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Computation of Time-Series Suspended-Sediment Concentrations and Loads Using In-Stream Turbidity and Streamflow

Patrick Rasmussen, USGS Kansas Water Science Center Lawrence, Kansas

Presented by Andy Ziegler

Real-Time Water-Quality Workshop
June 8, 2011
St. John’s, Newfoundland, CA

Turbidity-SSC Guidelines

- First deviation from USGS techniques using streamflow to compute fluvial-sediment discharge by Porterfield since 1972…
- Sub-daily time-series suspended-sediment concentration computed from turbidity
- Published USGS Techniques and Methods (June 2009, revised in 2011)

  http://pubs.usgs.gov/tm/tm3c4/

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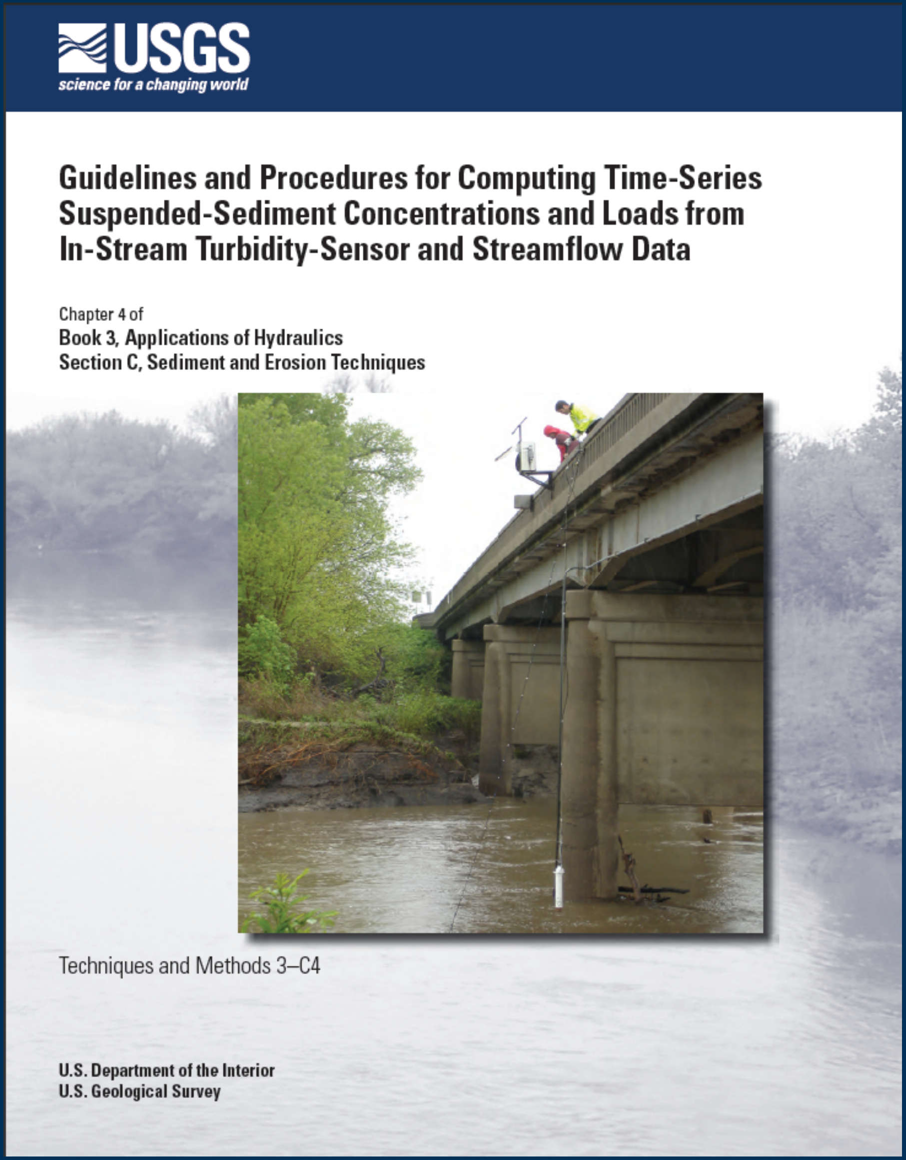
Contributing Authors

Patrick Rasmussen, KS WSC

John R. Gray, OSW

Doug Glysson, OWQ

Andrew Ziegler, KS WSC



Three steps to computing SSC

- Compile model calibration data set
- Develop a site-specific single or multiple linear regression model
- Compute a time series of suspended-sediment concentration and load

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Step 1 – Model calibration data set

- Calibration data set
  - Turbidity time-series record
    - Fixed in-stream sensor (Wagner and others, 2006)
    - Turbidity cross-section measurements
    - Turbidity includes-
      - Nephelometry
      - Optical Backscatter
  - SSC of samples
    - Depth integrated, EDI or EWI (Nolan and others, 2005; Edwards and Glysson,1999)
    - Sample full range of hydrologic conditions
  - Streamflow time-series record

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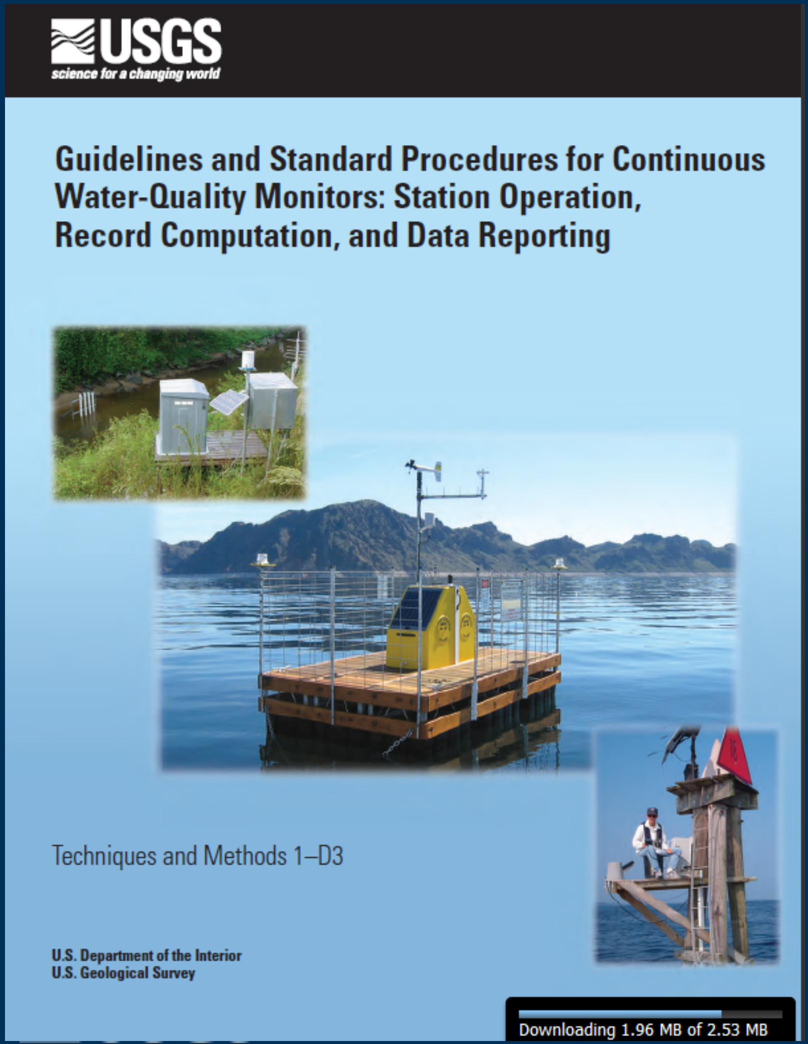
Step 1 – Model calibration data set

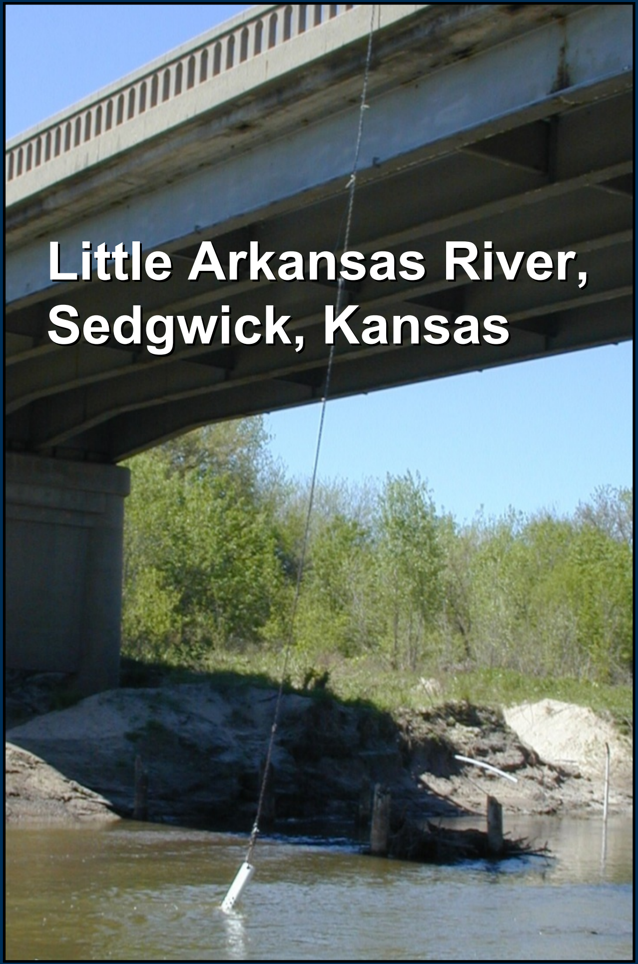
Fixed in-stream sensor (Wagner and others, 2006)

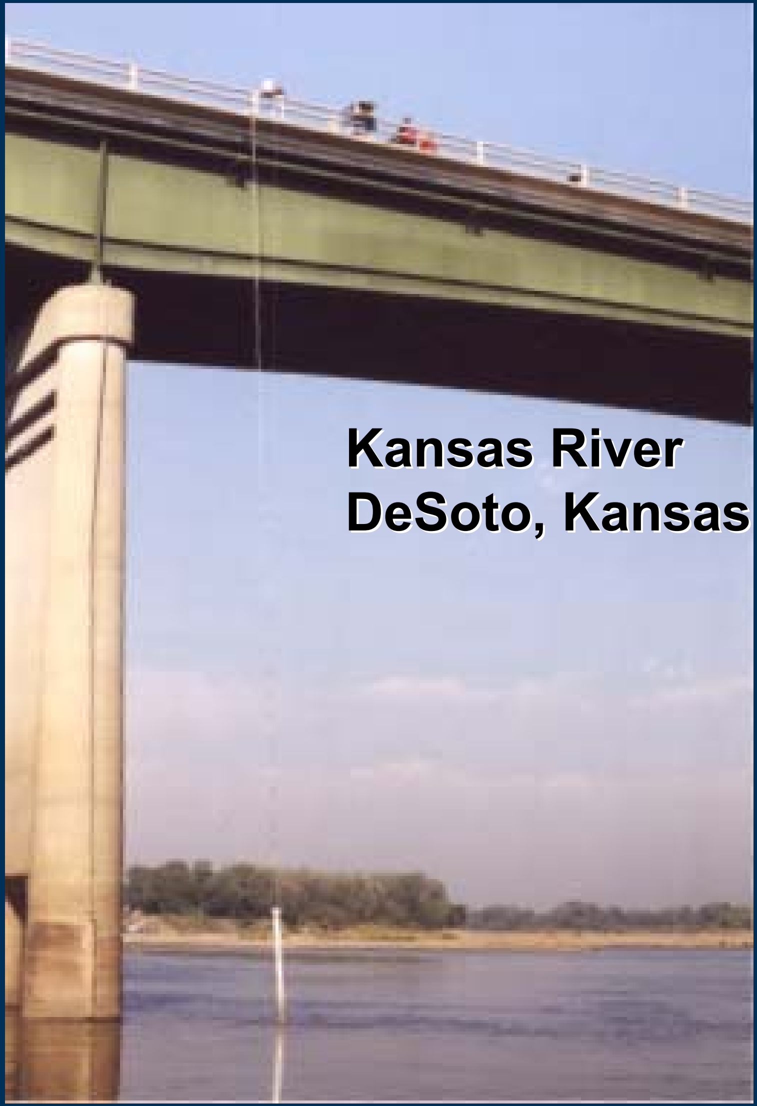


- Don't "over calibrate" optical sensors
- If recalibration needed, usually a problem with the standard
- New wipers are more robust
- Sensor stays clean in velocity

Step 1 – Model calibration data set

Fixed in-stream sensor (Wagner and others, 2006)





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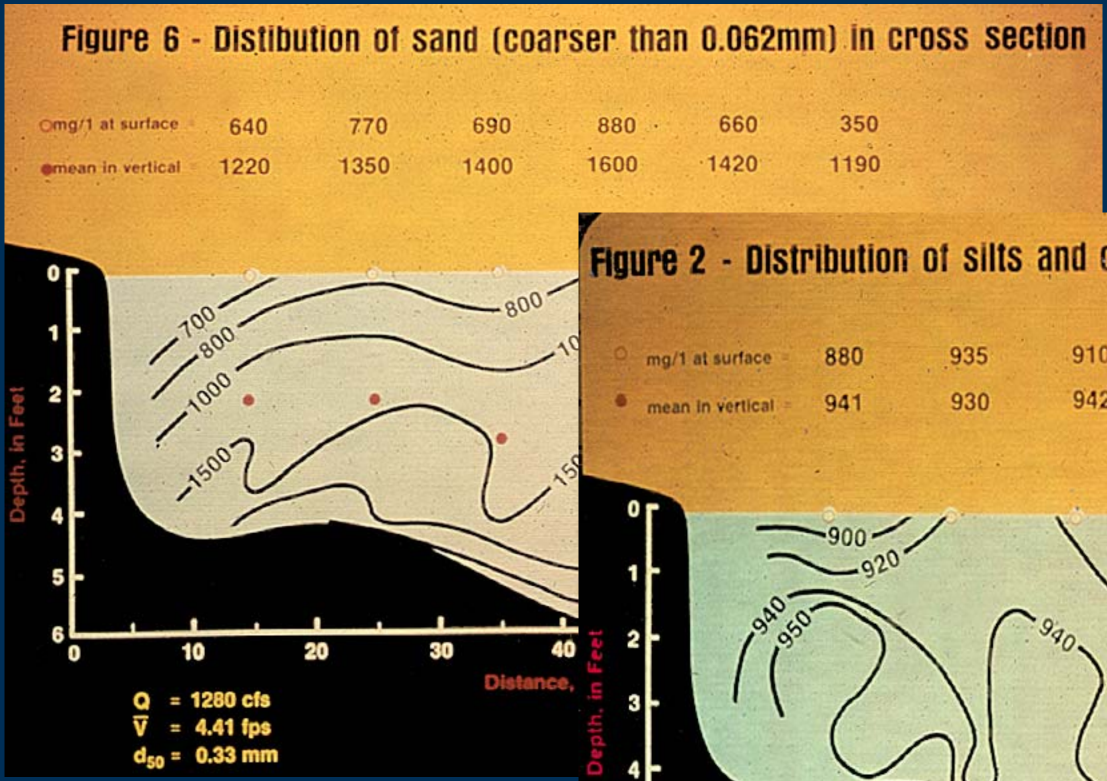
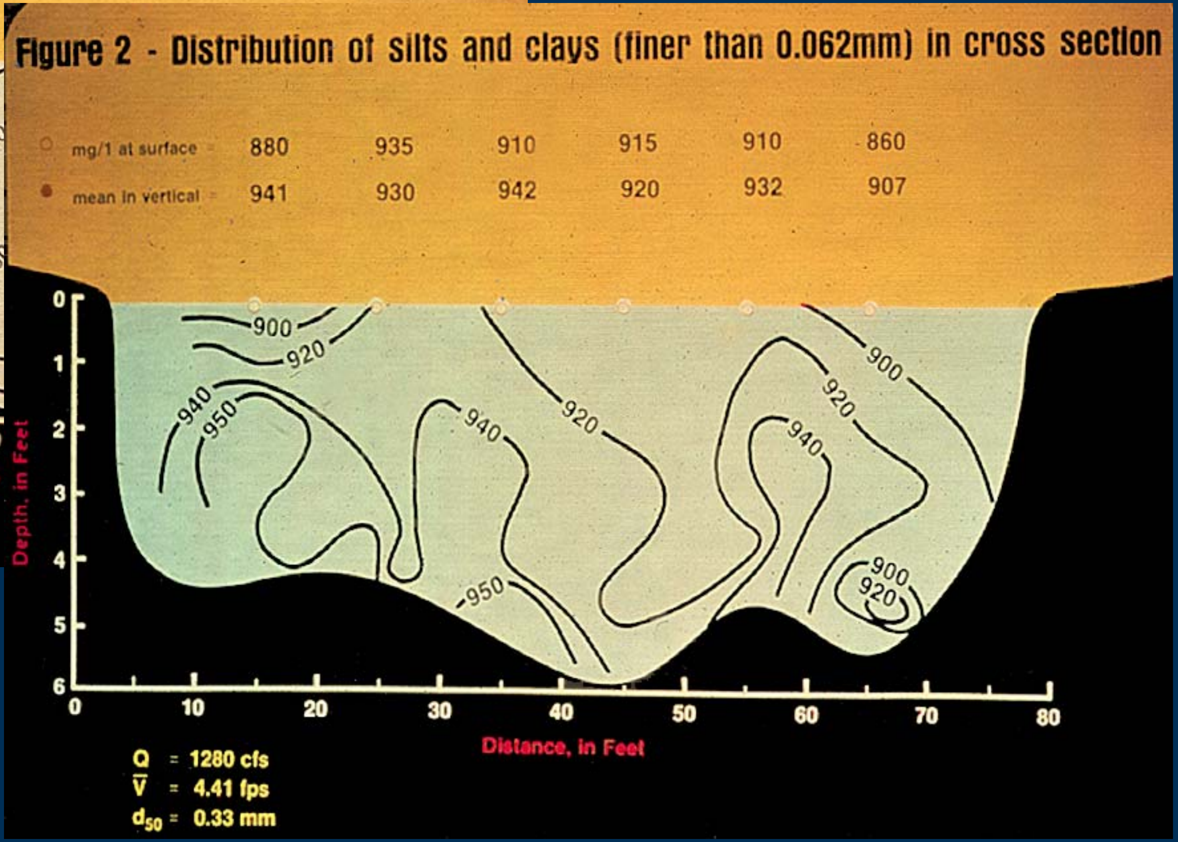
Step 1 – Model calibration data set

Turbidity cross-section measurements

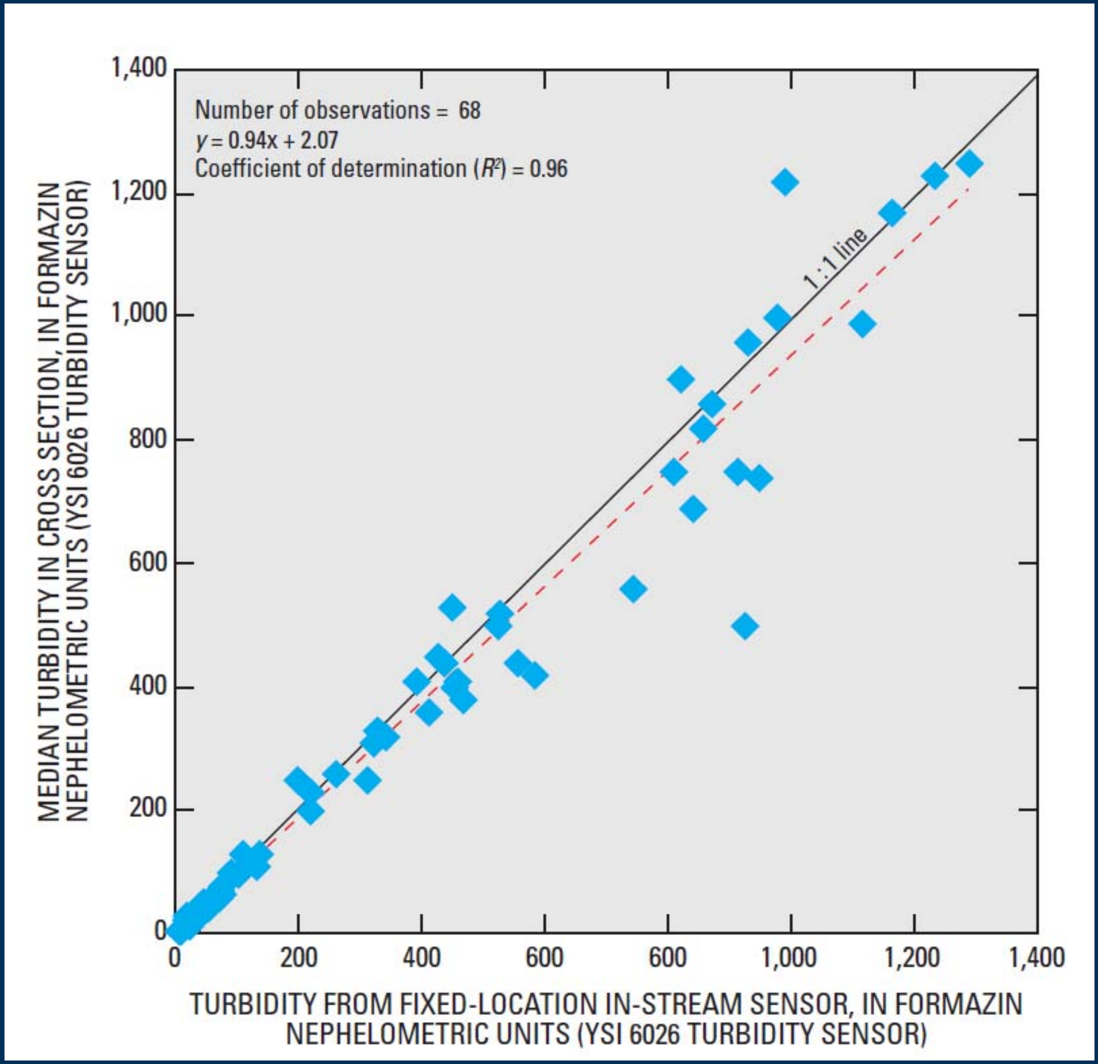




Step 1 – Model calibration data set

Turbidity cross-section measurements

Measurements must represent the entire stream



http://pubs.usgs.gov/tm/tm3c4/

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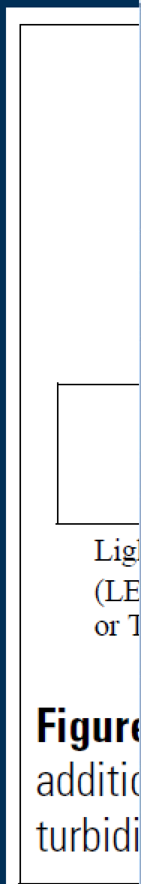
Step 1 – Model calibration data set

Turbidity measurements- nephelometry and optical backscatter



	A	B	C	D	E	F	G	H	I	J
1	Version: January 2007									
2	NWIS PCODE	Method Short Name	Method Source (NWQL, EPA, ASTM, Std. Meth., etc.)	Method Number	NWIS New Method Code	NWIS Old Method Code	Is Method Approved? (meets require-ments in OWQ Tech Memo 98.05)	Static / Submersible / Process	Comments	Website
71	FNU A93) Instruments - Near Infra-Red (780-900 nm) or Monochrome light source. 90 ° detection angle, one detector									
72	63680	Eureka Environmental, Sensor model Trimeter, FNU	ISO	7027	TS031	A	N/A		Uses Analite NEP9500 Series turbidity probe	
73	63680	Forest Technology Systems, Sensor Model DTS-12, FNU	ISO	7027	TS032	B	N/A	Dynamic	May not be technically compliant with ISO 7027, based on noise ratios	
74	63680	Greenspan, sensor model TS 100, FNU	ISO	7027	TS034	C	N/A	Dynamic		
75	63680	Greenspan, sensor model TS 300, FNU	ISO	7027	TS036	D	N/A	Dynamic		
76	63680	Greenspan, sensor model TS 1200, FNU	ISO	7027	TS035	E	N/A	Dynamic		
77	63680	HACH, sensor model 2100 N IS (Ratio OFF), FNU	ISO	7027	TS040	F	N/A	Static	With Infra-red filter installed downstream of white light source	
78	63680	HACH, sensor model 2100 AN IS (Ratio OFF), FNU	ISO	7027	TS038	G	N/A	Static	With Infra-red filter installed downstream of white light source	
79	63680	HACH, sensor model 1720 D/L, FNU	ISO	7027	TS037	H	N/A	Process	Discontinued	
80	63680	HACH, sensor model Optiquant, FNU	ISO	7027	TS041	I	N/A	Process		
81	63680	HACH, sensor model Pocket Turbidimeter, FNU	ISO	7027	TS042	J	N/A	Static		
	63680	HF Scientific, Sensor Model	ISO	7027	TS047	K	N/A	Static		

Sheet1 Sheet2 Sheet3

100%

http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html

Turbidity values different dependent on sensor

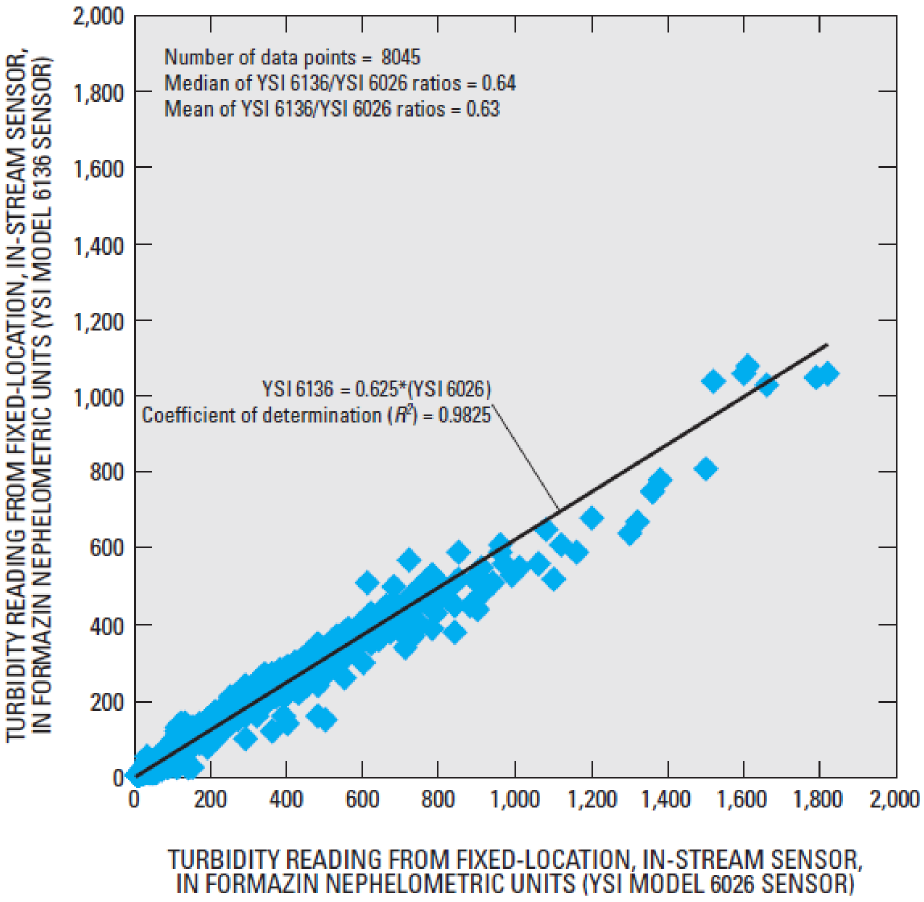


Figure 18. Relation between YSI 6026 and YSI 6136 turbidity sensor values, U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas, July 14, 2004, to August 26, 2005.

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Optical backscatter

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Products » Sensors » Turbidity Sensors » OBS-5+

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OBS-5+ High Suspended Sediment Concentration Monitoring System w/Pressure Sensor

Overview | Specifications | Compatibility | Ordering Info | Support | Ask an Expert

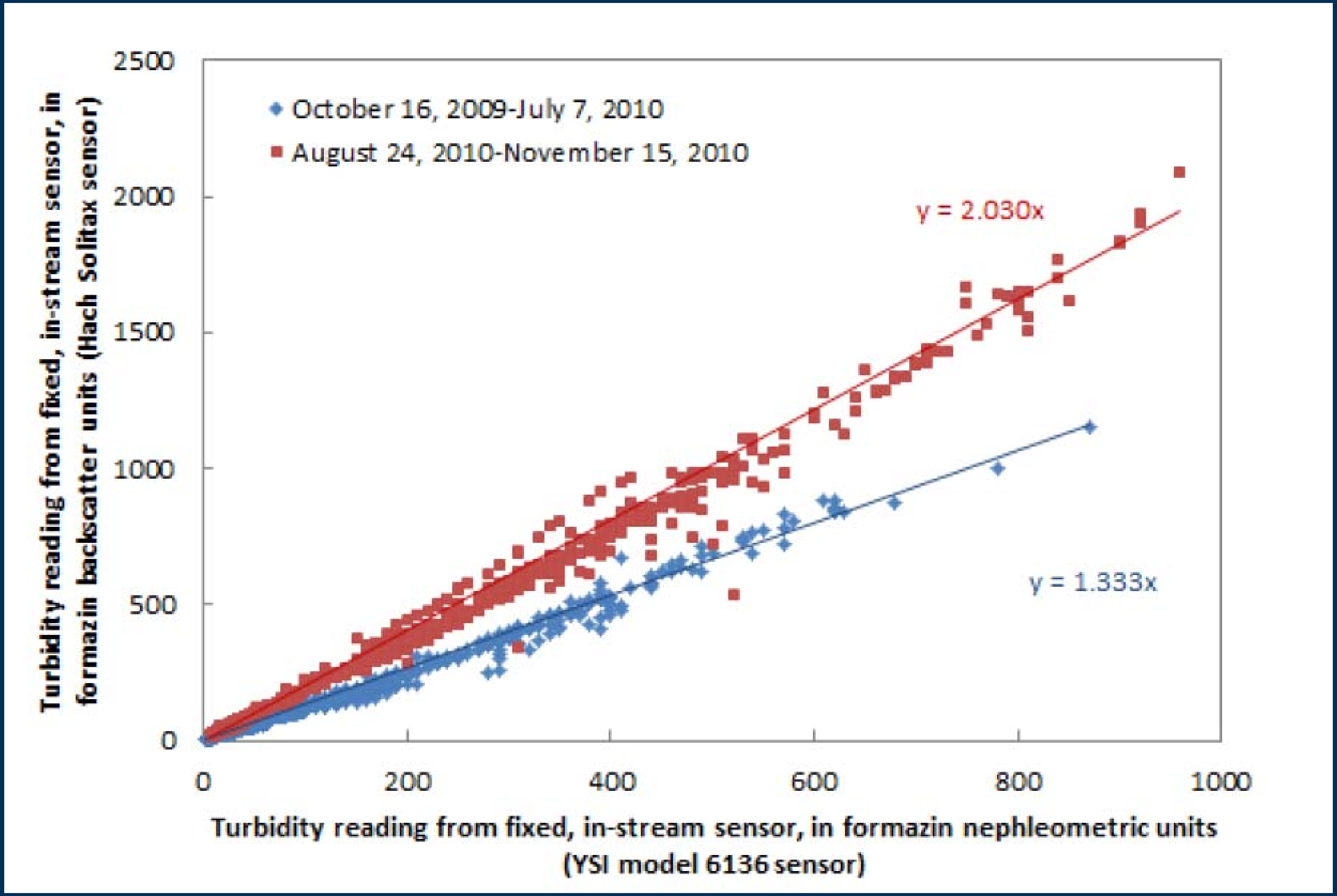
The OBS-5+ is a monitoring system that can measure high sediment concentrations in applications such as dredging and site remediation. It uses an infrared laser and a patented multiple-detector system. It connects to a PC and uses a Windows GUI to generate and store data tables containing concentration and depth. The OBS-5+ can also record data internally.

OBS-5+ Benefits

- Connects directly to a PC--no datalogger needed
- Can also store data internally
- Operates up to six months on three C-cell batteries
- Monitors very high sediment concentrations: up to 200g/l

sensor wipers reduce erroneous values and maintenance due to biological growth while eliminating the need for extraneous cleaning and air purge systems. With no potted components, fully-serviceable SOLITAX sc sensors deliver twice the typical sensor life at reduced maintenance cost. Ready-to-install sensor mounting kits allow tank immersion or in-pipe installation.

Turbidity vs OBS



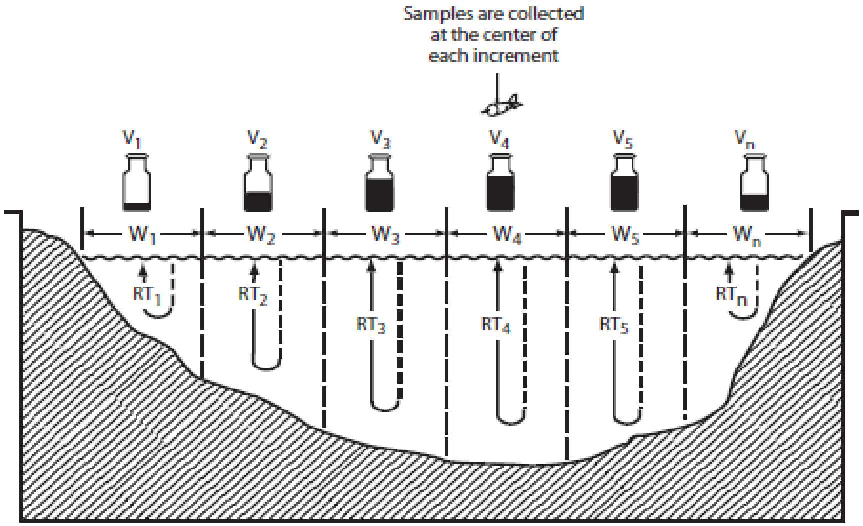
USGS **Always store the make and model with data**

Step 1 – Model calibration data set

SSC of samples
EDI/EWI

Isokinetic sampling

http://water.usgs.gov/owq/FieldManual/chapter4/pdf/Chap4_v2.pdf



EXPLANATION

RT TRANSIT RATE (transit rate at each sampling vertical is equal)

W WIDTH (width of each increment is equal)

V VOLUME COLLECTED AT EACH VERTICAL PROPORTIONAL TO THE DISCHARGE OF EACH INCREMENT

SAMPLING VERTICAL OF EACH EQUAL-WIDTH INCREMENT (SAMPLES COLLECTED)—The vertical transit rate relative to sample volume that is proportional to the stream discharge of each increment

Figure 4-4. Equal-width-increment method for collection of water samples (modified from Edwards and Glysson, 1999).

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Step 1 – Model calibration data set

SSC of samples related to in-stream monitor values

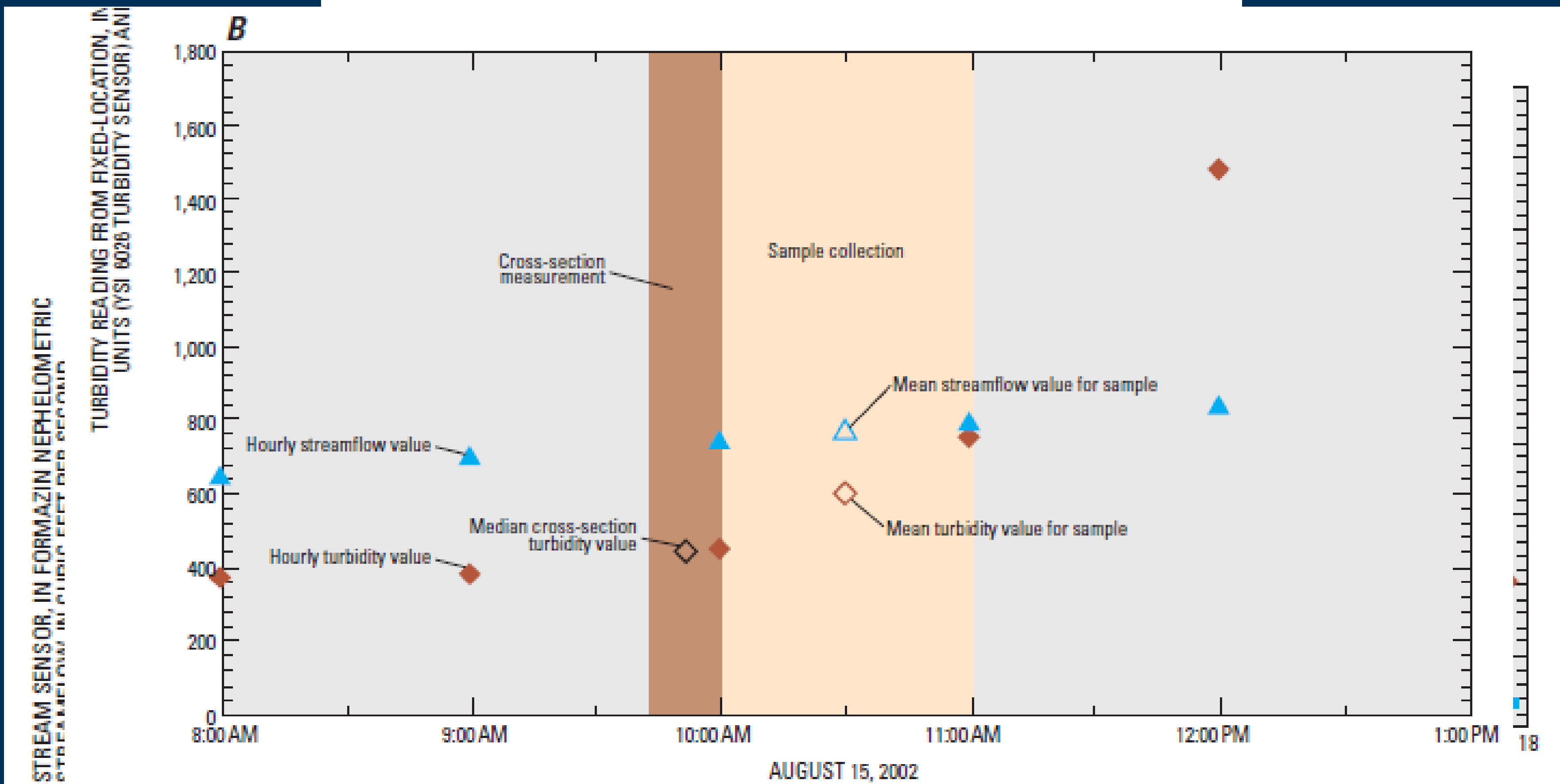
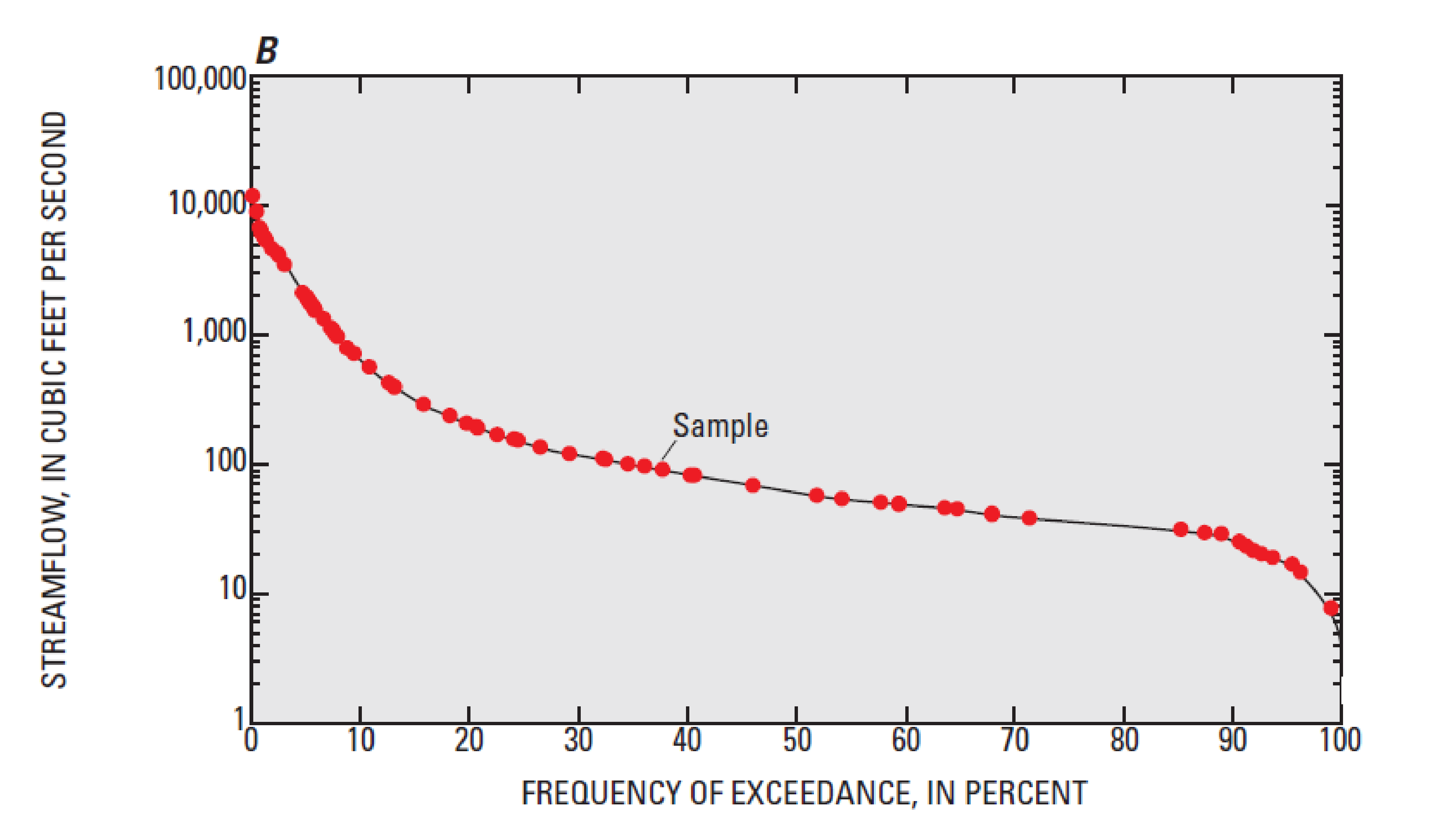


Figure 5. *A,* Time-series turbidity and streamflow data, August 14–18, 2002, and *B,* duration of cross-section turbidity and suspended-sediment sample collection, August 15, 2002, at U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas.

Figure 5. *A,* Time-series turbidity and streamflow data, August 14–18, 2002, and *B,* duration of cross-section turbidity and suspended-sediment sample collection, August 15, 2002, at U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas.

Step 1 – Model calibration data set

SSC samples collected over range in sensor conditions



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Step 1 – Model calibration data set

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    - Fixed in-stream sensor (Wagner and others, 2006)
    - Turbidity cross-section measurements
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  - SSC of samples
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    - Sample full range of hydrologic conditions
  - Streamflow time-series record

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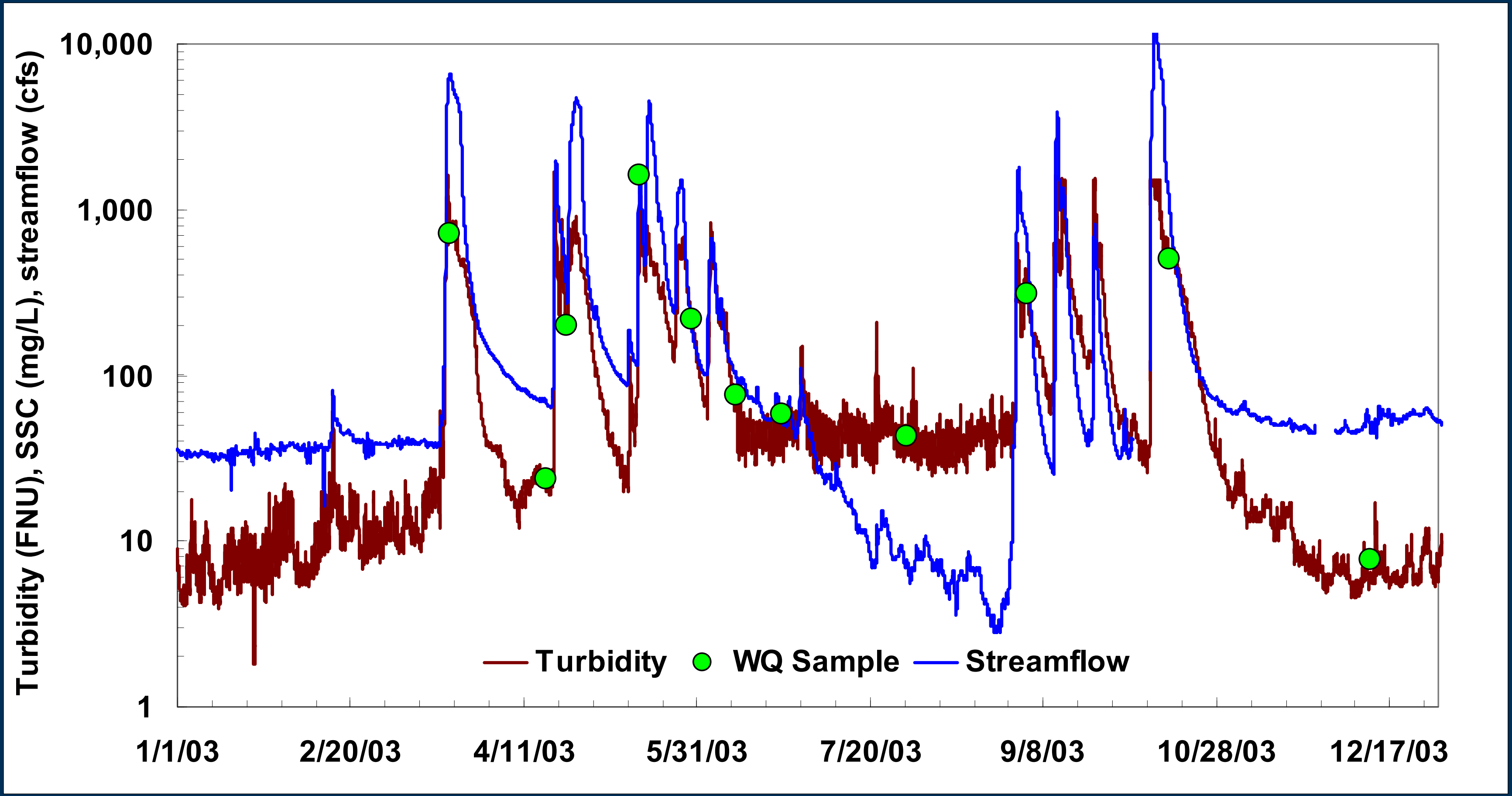
Step 1 – Compile calibration data set



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Step 2 – Develop regression model

- Simple linear regression (SLR)
  - Plot data
    - Turbidity is explanatory variable
    - SSC is response variable
  - $\log_{10}$ transformation
    - Symmetry, linear, constant variance
    - Retransformation requires bias correction factor
  - Regression provides expressions of uncertainty
  - Plot data

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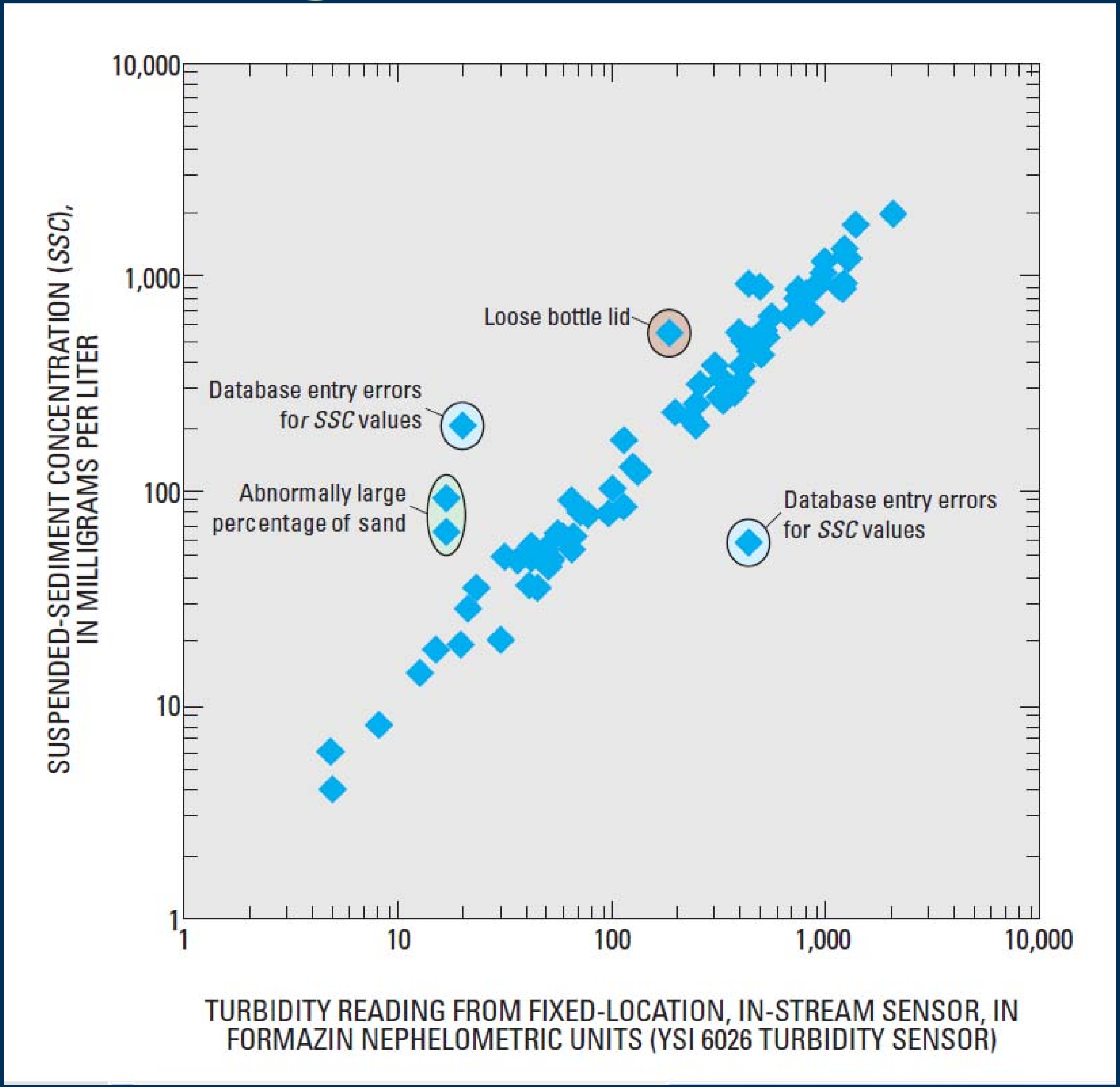
Step 2 – Develop regression model

Turbidity is explanatory variable

SSC is response variable



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Step 2 – Develop regression model

- **Untransformed**
- **Transformed**

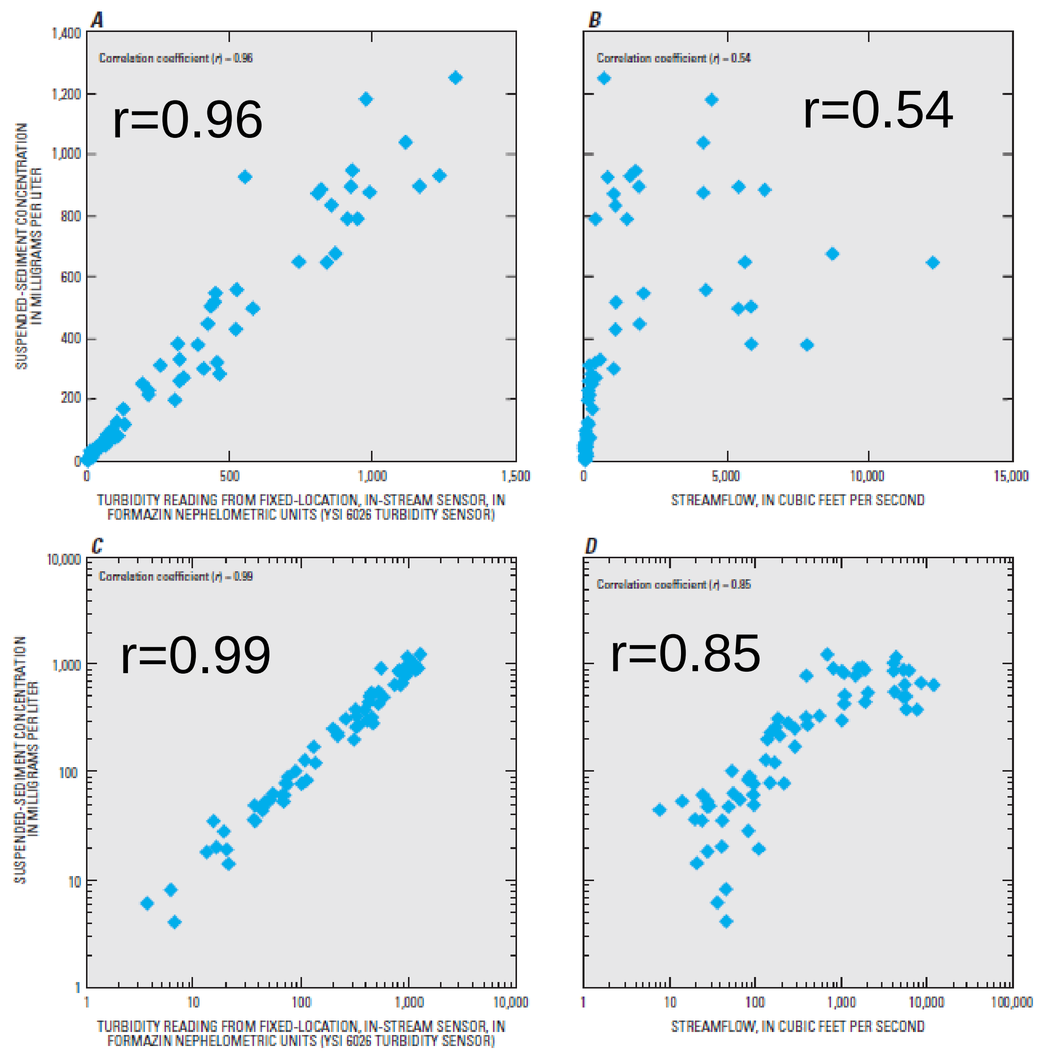

Figure 8. Relations between *A*, turbidity and suspended-sediment concentration, *B*, streamflow and suspended-sediment concentration in linear space, *C*, turbidity and suspended-sediment concentration, and *D*, streamflow and suspended-sediment concentration in $\log_{10}$ space for U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas, 1999–2005.

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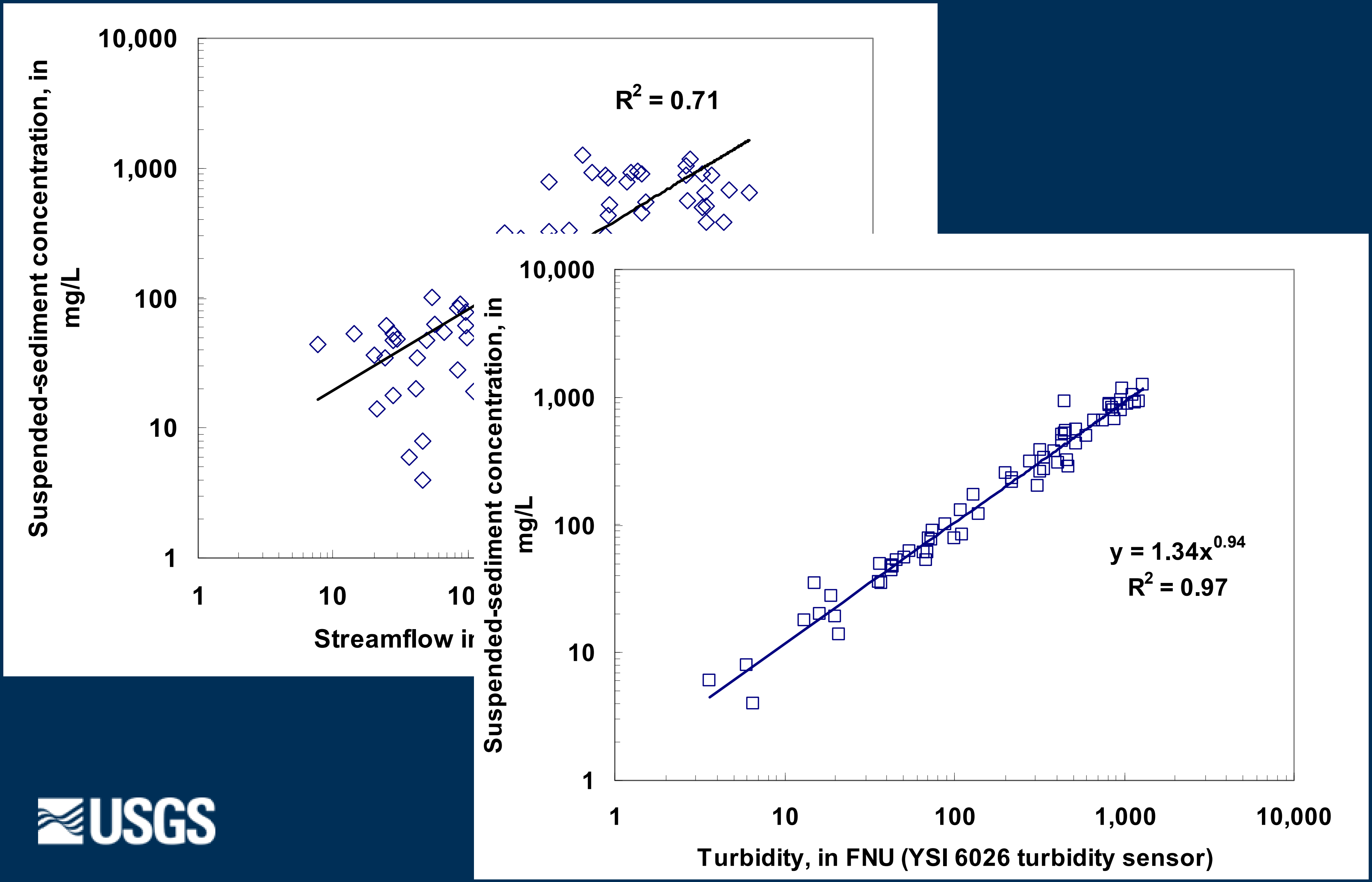
Turbidity is MUCH better for computing SSC



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Step 2 – Develop regression model

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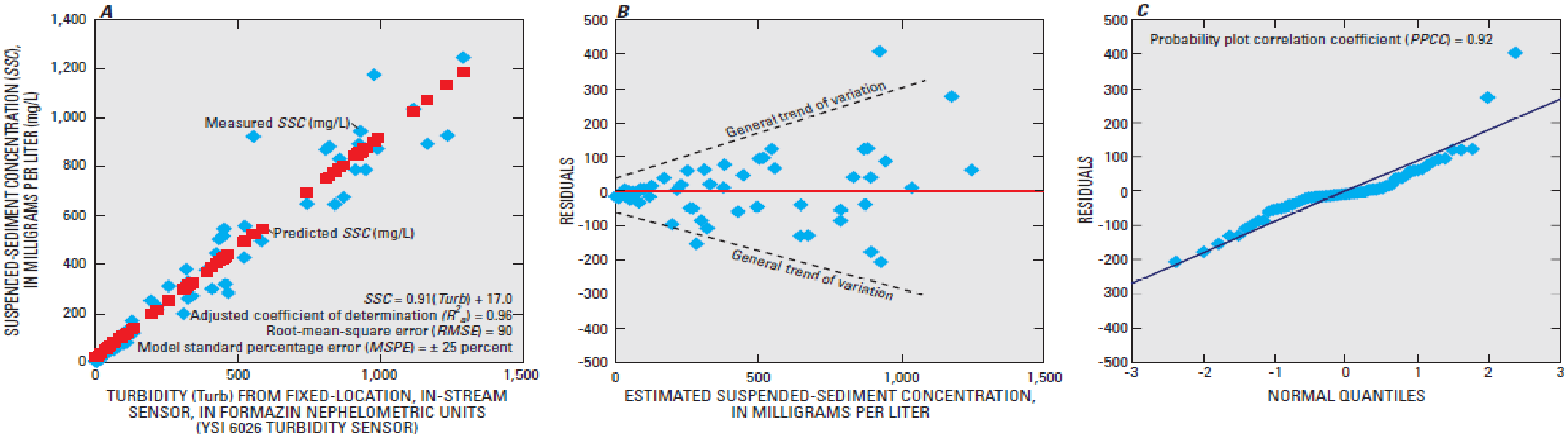


Figure 10. Results of simple linear regression analysis for *A*, turbidity and suspended-sediment concentration data, and a comparison of *B*, computed suspended-sediment concentrations and regression residuals, and *C*, probability plot of residuals for U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas, 1999–2005.

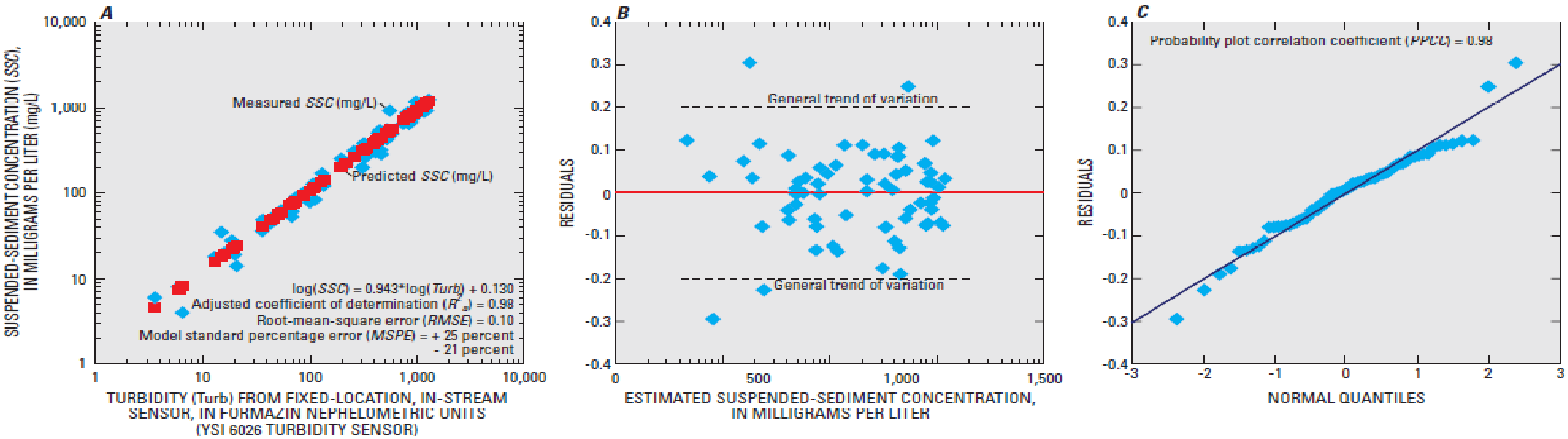


Figure 11. Results of simple linear regression analysis using log-transformed data for *A*, turbidity and suspended-sediment concentration data, and comparison of *B*, estimated $\log_{10}$ suspended-sediment concentration and regression residuals, and *C*, probability plot of residuals for U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas, 1999–2005.

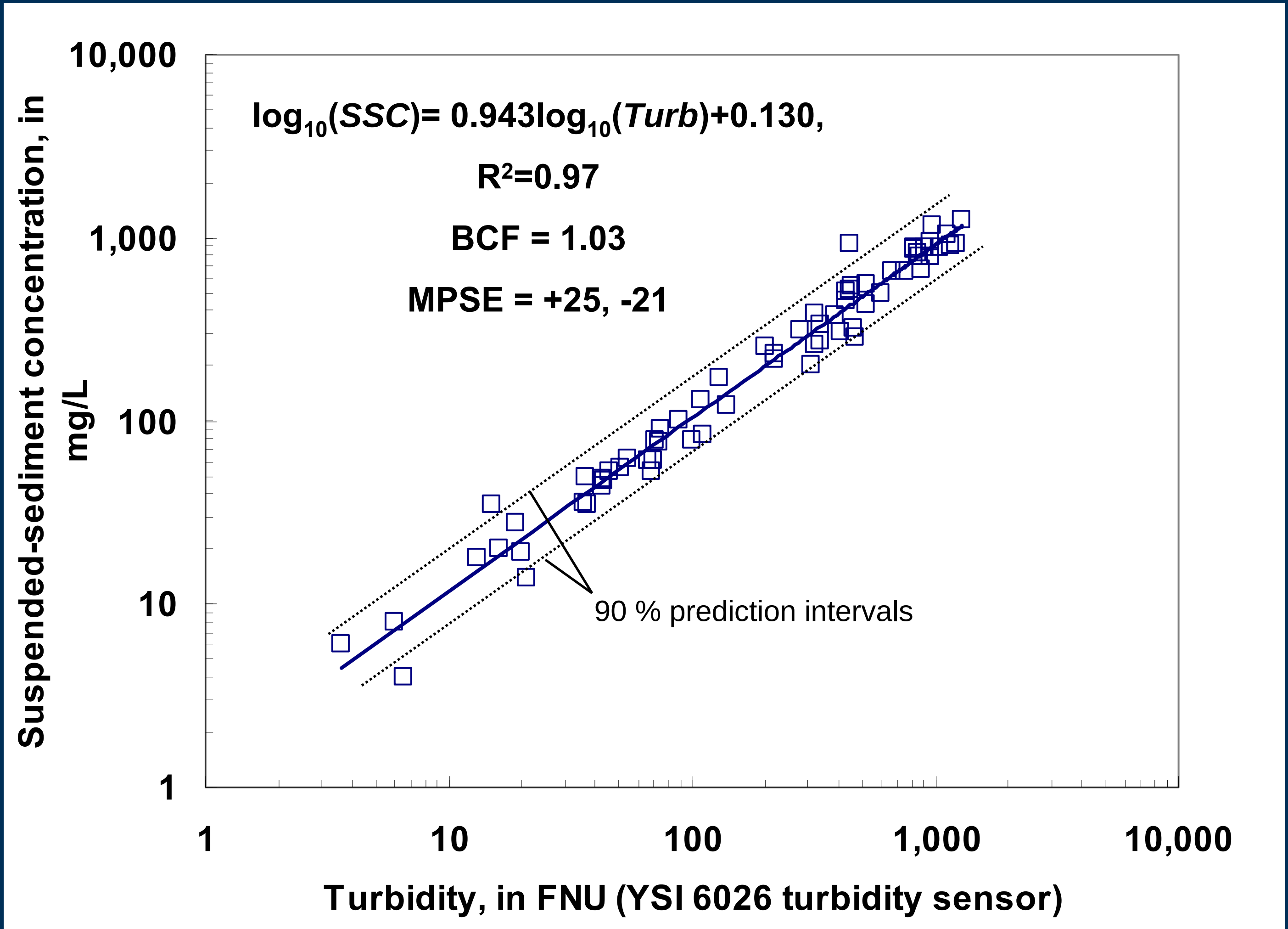
Step 2 – Develop regression model

Step 2 – Develop regression model

Retransformation requires bias correction factor

Regression provides expressions of uncertainty

Plot data



Step 2 – Develop regression model

$$\log_{10}(SSC) = b_1\log_{10}(Turb)+b_0 \qquad (6)$$

$$\log_{10}(SSC) = 0.943\log_{10}(Turb)+0.130$$

$$SSC = (10^{b_0}Turb^{b_1})* \text{BCF} \qquad (7)$$

$$SSC = (10^{0.130}Turb^{0.943})*1.03$$

$$SSC = 1.39Turb^{0.943}$$

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Step 2 – Develop regression model

- Multiple linear regression (MLR)
  - If SLR model percentage standard error (MPSE) > 20
  - Plot data
    - Streamflow vs. SLR residuals
    - Time vs. SLR residuals
  - Use MLR if-
    - MPSE < 20 or < SLR MPSE, and
    - Significant p-value (<0.025) for streamflow
    - Turbidity and streamflow are explanatory variables

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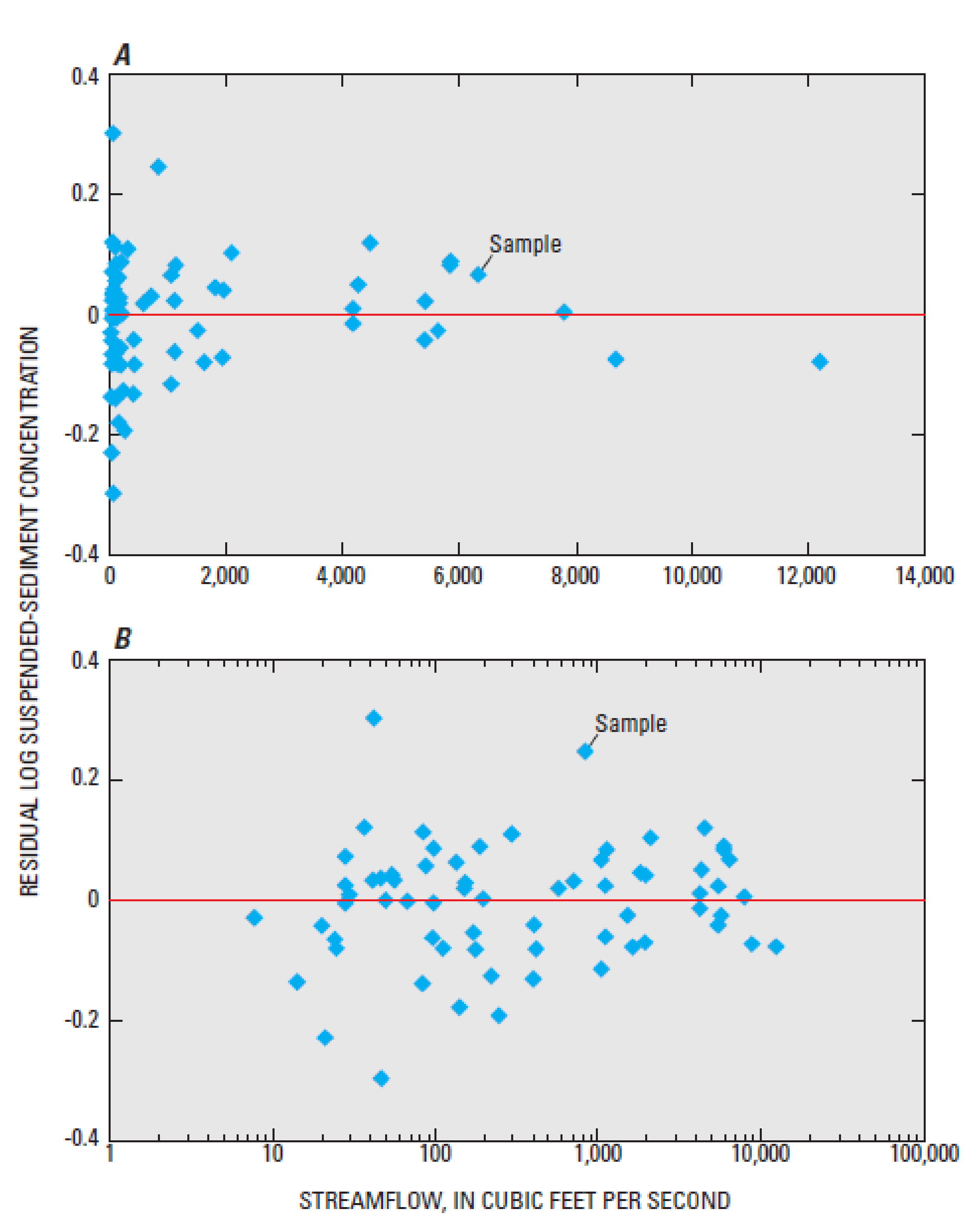
Step 2 – Develop regression model



Step 2 – Develop regression model

[*n*, number of samples; R^2_a, adjusted coefficient of determination; *RMSE*, root-mean-squared error in log units; *MSPE*, model standard percentage error; n/a, not applicable]

Explanatory variables	*n*	R^2_a	*RMSE*	*MSPE*	p-value for streamflow	t-statistic for streamflow
Turbidity	68	0.975	0.101	+25.9, -20.6	n/a	n/a
Turbidity and streamflow	68	0.977	0.098	+25.3, -20.2	0.043314	2.06

- R_a^2, RMSE, and MSPE all improve
- p-value for Q is < 0.05, but > 0.025
- Plot both model results

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Step 2 – Develop regression model

SLR
Turb

MLR
Turb
& Q

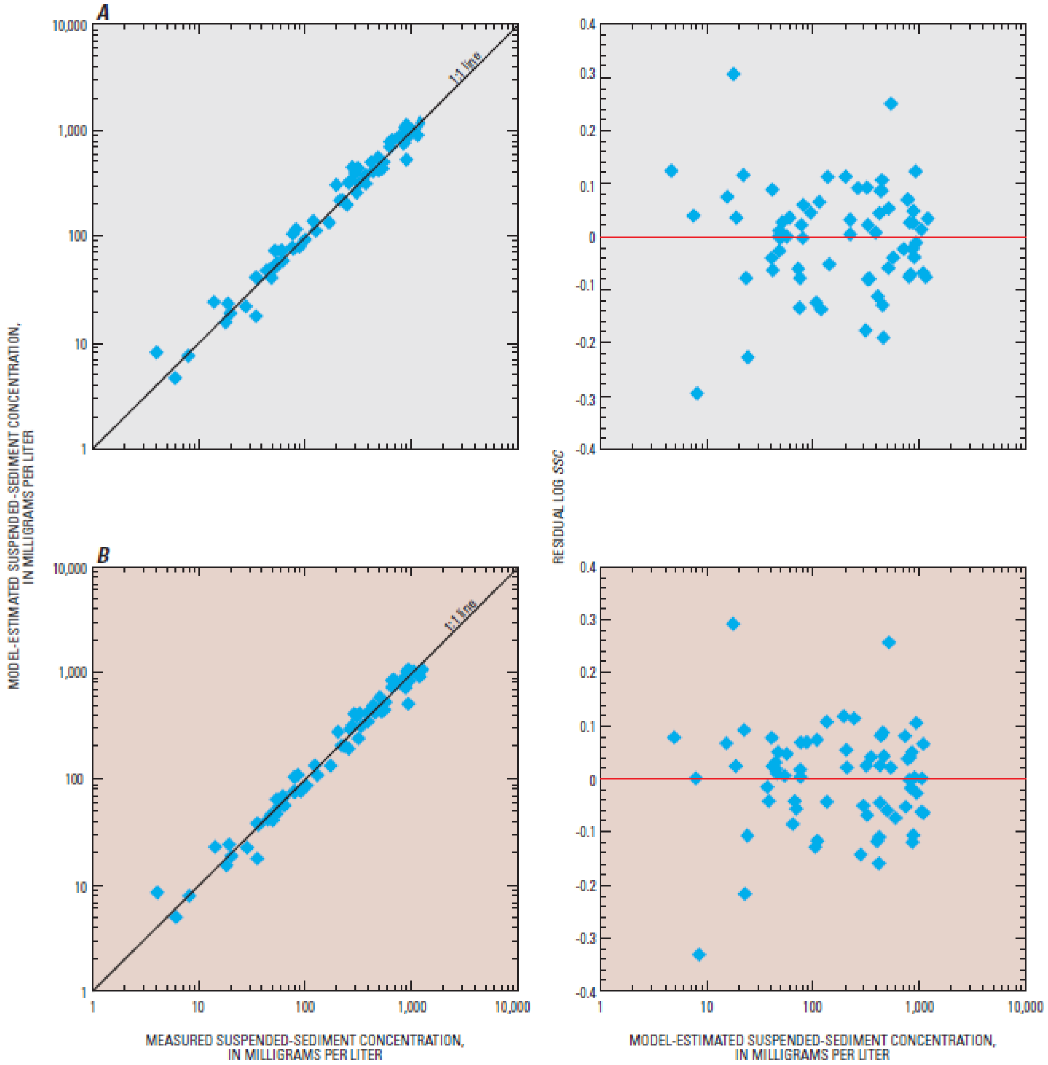

Figure 15. Comparison of measured and estimated suspended-sediment concentrations and residuals in log space from *A*, simple and *B*, multiple linear regression models for U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas.

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Step 3 – Compute SSC and SSL

- Apply regression model to continuous turbidity (and streamflow)
  - Modeled after Q process
  - Compute time-series SSC
    - SSC time interval same as turbidity
    - Multiply retransformed SSC by BCF
    - Missing and truncated turbidity values
  - Compute time-series SSL
    - Multiply SSC by Q and conversion factor
    - Missing streamflow
  - Update station analysis (appendix 1 of TM3C4)

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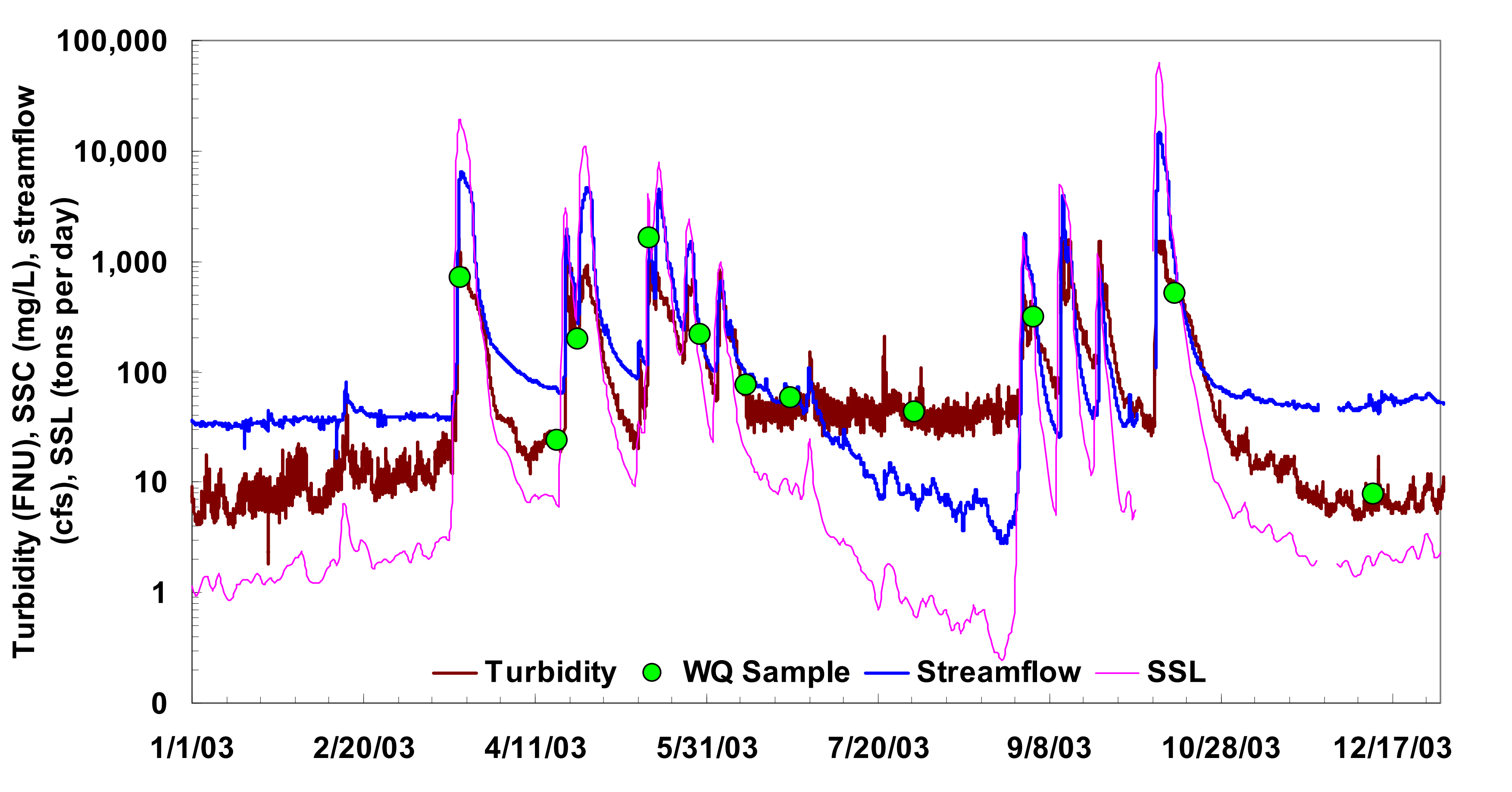
Step 3 – Compute SSC and SSL

[NWIS, U.S. Geological Survey National Water Information System; ADAPS, U.S. Geological Survey Automated Data Processing System; QWDATA, U.S. Geological Survey water-quality database; SSC, suspended-sediment concentration; SSL, suspended-sediment load, R^2, coefficient of determination; RMSE, root-mean-squared error; MSPE, model standard percentage error; PRESS, prediction error sum of squares; VIF, variance inflation factor; R^2a, adjusted coefficient of determination ; MVUE, minimum-variance unbiased estimator; ANCOVA, analysis of covariance]

Checklist for time-series suspended-sediment records

	Worked	Reviewed	Approved
1) Compile model calibration data set			
a) Retrieve data from NWIS	________	________	________
i) Approved time-series data: turbidity and streamflow (from ADAPS)	________	________	________
ii) Discrete sample data: SSC, sand-silt percentage (from QWDATA)	________	________	________
b) Assign turbidity and streamflow values to be used in regression	________	________	________
c) Plot raw data to identify potential outliers (turb against SSC)	________	________	________
d) Plot samples on turbidity and streamflow duration curves	________	________	________
e) Compile statistical summary of model calibration data set	________	________	________
f) Write model-calibration data-set summary in station analysis	________	________	________
2) Development of a regression model			
a) Correlations and scatter plots of all data	________	________	________
b) Simple linear regression turbidity/SSC, untransformed and $\log_{10}$ transformed and regression diagnostics (R^2, R^2_a, RMSE, PRESS, MSPE)	________	________	________
c) Determine proper transformation	________	________	________
d) Model residual plots	________	________	________
e) Plot model residual against streamflow, Julian day	________	________	________
f) Evaluate simple and multiple linear regression models	________	________	________
(residual plots, VIF, partial F-test, R^2_a, PRESS, MSPE)	________	________	________
g) Bias correction factor (Duan or MVUE)			
h) 90-percent prediction interval	________	________	________
i) Regression model summary in station analysis	________	________	________
3) Computation and storage of time-series suspended-sediment concentration and load record in NWIS			
a) Set up data descriptors in ADAPS	________	________	________
b) Enter bias adjusted equation	________	________	________
c) Select period of suspended-sediment record for application of model	________	________	________
d) Compute SSC unit value and SSL daily values	________	________	________
e) Estimate missing SSC or SSL data	________	________	________
f) Evaluate period of record graphs	________	________	________
g) Update station analysis	________	________	________
4) Annual model validation			
a) Plot calibration data set and recent annual data	________	________	________
b) Compare original model to model with additional data (ANCOVA)	________	________	________
c) Update model in ADAPS	________	________	________
d) Determine start date and time of new model	________	________	________

Step 3 – Compute SSC and SSL



SSC varies 3 orders of magnitude
Q varies 4 orders of magnitude
SSL varies 6 orders of magnitude!
Impossible to sample this variability without continuous!

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Step 3 – Compute SSC and SSL

Example 1. Complete Review Package for Little Arkansas River near Sedgwick, Kansas

WATER-QUALITY MONITOR STATION ANALYSIS
2005 WATER YEAR
SUSPENDED-SEDIMENT RECORD
07144100
Little Arkansas River near Sedgwick, Kansas

MODEL-CALIBRATION DATA SET—All data were collected using USGS protocols and are stored in USGS NWIS databases. The regression model is based on 68 concurrent measurements of turbidity and streamflow and *SSC* samples collected from November 1998 through June 2005. Samples were collected throughout the range of continuously observed hydrologic and turbidity conditions. Turbidity and streamflow values are time-averaged approved unit values corresponding with the duration of sample collection. A comparison of cross-section mean and corresponding time-series monitor readings is provided. Water-quality data were collected using an YSI 6600 monitor with a 6026 turbidity sensor (FNU). Selected data values used to develop the regression models were removed on the basis of sample evaluation. Five *SSC* values were removed from the data set because of transcription errors, sampling errors, and a sample compromised during shipping. Three data values were affected by sensor limitations (within 10 percent of the sensor maxima) and, therefore, were removed from the data set. Summary statistics and the complete model-calibration data set are provided.

MODEL DEVELOPMENT—Initially, data plots of the response variable (*SSC*) and possible explanatory variables turbidity and streamflow indicate both are correlated to *SSC*. Regression analysis was done using S-Plus software, and the final output is provided. Turbidity and streamflow were examined together as explanatory variables for estimating *SSC*, but the p-values for streamflow were larger than 0.025. Different combinations of untransformed and $\log_{10}$-transformed data were evaluated. Log_{10}-transformed turbidity and *SSC* were selected as the best model on the basis of residual plots, *MSPE*, and p-value for streamflow. Residual plots for evaluating variance, normality, homoscedasticity, and curvature are provided. For $\log_{10}$-transformed models, estimated values were multiplied by a calculated retransformation bias correction factor (Duan, 1983). Ninety-percent prediction intervals are provided for evaluating uncertainty of the estimates.

MODEL SUMMARY—Summary of final regression analysis for suspended-sediment concentration at Little Arkansas River near Sedgwick, Kansas.

$$\log_{10}(SSC) = 0.943 \log_{10}(Turb) + 0.130,$$

where

SSC = Suspended-sediment concentration, in milligrams per liter; and
Turb = Turbidity (YSI 6026), in formazin nephelometric units.

Model information:

Number of measurements = **68**,
root-mean-squared error (*RMSE*) = **0.10**,
model standard percentage error (*MSPE*) = **+25.9 and -20.6 percent**
90-percent prediction intervals = **$\pm$ 41 percent**,
adjusted coefficient of determination (R^2_a) = **0.98**,
PRESS = **0.663**,
Duan's bias correction factor = **1.03**.

Coefficients:

	Coefficient	Standard error	t-statistic	p-value
Intercept	0.130	0.041	3.02	0.0035
$\log_{10}(Turb)$	0.943	0.018	50.9	1.13E-54

Correlation matrix of coefficients:

	Intercept	$\log_{10}(Turb)$
Intercept	1	
$\log_{10}(Turb)$	-0.9588	1

***SSC* RECORD**—The record is computed using a regression model and ADAPS software. Data are computed at 15-minute intervals. The record is complete for the year except as noted. The turbidity monitor was removed for a short period in December-February to avoid ice damage.

Daily values for partial days were updated where data existed during the expected time for the occurrence of the maximum or minimum, if at least 12 hours of values were available for the day, and if values were present adjacent to the extreme for the day.

312 days of record out of 365 days (85 percent) will be published.

REMARKS—

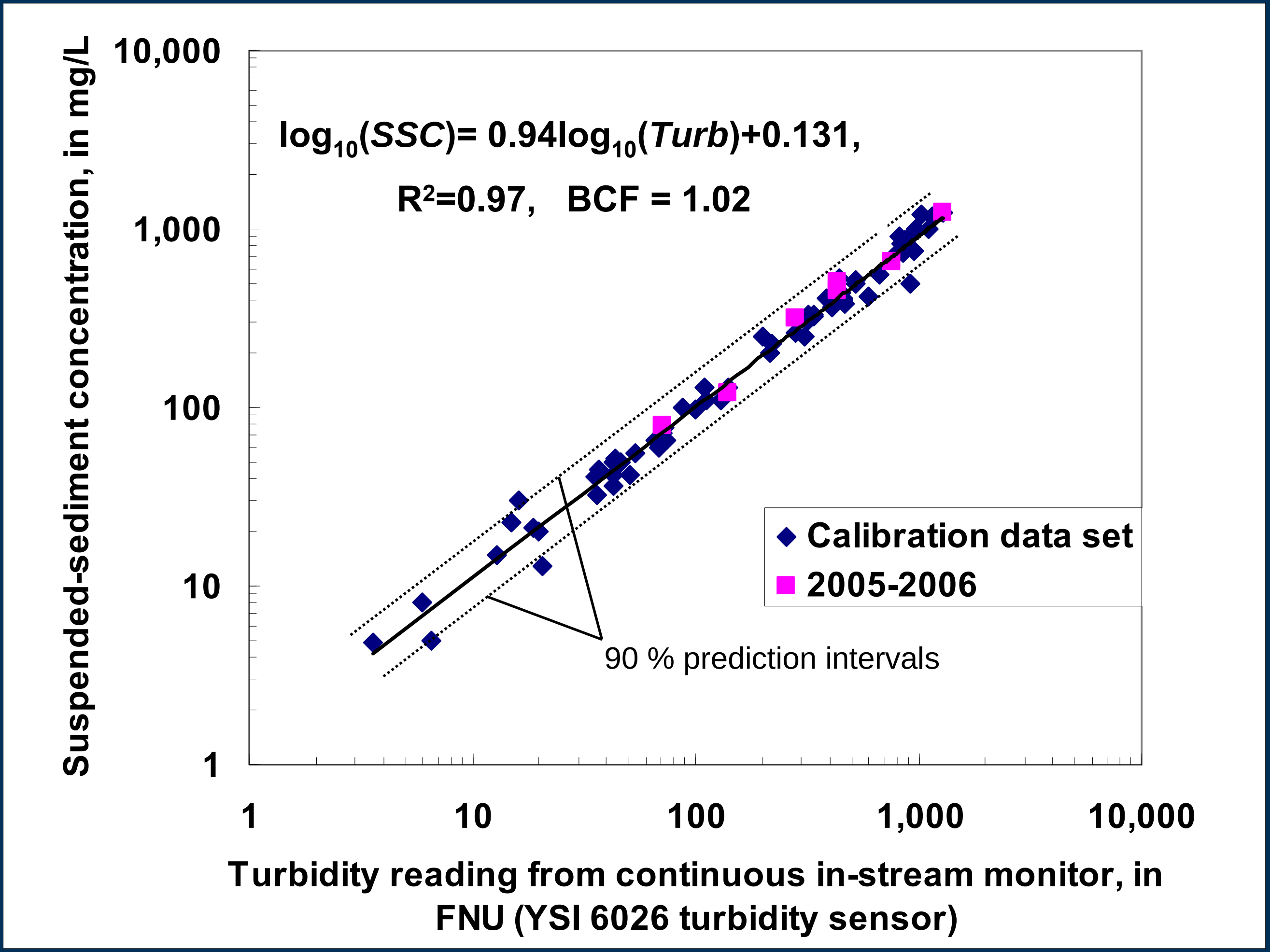
- A new turbidity sensor, YSI model 6136, was installed to collected concurrent turbidity measurements. These measurements will be used to convert YSI model 6136 values to the YSI model 6026 to compute *SSC* with the new 6136 sensor.
- T.B. Bennett collected field data.
- Cross-section survey results can be retrieved from NWIS, database 02.
- The Excel® "Field Measurement Summary" spreadsheet for this site and water year summarizes the number of site visits, calibration results, and calculations of the magnitude of fouling and calibration drift.

Computed: P.P. Rasmussen, November 1, 2005
Checked: C.J. Lee, November 22, 2005
Reviewed: T.J. Rasmussen, November 26, 2005

Maintaining sediment record

- Continue monitoring turbidity
  - Continuously at a single point
  - Periodic cross-sectional measurements
- Continue collecting SSC samples
  - > 4 per year
  - Over the hydrologic range

Maintaining sediment record



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Maintaining sediment record

- Employing new model
  - Do not recompute historic SSC UVs
  - Determine start date
  - Update station analysis
- New model form
  - Compare old and new
  - May need to recompute SSC Uvs
  - Simple is usually best

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Maintaining sediment record

- Evaluate new turb/SSC pairs with old pairs annually
  - ANCOVA – analysis of covariance
  - Similar distribution verifies current regression
  - Differences may indicate a change in sediment sources/transport and a need for new regression
  - Additional data may not significantly change the model, but does improve uncertainty

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Maintaining sediment record

- New model
  - When to end old and start new
  - Moving window
  - Annual
  - Do not recompute approved SSC unit values
  - Update station analysis

USGS

Maintaining sediment record

Upstream at Halstead,

$\log(SSC) = 0.945 \log(\text{Turb, YSI 6026}) + 0.132$ — 2003

2011 - $\log(SSC) = 0.852 \log(\text{Turb, YSI 6136}) + 0.591$

At Sedgwick,

2003 - $\log SSC = 0.716 \log(Turb, YSI\ 6026) + 0.19 \log(Q) + 0.18$

2011 - $\log(SSC) = 0.906 \log(\text{Turb,YSI 6136}) + 0.427$

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Maintaining sediment record

Table 11. Percent Difference in Annual Loads Calculated using Updated and Old Regression Models for Little Arkansas River at Highway 50 near Halstead (site 07143672), Kansas, 1999-2010.

Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Average**
Constituent	**% Difference**												
Hardness	1%	2%	2%	2%	2%	2%	2%	1%	2%	1%	2%	2%	2%
Dissolved Solids	1%	1%	1%	1%	1%	2%	1%	1%	2%	1%	1%	2%	1%
Total Suspended Solids	-1%	0%	-3%	-2%	-2%	-2%	1%	3%	1%	-1%	1%	1%	0%
Calcium	1%	1%	1%	1%	1%	1%	1%	1%	2%	1%	1%	1%	1%
Sodium	-6%	-7%	-9%	-12%	-10%	-13%	-9%	-1%	-27%	-4%	-8%	-13%	-10%
Alkalinity	13%	10%	9%	1%	7%	3%	6%	-9%	7%	9%	12%	5%	6%
Bicarbonate	2%	2%	2%	2%	2%	2%	2%	2%	1%	2%	2%	2%	2%
Chloride	-7%	-7%	-10%	-12%	-11%	-14%	-10%	-2%	-29%	-5%	-8%	-14%	-11%
Sulfate	-4%	-4%	-5%	-5%	-4%	-5%	-5%	-2%	-6%	-4%	-5%	-5%	-4%
Total Organic Nitrogen	0%	1%	-2%	-1%	-1%	0%	2%	6%	3%	1%	3%	3%	1%
Total Phosphorus	5%	6%	3%	4%	4%	5%	8%	11%	8%	6%	8%	8%	6%
Escherichia Coli Bacteria	18%	19%	17%	18%	18%	18%	19%	20%	19%	18%	19%	19%	19%
Fecal Coliform Bacteria	3%	5%	1%	2%	2%	2%	7%	9%	7%	4%	7%	7%	5%
Arsenic	-12%	-12%	-12%	-13%	-12%	-13%	-13%	-19%	-11%	-14%	-12%	-12%	-13%
Atrazine	0%	-2%	-4%	-6%	-4%	-1%	-6%	3%	-9%	1%	-6%	-4%	-3%
Suspended-Sediment	4%	6%	1%	3%	2%	3%	10%	14%	10%	6%	10%	11%	7%

HWY50 models robust–

-mostly single explanatory variables models

-most years within 10%

Maintaining sediment record

Table 12. Percent Difference in Annual Loads Calculated using Updated and Old Regression Models for Little Arkansas River near Sedgwick (site 07144100), Kansas, 1999-2010.

Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Average**
Constituent	**% Difference**												
Hardness	1%	1%	1%	1%	1%	1%	0%	2%	0%	1%	1%	1%	1%
Dissolved Solids	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
Total Suspended Solids	23%	28%	25%	27%	32%	39%	42%	17%	46%	24%	35%	48%	32%
Calcium	0%	0%	0%	0%	0%	0%	0%	1%	-1%	0%	0%	0%	0%
Sodium	-7%	-8%	-10%	-5%	-9%	-10%	-9%	2%	-12%	-5%	-8%	-11%	-8%
Alkalinity	10%	11%	7%	2%	6%	3%	5%	-7%	4%	9%	10%	5%	5%
Bicarbonate	14%	15%	5%	-1%	3%	-4%	3%	-7%	2%	13%	15%	2%	5%
Chloride	-16%	-20%	-15%	-3%	-14%	-11%	-12%	8%	-15%	-13%	-21%	-17%	-12%
Sulfate	-5%	-4%	-7%	-6%	-6%	-7%	-9%	3%	-11%	-3%	-5%	-7%	-6%
Total Organic Nitrogen	9%	17%	-3%	6%	6%	11%	22%	10%	25%	16%	22%	24%	14%
Total Phosphorus	13%	11%	14%	13%	13%	12%	10%	8%	10%	11%	10%	9%	11%
Escherichia Coli Bacteria	55%	54%	56%	55%	55%	55%	53%	53%	53%	54%	53%	52%	54%
Fecal Coliform Bacteria	70%	70%	69%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
Arsenic	3%	3%	4%	1%	3%	3%	4%	-13%	5%	1%	3%	4%	2%
Atrazine	0%	17%	4%	-2%	11%	7%	-1%	-1%	2%	3%	4%	-6%	3%
Suspended-Sediment	-10%	-20%	-12%	-8%	-18%	-26%	-27%	17%	-31%	-14%	-26%	-38%	-18%

Sedgwick models for sediment not as robust–-WHY?

-Original model contained a Q term MLR suggests that relation of turb and q has changed

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Advantages of turbidity/SSC

- Time series of turbidity is easily measured and maintained in ADAPS
- Rarely hysteresis in turb/SSC
- Relations are defined by a single slope
- Results are reproducible
- Uncertainty is easily defined

USGS

Advantages of turbidity/SSC

- Comparisons indicate turb/SSC estimates have less uncertainty than Q/SSC estimates

- SSC and SSL are computed in real time

- Can be used for TSS data
  - Largest issue with TSS is the subsampling for analysis

USGS

Limitations

- Turbidity truncation – use backscatter
- Turbidity values from different sensors are not equivalent
- Each regression model is site specific
- Statistical significance of Turb/SSC relation decreases if —
  - the Δ sand/silt is disproportional to Δ SSC
  - SSC sources vary in grain-size distributions or color
  - Samples do not evenly span the observed range

USGS

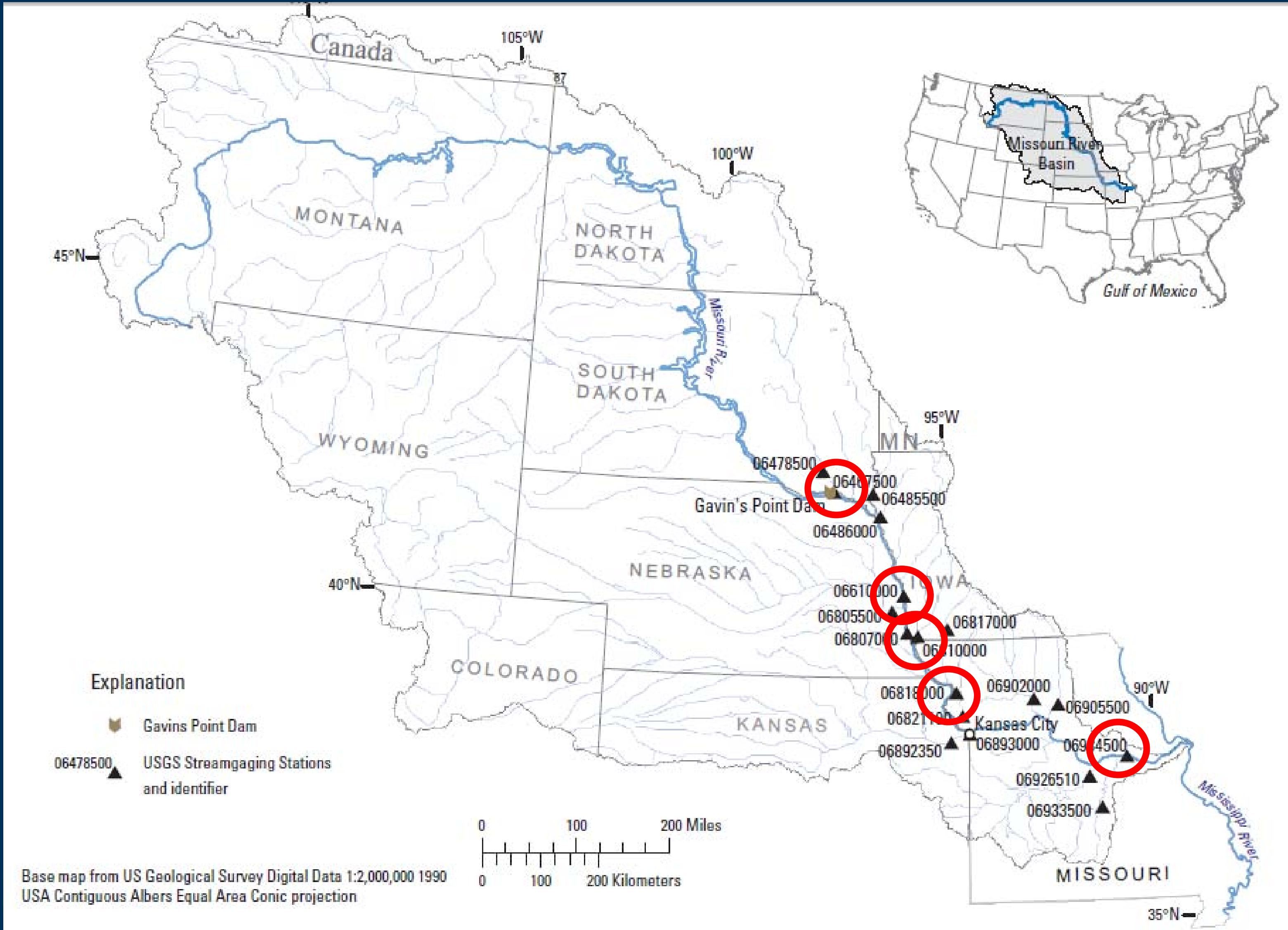
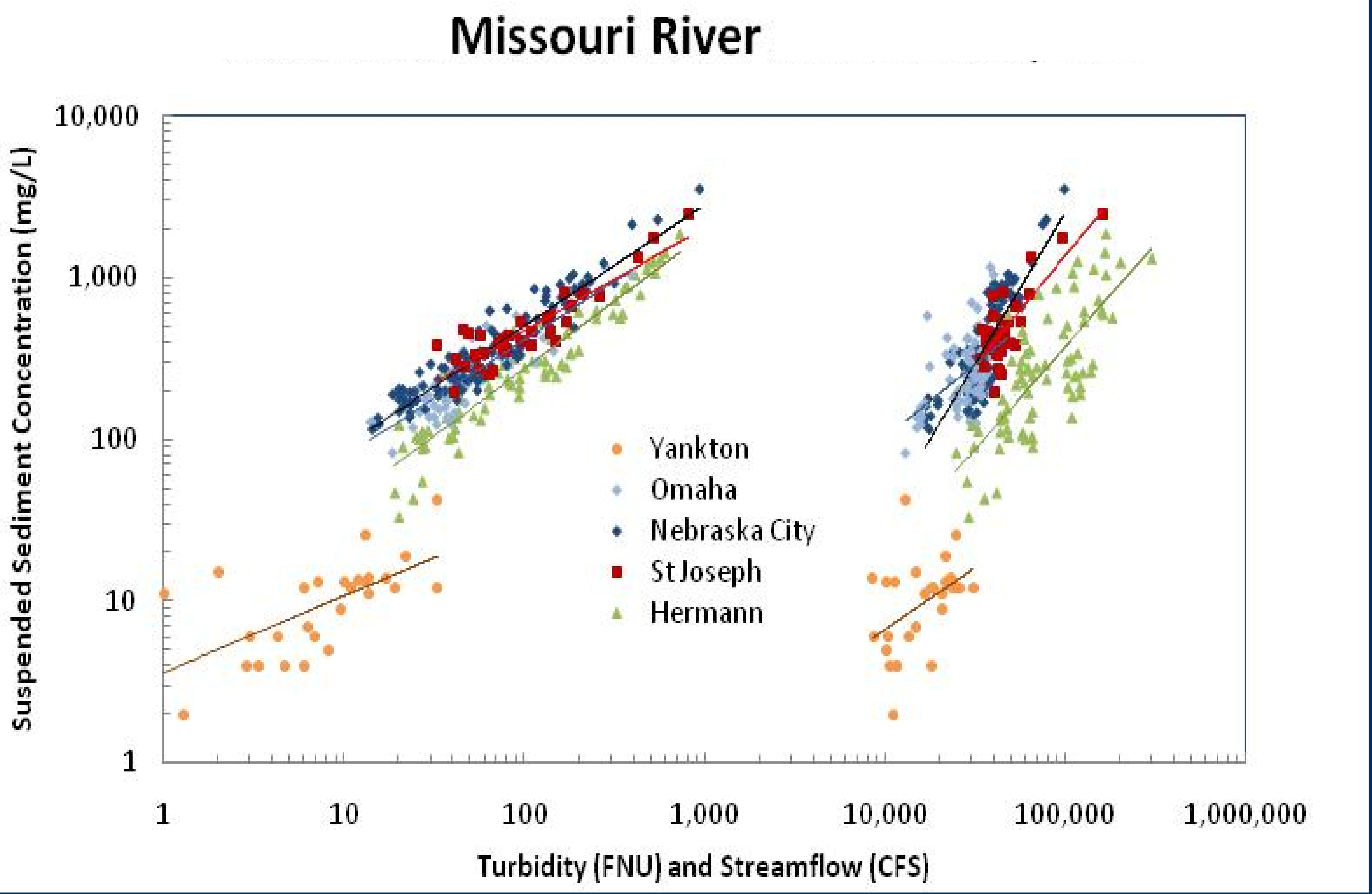


Figure 1. Location of selected sediment-sampling stations in the lower Missouri River Basin for which data are presented (see table 1 for station names corresponding to station identifiers).

USGS

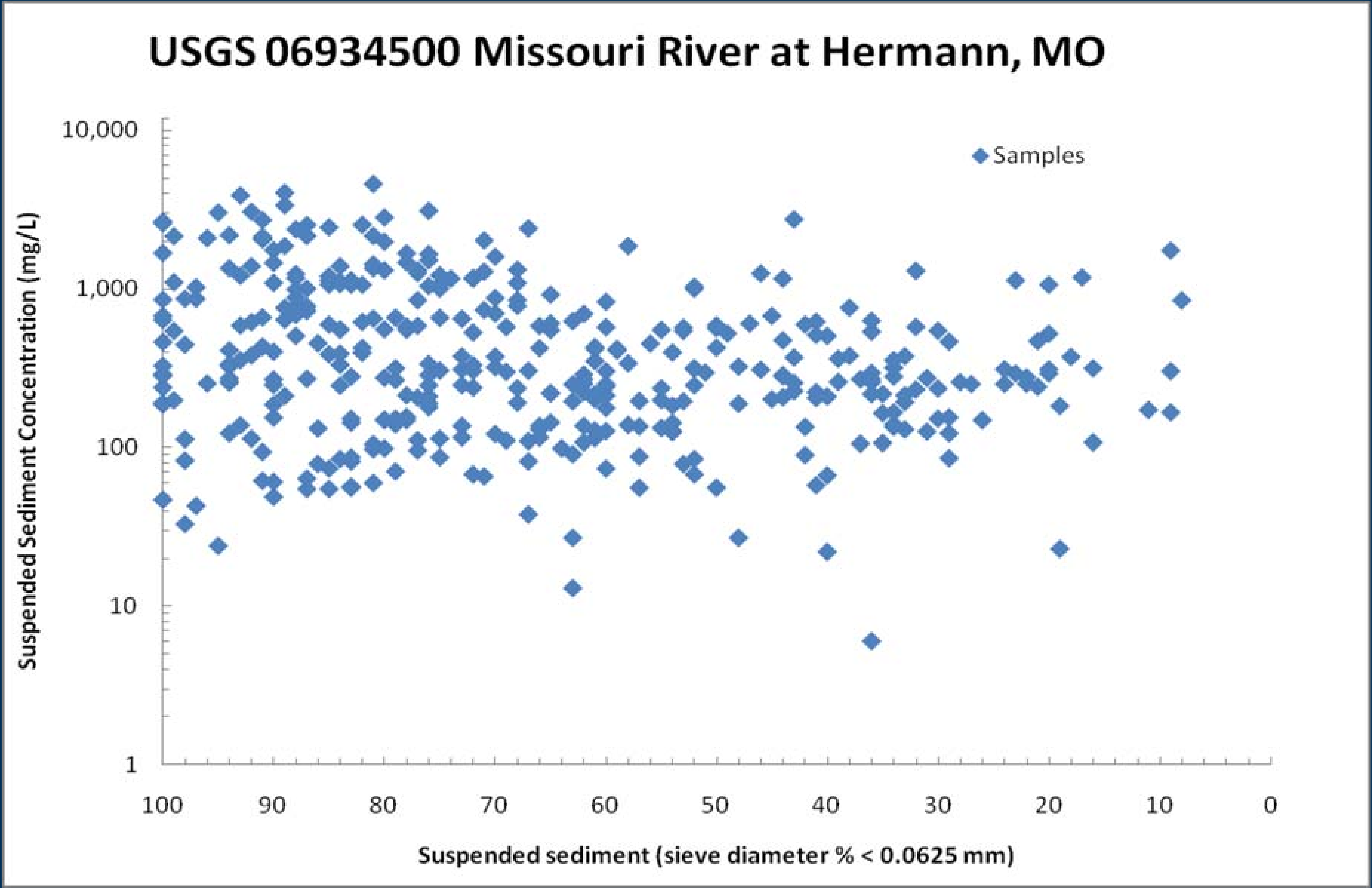
http://pubs.usgs.gov/ds/530/pdf/ds530.pdf

Heimann and others 2010



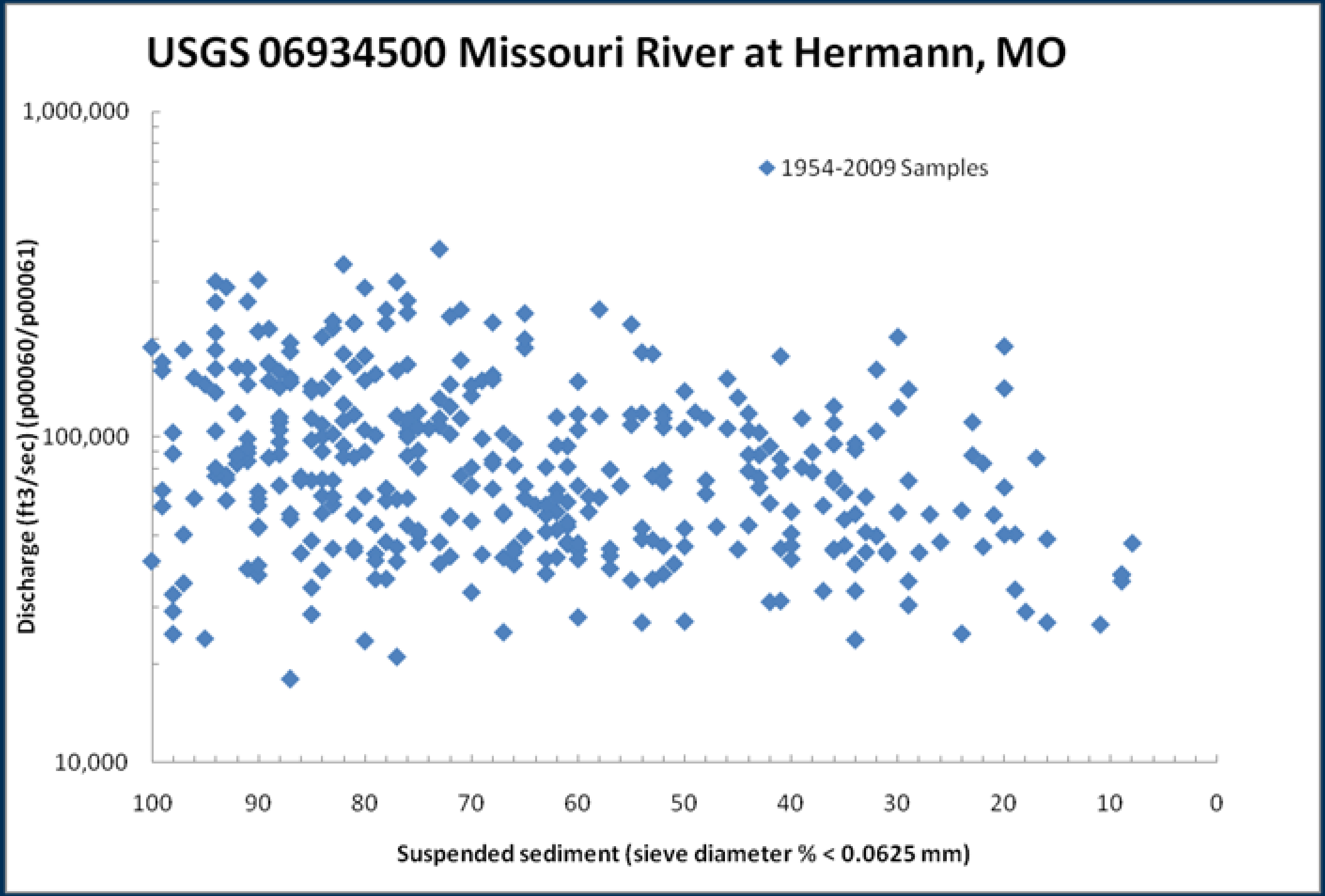
USGS

Each model is site specific



Turbidity-SSC with a varying proportion of sand and silt

Turbidity-SSC with a varying proportion of sand and silt



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http://nrtwq.usgs.gov/

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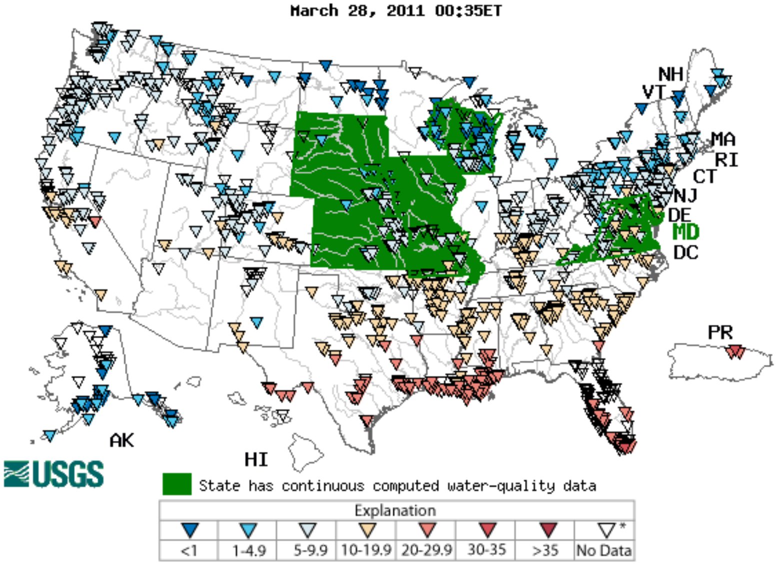
US Geological Survey Real-Time Water Quality Data For the Nation

NATIONAL REAL-TIME WATER QUALITY

Real-Time Water Temperature, in °C

March 28, 2011 00:35ET



Temp | Cond | pH | D.O. | Turb | Disch

Continuous real-time water-quality data are used for decisions regarding drinking water, water treatment, regulatory programs, recreation, and public safety. Sensors in streams typically measure streamflow, water temperature, specific conductance, pH, dissolved oxygen and turbidity. Additionally, these measurements can be used as surrogates to compute real-time concentrations and loads of other water-quality constituents.

Click the Map for Real-Time Water-Quality Data. This Will Either Show:

1. This National Real-Time Water Quality (NRTWQ) website (currently Iowa, Kansas, Maryland, Missouri, Nebraska, South Dakota, Virginia, and Wisconsin) provides hourly computed concentrations and loads for sediment, nutrients, bacteria, and many additional constituents; uncertainty values and probabilities for exceeding drinking water or recreational criteria; frequency distribution curves; and all historical hourly in-stream sensor measurements.

2. WaterQualityWatch presents colorful maps of recent hourly measurements of streamflow, water temperature, specific conductance, pH, dissolved oxygen, and turbidity. The most recent 120 days of real-time data also are available for download. Similar to NRTWQ, its data are obtained from the USGS National Water Information System.

Questions?

Patrick Rasmussen
USGS, Kansas
pras@usgs.gov
785-832-3542

http://pubs.usgs.gov/tm/tm3c4/

http://water.usgs.gov/osw/suspended_sediment/time_series.html

http://waterwatch.usgs.gov/wqwatch/

http://nrtwq.usgs.gov

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