

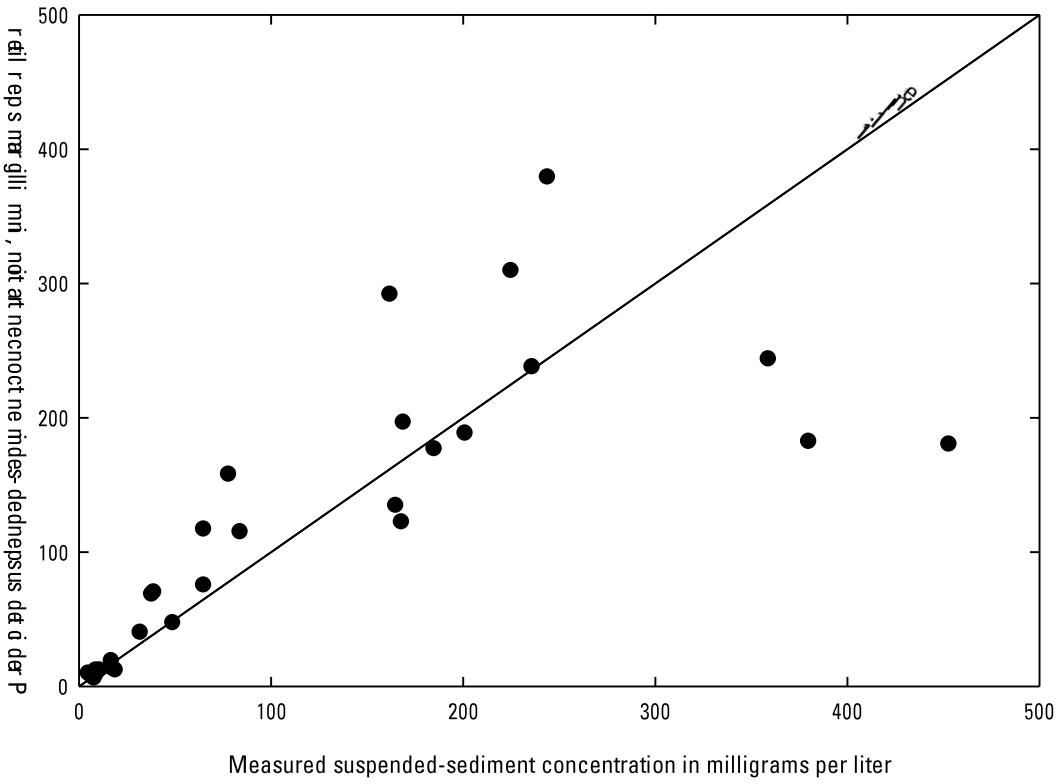


Figure 3. Model predicted and measured suspended-sediment concentrations at USGS station 08067252 Trinity River at Wallisville, Tex.

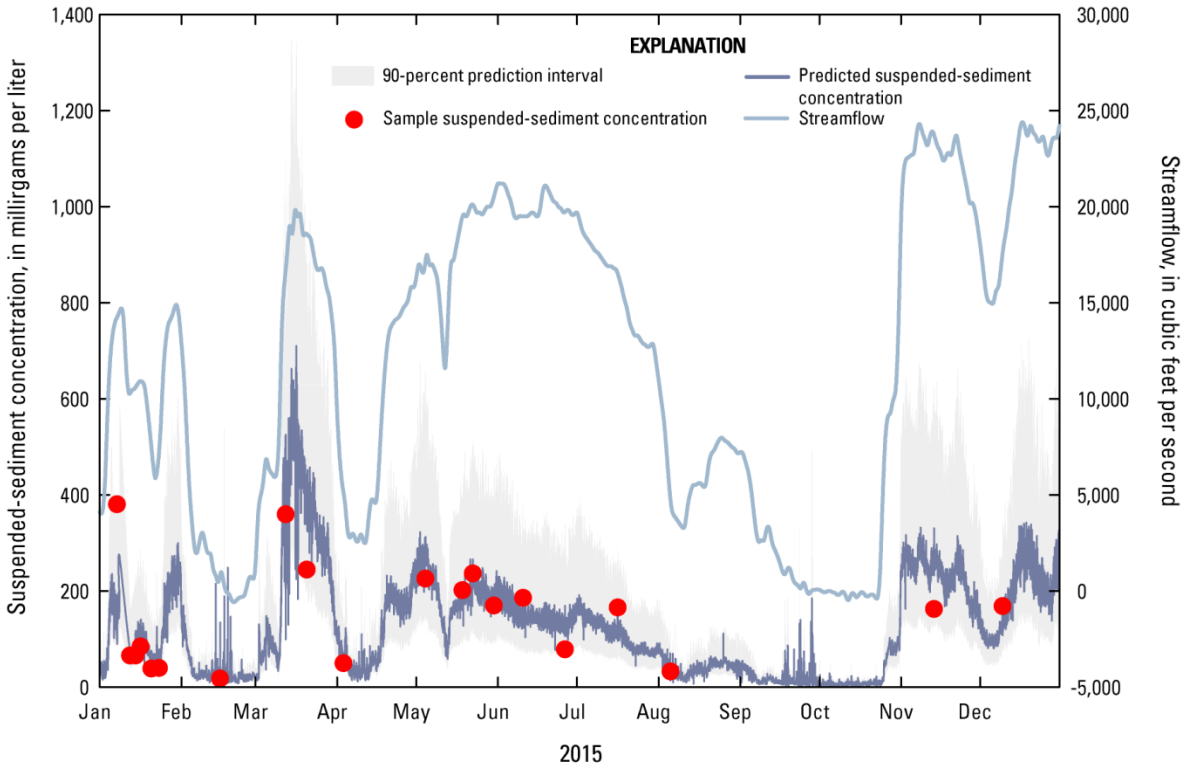
Calibration Dataset

[CST, Central Standard Time; mg/L, milligrams per liter; dB, decibels; ft^3/s, cubic feet per second; log10, base-10 logarithm]

Suspended Sediment Sample			Explanatory Variables		Model Results							
Date and time	Measured SSC		Mean SCB	Computed Discharge	Predicted		Residuals log10	Standardized Residuals	Normal quantiles	Leverage	Cook's D	DFFITS
(CST)	(mg/L)	log10	(dB)	(ft^3/s)	(mg/L)	log10						
5/16/2014 11:35	453	2.656	81.73	12900	180	2.219	0.437	2.538	2.070	0.100	0.239	0.948
6/19/2014 12:40	17	1.230	62.68	1960	14	1.097	0.133	0.759	0.801	0.067	0.014	0.203
7/30/2014 11:45	7	0.845	57.40	-310	7	0.809	0.036	0.210	0.243	0.117	0.002	0.075
8/6/2014 11:13	9	0.954	59.61	-337	9	0.900	0.054	0.312	0.413	0.094	0.003	0.099
8/26/2014 11:38	5	0.699	60.28	132	10	0.942	-0.243	-1.402	-1.633	0.088	0.063	-0.443
9/10/2014 12:13	6	0.778	59.13	943	9	0.919	-0.141	-0.817	-0.695	0.098	0.024	-0.268
9/22/2014 14:00	19	1.279	61.20	2190	12	1.042	0.236	1.355	1.383	0.078	0.052	0.401
10/10/2014 11:46	8	0.903	55.06	469	6	0.735	0.168	1.009	0.917	0.163	0.066	0.445
10/15/2014 12:27	11	1.041	62.13	770	12	1.039	0.003	0.016	0.080	0.075	0.000	0.005
11/3/2014 11:24	9	0.954	62.68	81	12	1.040	-0.086	-0.494	-0.413	0.078	0.007	-0.142
12/12/2014 11:35	9	0.954	60.78	1370	11	1.000	-0.046	-0.265	-0.243	0.082	0.002	-0.078
1/7/2015 12:22	380	2.580	80.55	14700	182	2.224	0.356	2.029	1.633	0.067	0.099	0.579
1/12/2015 11:29	65	1.813	73.71	11400	75	1.840	-0.027	-0.152	-0.080	0.034	0.000	-0.028
1/14/2015 13:12	65	1.813	78.87	10600	117	2.031	-0.218	-1.252	-1.047	0.083	0.047	-0.380
1/16/2015 11:06	84	1.924	78.33	11100	115	2.023	-0.099	-0.565	-0.502	0.069	0.008	-0.151
1/20/2015 12:20	38	1.580	74.76	8550	68	1.798	-0.218	-1.234	-1.198	0.053	0.029	-0.296
1/23/2015 11:42	39	1.591	76.37	6670	70	1.808	-0.217	-1.263	-0.917	0.105	0.062	-0.438
2/15/2015 15:20	17	1.230	68.00	-691	19	1.238	-0.008	-0.047	0.000	0.126	0.000	-0.017
3/12/2015 12:10	359	2.555	83.44	14900	244	2.350	0.205	1.193	1.198	0.107	0.057	0.415
3/20/2015 12:24	244	2.387	86.54	17000	379	2.542	-0.155	-0.920	-0.801	0.142	0.047	-0.374
4/3/2015 10:55	49	1.690	73.24	5290	47	1.636	0.054	0.309	0.327	0.080	0.003	0.089
5/4/2015 12:50	225	2.352	84.42	17000	310	2.454	-0.102	-0.594	-0.596	0.104	0.014	-0.200
5/18/2015 13:00	201	2.303	76.76	20400	188	2.238	0.065	0.381	0.596	0.116	0.006	0.136
5/22/2015 11:45	236	2.373	79.13	20500	238	2.340	0.033	0.193	0.161	0.097	0.001	0.062
5/30/2015 11:30	169	2.228	77.35	20200	196	2.257	-0.029	-0.167	-0.161	0.106	0.001	-0.056
6/10/2015 14:15	185	2.267	75.44	21300	177	2.210	0.057	0.340	0.502	0.158	0.007	0.145
6/26/2015 12:57	78	1.892	74.76	20600	158	2.161	-0.269	-1.607	-2.070	0.151	0.153	-0.697
7/16/2015 12:59	165	2.217	75.72	17000	135	2.092	0.125	0.714	0.695	0.067	0.012	0.190
8/5/2015 12:20	32	1.505	71.77	4920	40	1.564	-0.059	-0.338	-0.327	0.067	0.003	-0.089
11/13/2015 12:45	162	2.210	78.95	23700	292	2.429	-0.219	-1.322	-1.383	0.167	0.117	-0.600
12/9/2015 11:55	168	2.225	75.22	16300	122	2.051	0.175	0.992	1.047	0.062	0.022	0.254

Suspended-sediment concentration record

The continuous time-series SSC record is computed using the regression model from May 16, 2014 through December 31, 2015. Data are computed at 15-minute intervals. Figure 4 shows the suspended-sediment concentration continuous record from January-December 2015.



Alternative models

[--, not applicable]

Response variable	Explanatory variables	Root mean square error	R^2	Adjusted R^2	Variance Inflation Factor
SSC	meanSCB	82.0	0.58	0.57	--
log_{10}SSC	meanSCB	0.229	0.87	0.87	--
log_{10}SSC	log_{10}Q	0.281	0.79	0.79	--
log_{10}SSC	Q	0.276	0.81	0.80	--
log_{10}SSC	SAC	0.590	0.14	0.11	--
log_{10}SSC	meanSCB, SAC	0.223	0.88	0.87	1.0, 1.0
log_{10}SSC	meanSCB, log_{10}Q	0.209	0.89	0.99	1.6,1.6
log_{10}SSC	meanSCB, Q, SAC	0.213	0.89	0.87	2.5, 2.4, 3.9