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/
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
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
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)

Little Arkansas River, Sedgwick, Kansas

Kansas River DeSoto, Kansas
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/
### Step 1 – Model calibration data set

**Turbidity measurements- nephelometry and optical backscatter**

<table>
<thead>
<tr>
<th>NWIS PCODE</th>
<th>Method Short Name</th>
<th>Method Source (NWQL, EPA, ASTM, Std., Meth., etc.)</th>
<th>Method Number</th>
<th>NWIS New Method Code</th>
<th>NWIS Old Method Code</th>
<th>Is Method Approved? (meets requirements in OWQ Tech Memo 98.06)</th>
<th>Static / Submersible / Process</th>
<th>Comments</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNU A93</td>
<td>Instruments - Near Infra-Red (780-900 nm) or Monochrome light source. 90° detection angle, one detector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63080</td>
<td>Eureka Environmental, Sensor model Trimeter, FNU</td>
<td>ISO 7027 TS031 A</td>
<td>N/A</td>
<td>Dynamic</td>
<td>Uses Analytik NEP5000 Series turbidity probe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>Forest Technology Systems, Sensor Model DTS-12, FNU</td>
<td>ISO 7027 TS032 B</td>
<td>N/A</td>
<td>Dynamic</td>
<td>May not be technically compliant with ISO 7027, based on noise ratios</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>Greenspan, sensor model TS 100, FNU</td>
<td>ISO 7027 TS034 C</td>
<td>N/A</td>
<td>Dynamic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>Greenspan, sensor model TS 300, FNU</td>
<td>ISO 7027 TS036 D</td>
<td>N/A</td>
<td>Dynamic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>Greenspan, sensor model TS 1200, FNU</td>
<td>ISO 7027 TS035 E</td>
<td>N/A</td>
<td>Dynamic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>HACH, sensor model 2100 N (Ratio OFF), FNU</td>
<td>ISO 7027 TS040 F</td>
<td>N/A</td>
<td>Static</td>
<td>With infra-red filter installed downstream of white light source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>HACH, sensor model 2100 AN (Ratio OFF), FNU</td>
<td>ISO 7027 TS038 G</td>
<td>N/A</td>
<td>Static</td>
<td>With infra-red filter installed downstream of white light source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>HACH, sensor model 1720 0.5 L, FNU</td>
<td>ISO 7027 TS037 H</td>
<td>N/A</td>
<td>Process</td>
<td>Discontinued</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>HACH, sensor model Optiquant, FNU</td>
<td>ISO 7027 TS041 I</td>
<td>N/A</td>
<td>Process</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>HACH, sensor model Pocket Turbidimeter, FNU</td>
<td>ISO 7027 TS042 J</td>
<td>N/A</td>
<td>Static</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63680</td>
<td>HF Scientific, Sensor Model</td>
<td>ISO 7027 TS047 K</td>
<td>N/A</td>
<td>Static</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
Optical backscatter

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

Meantime for on-the-spot process decisions and reduces costly manual testing. Our cleaning 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® 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

Always store the make and model with data
Step 1 – Model calibration data set

SSC of samples
EDI/EWI

Isokinetic sampling


Figure 4-4. Equal-width-increment method for collection of water samples (modified from Edwards and Glysson, 1999).
Step 1 – Model calibration data set
SSC of samples related to in-stream monitor values
Step 1 – Model calibration data set
SSC samples collected over range in sensor conditions
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 Backscatterance
  - SSC of samples
    - Depth integrated, EDI or EWI (Nolan and other, 2005; Edwards and Glysson, 1999)
    - Sample full range of hydrologic conditions
  - **Streamflow time-series record**
Step 1 – Compile calibration data set

![Graph showing turbidity (FNU), SSC (mg/L), and streamflow (cfs) over time from 1/1/03 to 12/17/03. The graph includes data points marked with green circles, which represent WQ samples. The data is plotted on a logarithmic scale for turbidity and SSC, with streamflow on a linear scale.]
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
Step 2 – Develop regression model

Turbidity is explanatory variable

SSC is response variable
Step 2 – Develop regression model

- Untransformed
  - $r=0.96$
  - $r=0.54$

- Transformed
  - $r=0.99$
  - $r=0.85$

Figure B. 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.
Turbidity is MUCH better for computing SSC

\[ y = 1.34x^{0.94} \]

\[ R^2 = 0.97 \]

- Suspended-sediment concentration, in mg/L
- Turbidity, in FNU (YSI 6026 turbidity sensor)
- Streamflow in cubic feet per second
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
Step 2 – Develop regression model
Step 2 – Develop regression model

Retransformation requires bias correction factor

Regression provides expressions of uncertainty

Plot data

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

\[R^2 = 0.97\]

BCF = 1.03

MPSE = +25, -21

90% prediction intervals
Step 2 – Develop regression model

\[ \log_{10}(SSC) = b_1 \log_{10}(Turb) + b_0 \]  

(6)

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

SSC = \( (10^{b_0 T urb^{b_1}}) \) * BCF  

(7)

SSC = \( (10^{0.130 T urb^{0.943}}) \) * 1.03

SSC = 1.39 Turb\(^{0.943}\)
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
Step 2 – Develop regression model
Step 2 – Develop regression model

- $R_a^2$, RMSE, and MSPE all improve
- p-value for Q is $< 0.05$, but $> 0.025$
- Plot both model results
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 multiple linear regression models for U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas.
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)
Step 3 – Compute SSC and SSL

[Checklist for time-series suspended-sediment records]

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, land-use percentage (from QWDATA)
   b) Assign turbidity and streamflow values to be used in regression
   c) Plot raw data to identify potential outliers (match 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, R$^2$, RMSE, PRESS, MSE)
   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$^2$, PRESS, MSE)
   g) Bias correction factor (Durbin 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 descriptions in ADAPS
   b) Enter bias adjusted equation
   c) Select period of suspended-sediment record for application of model
   d) Compute SSC 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!
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
07144000
Little Arkansas River near Sedgwick, Kansas

MODEL CALIBRATION DATA SET—All data were collected using USGS protocols and are from USGS NWIS databases. The regression model is based on 38 concurrent measurements of turbidity and suspended SSS samples collected from November 1998 through June 2005. Samples were collected throughout the range of continuously observed hydraulic and turbidity conditions. Turbidity and suspended values are time-averaged and are reported in the form of sample collection. A comparison of cross-section means and corresponding time-series monitor readings is provided. Turbidity data were collected using an YSI 6600 automatic with a 0.025 field-of-view (FOV) 200 turbidity sensor (YSI). Selected data values used to develop the regression models were removed from the basis of sample collection. Five SSC values were removed from the data set because of transcription errors, sampling errors, and a sample contamination sample (SSC). These values were affected by sensor limitations (within 10 percent of the sensor's range) and, therefore, were removed from the data set. Summary statistics model for 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 regressions were less than 0.05. Different combinations of turbidity and 10₉ tactile turbidity and SSC were selected as the best model on the basis of residual plots, ADME, and p-value for streamflow. Residual plots for evaluating variance, normality, homoscedasticity, and curvature were provided. For log₉-transformed models, estimated values were multiplied by a calculated coefficient of variation correction factor (Duan 1983). Near-frontal prediction intervals are provided for evaluating accuracy of the estimates.

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

log₉(10₉) = 0.943 log₉(Turbidity) + 0.550,

where

SSC = Suspended-sediment concentration, in milligrams per liter; and

Turbidity (YSI 660) = TSS (USGS 605).

Model Information:
Number of measurements = 48,
Mean turbidity square root (NTU) = 9.45,
model standard error (SSE) = 3.90
90 percent prediction intervals = ± 2.45 percent,
square root of the coefficient of determination (R²) = 0.38,
PRESS = 3.63,
Duan's bias correction factor = 1.03.

Coefficients:

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.100</td>
<td>0.014</td>
<td>3.32</td>
</tr>
<tr>
<td>log₉(Turbidity)</td>
<td>0.943</td>
<td>0.018</td>
<td>56.9</td>
</tr>
</tbody>
</table>

SUSPEND RECORD - The record is complete using a regression model and ADAPT software. Data are computed at 15-minute intervals. The record is complete for the year except as noted. The turbidity monitor was repaired for a short period in December/January to avoid damage.

Daily data values for periods were updated when data were collected during the expected time for the occurrence of the minimum or maximum, if at least 12 hours of values were available for the day, and if values were present adjacent to the extreme for the day. 341 days of record out of 365 days (93 percent) will be published.

REMARKS—
- A new turbidity sensor, YSI model 6136, was installed to collect concurrent turbidity measurements. These measurements will be used to convert YSI model 6136 values to the YSI model 6136 to complete SSC with the new 6136 sensor.
- J.B. Bennett collected field data.
- Cross-section survey results can be retrieved from NWIS, database 82.
- 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 finding and calibration shift.

Computed: J.F. Rasmussen, November 3, 2005
Checked: C.J. Lise, November 22, 2005
Reviewed: T.J. Rasmussen, November 28, 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

\[ \log_{10}(\text{SSC}) = 0.94 \log_{10}(\text{Turb}) + 0.131, \]
\[ R^2 = 0.97, \quad \text{BCF} = 1.02 \]

90% prediction intervals
Maintaining sediment record

- Employing new model
  - Do not recomputes 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
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
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
Maintaining sediment record

Upstream at Halstead,

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

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

At Sedgwick,

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

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

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

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.

<table>
<thead>
<tr>
<th>Year</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constituent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>0%</td>
<td>2%</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Dissolved Solids</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>23%</td>
<td>28%</td>
<td>25%</td>
<td>27%</td>
<td>32%</td>
<td>39%</td>
<td>42%</td>
<td>17%</td>
<td>46%</td>
<td>24%</td>
<td>35%</td>
<td>48%</td>
<td>32%</td>
</tr>
<tr>
<td>Calcium</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>-1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Sodium</td>
<td>-7%</td>
<td>-8%</td>
<td>-10%</td>
<td>-5%</td>
<td>-9%</td>
<td>-10%</td>
<td>-9%</td>
<td>2%</td>
<td>-12%</td>
<td>-5%</td>
<td>-8%</td>
<td>-11%</td>
<td>-8%</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>10%</td>
<td>11%</td>
<td>7%</td>
<td>2%</td>
<td>6%</td>
<td>3%</td>
<td>5%</td>
<td>-7%</td>
<td>4%</td>
<td>9%</td>
<td>10%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>14%</td>
<td>15%</td>
<td>5%</td>
<td>-1%</td>
<td>3%</td>
<td>-4%</td>
<td>3%</td>
<td>-7%</td>
<td>2%</td>
<td>13%</td>
<td>15%</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Chloride</td>
<td>-16%</td>
<td>-20%</td>
<td>-15%</td>
<td>-3%</td>
<td>-14%</td>
<td>-11%</td>
<td>-12%</td>
<td>8%</td>
<td>-15%</td>
<td>-13%</td>
<td>-21%</td>
<td>-17%</td>
<td>-12%</td>
</tr>
<tr>
<td>Sulfate</td>
<td>-5%</td>
<td>-4%</td>
<td>-7%</td>
<td>-6%</td>
<td>-6%</td>
<td>-7%</td>
<td>-9%</td>
<td>3%</td>
<td>-11%</td>
<td>-3%</td>
<td>-5%</td>
<td>-7%</td>
<td>-6%</td>
</tr>
<tr>
<td>Total Organic Nitrogen</td>
<td>9%</td>
<td>17%</td>
<td>-3%</td>
<td>6%</td>
<td>6%</td>
<td>11%</td>
<td>22%</td>
<td>10%</td>
<td>25%</td>
<td>16%</td>
<td>22%</td>
<td>24%</td>
<td>14%</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>13%</td>
<td>11%</td>
<td>14%</td>
<td>13%</td>
<td>13%</td>
<td>12%</td>
<td>10%</td>
<td>8%</td>
<td>10%</td>
<td>11%</td>
<td>10%</td>
<td>9%</td>
<td>11%</td>
</tr>
<tr>
<td><em>Escherichia Coli</em> Bacteria</td>
<td>55%</td>
<td>45%</td>
<td>16%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>53%</td>
<td>53%</td>
<td>54%</td>
<td>53%</td>
<td>52%</td>
<td>54%</td>
</tr>
<tr>
<td>Fecal Coliform Bacteria</td>
<td>70%</td>
<td>70%</td>
<td>69%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Arsenic</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>1%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>-13%</td>
<td>5%</td>
<td>1%</td>
<td>3%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Atrazine</td>
<td>0%</td>
<td>17%</td>
<td>4%</td>
<td>-2%</td>
<td>11%</td>
<td>7%</td>
<td>-1%</td>
<td>-1%</td>
<td>2%</td>
<td>3%</td>
<td>4%</td>
<td>-6%</td>
<td>3%</td>
</tr>
<tr>
<td>Suspended-Sediment</td>
<td>-10%</td>
<td>-20%</td>
<td>-12%</td>
<td>-8%</td>
<td>-18%</td>
<td>-26%</td>
<td>-27%</td>
<td>17%</td>
<td>-31%</td>
<td>-14%</td>
<td>-26%</td>
<td>-38%</td>
<td>-18%</td>
</tr>
</tbody>
</table>

Sedgwick models for sediment not as robust—**WHY?**

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


Heimann and others 2010
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
http://nrtwq.usgs.gov/

Real-Time Water Temperature, in °C

March 20, 2011 00:35ET

NATIONAL REAL-TIME WATER QUALITY

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