Continuous Real-Time Water-Quality Monitoring— Yesterday, Today, and a Vision for Tomorrow

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Steve Brady ….

and many, many, many others

U.S. Department of the Interior
U.S. Geological Survey

Real-Time Water Quality Monitoring Workshop
St. John’s, Newfoundland, CA
June 7 and 8, 2011

About 2,700 miles (4,320 km)

The Beauty of Kansas

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USGS serves the Nation by providing reliable unbiased scientific information to:

- describe and understand the Earth;
- minimize loss of life and property from natural disasters;
- manage its water, biological, energy, and mineral resources; and
- enhance and protect the quality of life.

USGS Mission areas include Climate and Land Use Change, Core Science Systems, Ecosystems, Energy, Minerals, and Environmental Health, Natural Hazards, Scientific Quality and Integrity, and Water. Missions are accomplished by collecting, storing, interpreting, and distributing our information to the public and resource-management agencies. http://www.usgs.gov/start_with_science/

Funded through National programs (National Streamflow Information Program), NAWQA, and the Cooperative Water program with State and Local agencies…..

This approach requires USGS to work on relevant environmental issues…

Outline:

- So what and who cares?
- Historical perspective
- Worldwide perspective
- Vision for RTWQ
- Today --WaterQualityWatch, NRTWQ, and surrogates
- Networks- a Mississippi River example
- Needs and Tomorrow

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Goals:

- Whet your appetite for the fantastic collection of presentations the next 2 days
- Present an overview and vision of continuous monitoring, some history, tools, and networks
- Spur discussions

And…

Help EACH of us to

Make a Difference!

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Why monitor water quality continuously?

- Time-dense information improves our understanding of hydrology and water quality and can lead to more effective resource management
- Provides warning for water supply and recreation
- Captures seasonal, diel, and event-driven fluctuations
- Improves concentration and load estimates with defined uncertainty (8,760 hourly values per year)
- Optimizes the collection of samples

AND…..

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SO WHAT? and WHO CARES?

Continuous instantaneous real-time water-quality data MEETS OUR INFORMATION NEEDS for time-dense information that are used to improve the quality of human life and the environment

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We all MUST collaborate to:

- Move this innovative science tool forward
- GET MORE SITES, consistent approaches and networks implemented to answer the needs of society and the environment
- If we can think of "it", we can do "it"– let's define "it" and *Just Do It!*
- *Collaborators include the public, industry, manufacturers, researchers, academia, governments, ……………*

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Some Water-Quality Historical Perspective………..

Water-quality data are obtained with almost the same processes used more than 50-100 years ago….

Mississippi River below Birds Point Beach– photo by Bob Holmes May 2011

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Obtaining Water-Quality Data

Objective is to collect a sample that represents the entire stream at a point in time

- A water sample is collected from a stream and placed/collected in a bottle
- The sample is preserved
- The sample is transported to a laboratory
- The sample is analyzed
- AND we continue to wait for analysis (and wait, and wait, …….)

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Sampling methods

1. Equal Discharge Increment (EDI)

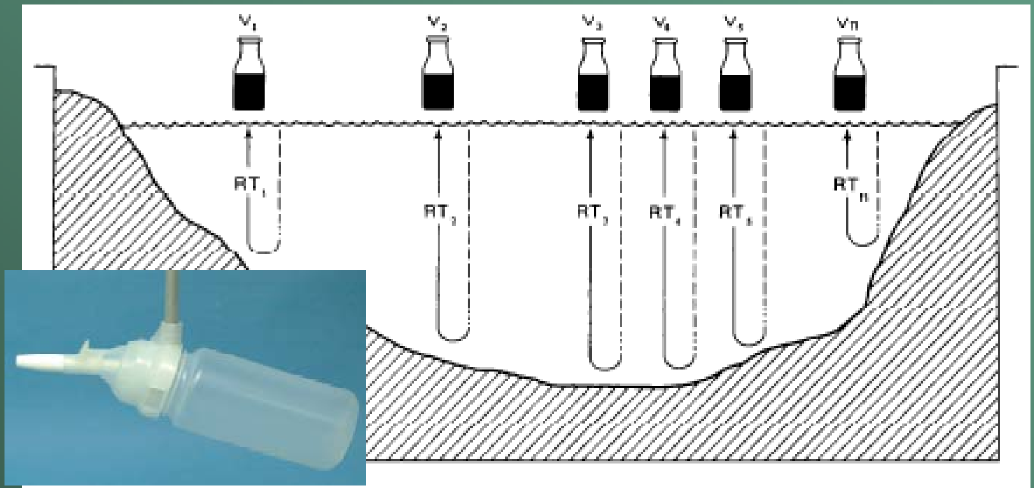


Figure 35. Vertical transit rate relative to sample volume collected at each equal-discharge-increment centroid.

Composite in Churn Splitter

2. Equal Width Increment (EWI)

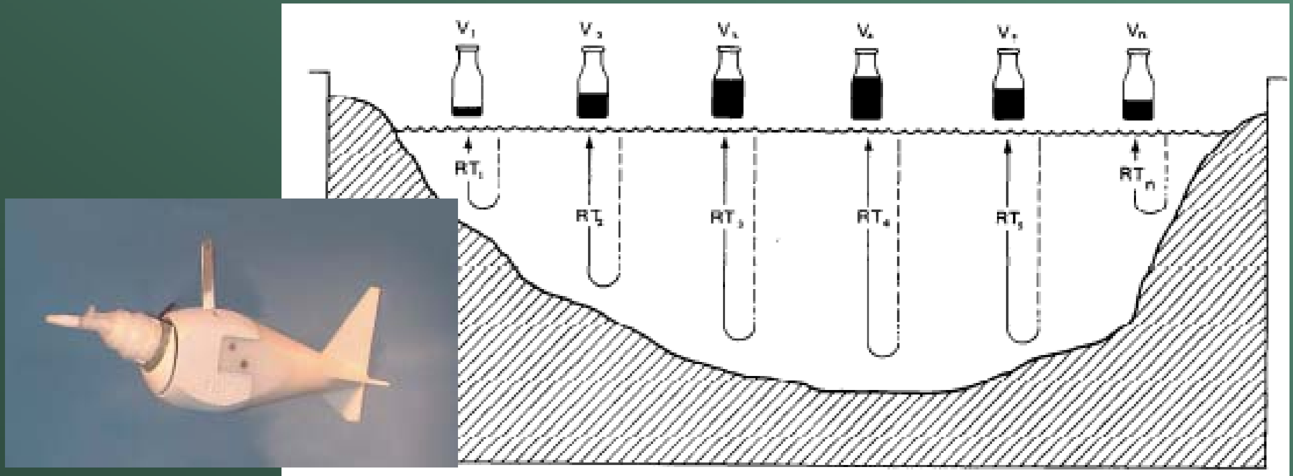
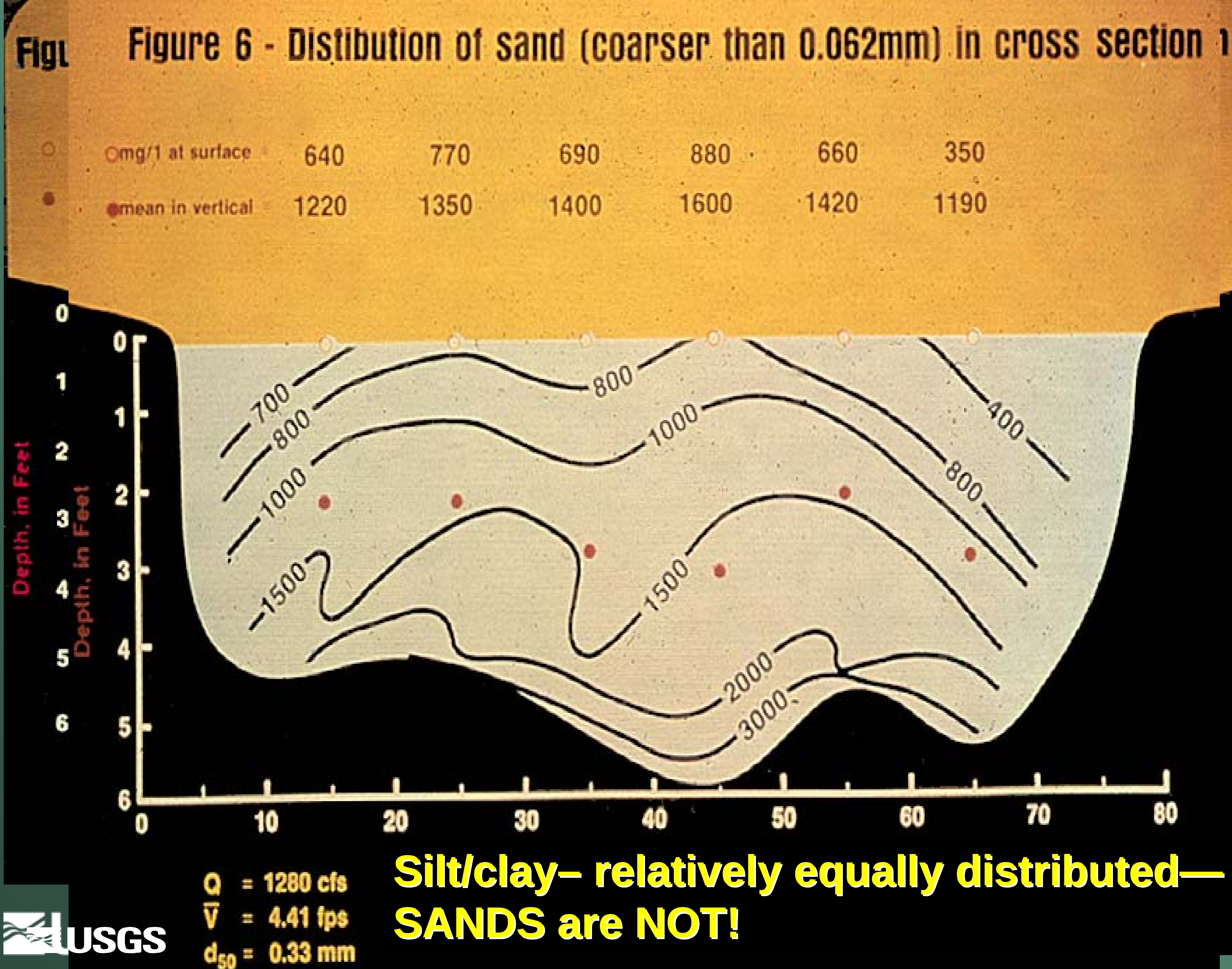


Figure 37. Equal-width-increment vertical transit rate relative to sample volume, which is proportional to water discharge at each vertical.

3. Autosampler



Silt/clay– relatively equally distributed— SANDS are NOT!

The historical improvements in clean sampling techniques, processing, and laboratory analysis are very important: but there is still something missing……

- **To answer the questions we face today, we must quantify the temporal variability of water quality**

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History of USGS continuous water-quality monitoring in Kansas

- Streamflow- more than 100 years
- Continuous estimated SC (Ohm-1827 VIR)– Stabler (1911)—Daily samples—time-weighted composites with streamflow
- Continuous SC in Kansas- 1958, Albert
- YSI- Clark cell dissolved oxygen- 1963
- Hydrolab, 1968
- USGS monitors in 1970’s at NASQAN sites
- Continuous real-time water quality in Kansas since 1998
- Large increase in the number of “gizmos” in last 10 years

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Types of continuous water-quality sensors/monitors

- Electrometric
  - Gage height, temperature, pH, DO, SC
- Electromagnetic spectrum—optical; acoustics
  - Streamflow, turbidity, chlorophyll, nitrate, DO
- In-situ analyzers (bench chemistries)
  - Nitrate, silicate, phosphorus, chloride, ….
- Labs in field at gage house
  - GC/MS- ORSANCO, Greenspan, etc…

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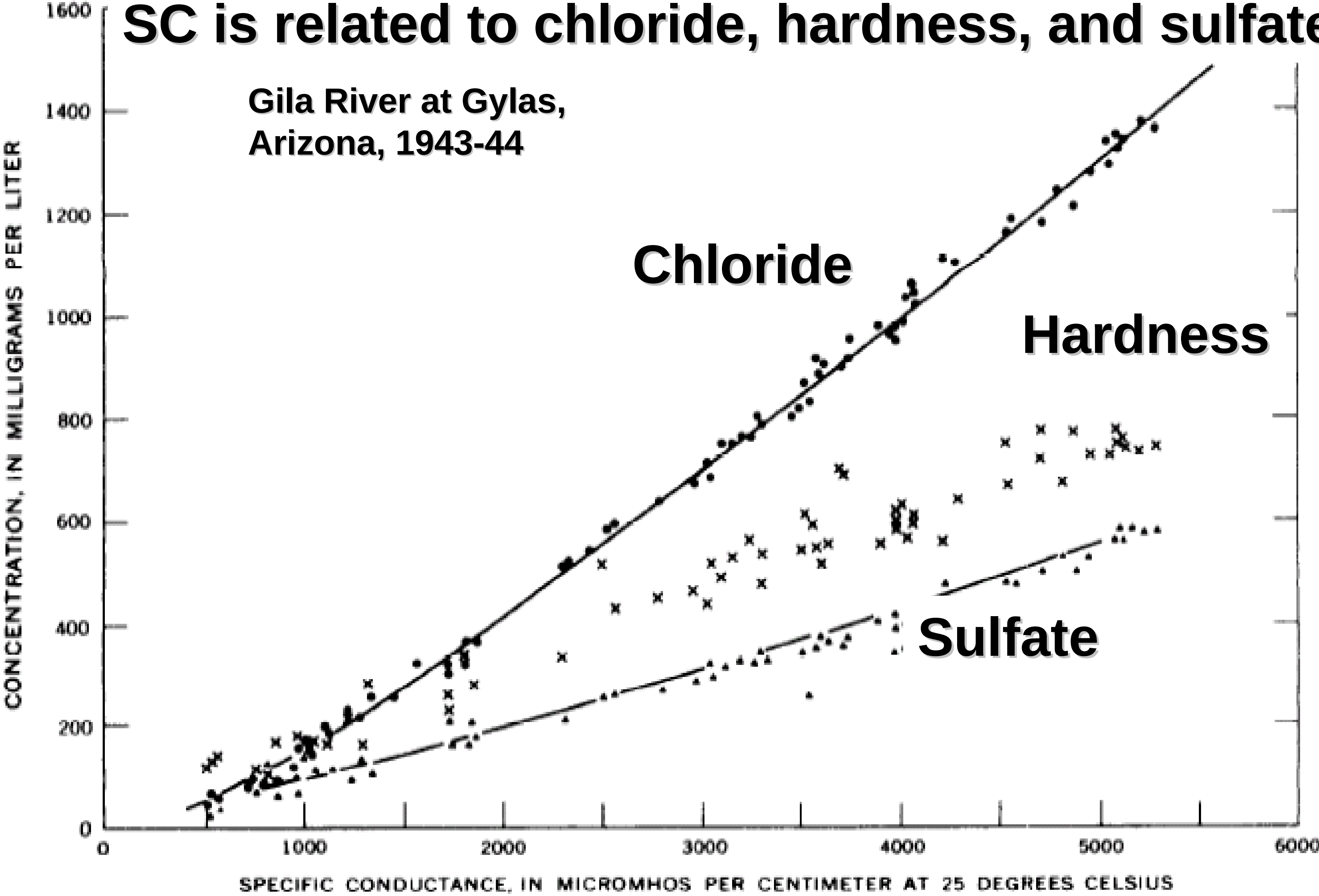
Early USGS *Minimonitors* (~1985)

SC is related to chloride, hardness, and sulfate



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From Hem, 1985, Study and interpretation of the chemical characteristics of natural water

Use of frequency distribution curves to evaluate water quality and compare basins

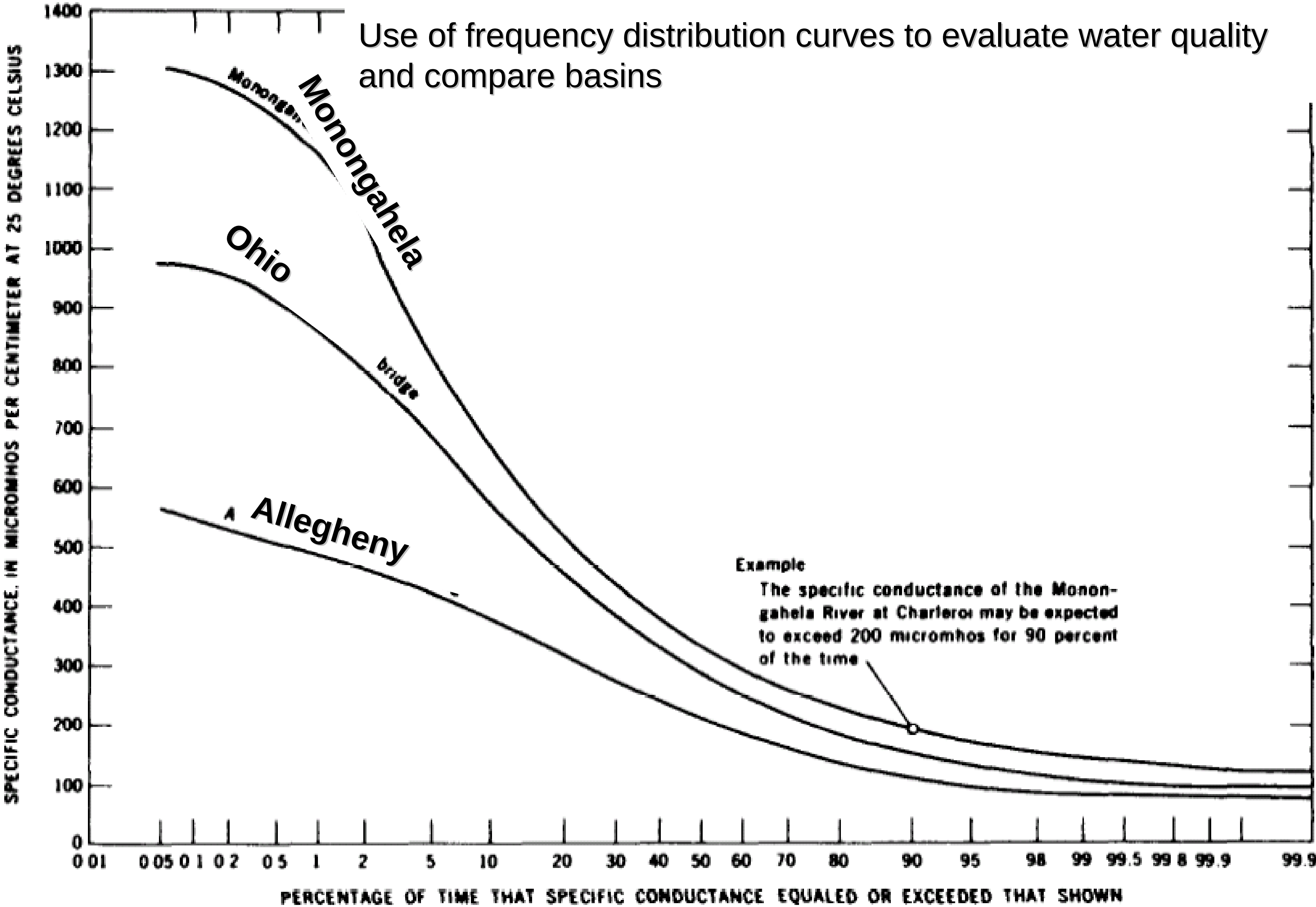

Figure 24. Cumulative frequency of conductance, Allegheny, Monongahela, and Ohio River waters, Pittsburgh area, Pennsylvania, 1944-50.

(From Hem, 1985, Study and interpretation of the chemical characteristics of natural water)

"New" tools are available- In-stream continuous monitors…

Turbidity sensor

- pH
- Water Temperature
- Dissolved Oxygen
- Specific Conductance
- Turbidity
- ORP
- Fluorescence
- UV nitrate/ CDOM

Turbidity used as early as 1940s (JTU for sediment). Walling used in 1974 similar to today's instruments. Dave Schoellhamer in USGS among first to develop sediment concentrations using OBS– late 1980s in SF Bay

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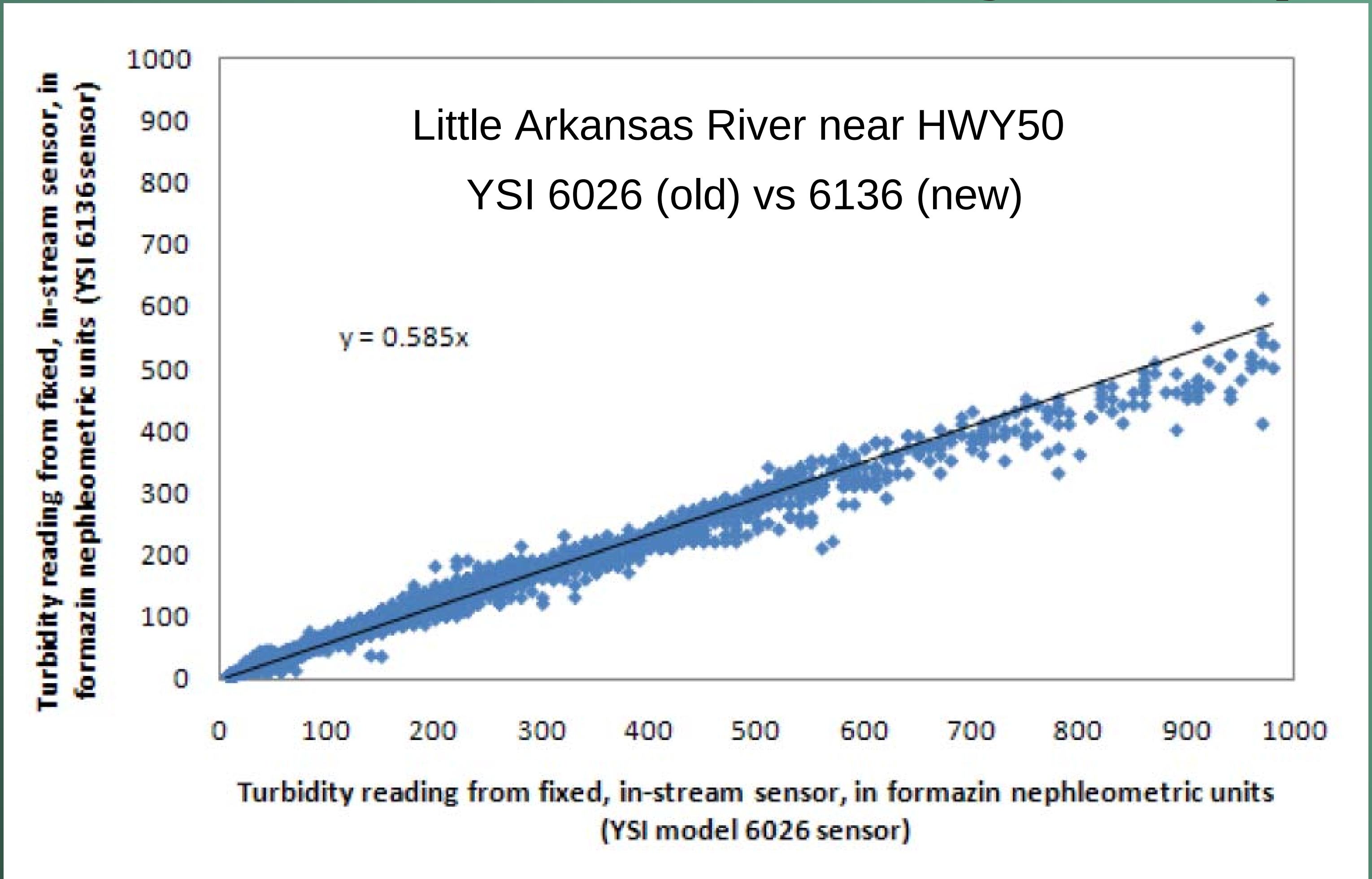
BEWARE– not all gizmos yield equivalent values! Turbidity example



Must understand how and what a gizmo measures and reports

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Today--Worldwide—lots of sites added

- Lots of similarity of sensor measurements
  - Stage, Q, wave height, Temp, sc, pH, DO, turbidity, fluorescence, some nitrate, carbon, few others
- Display of values measured last 30 (or so) days. Some access to “old” continuous data
- Wide variability in complexity of display and user ability to select information
- Surrogates?

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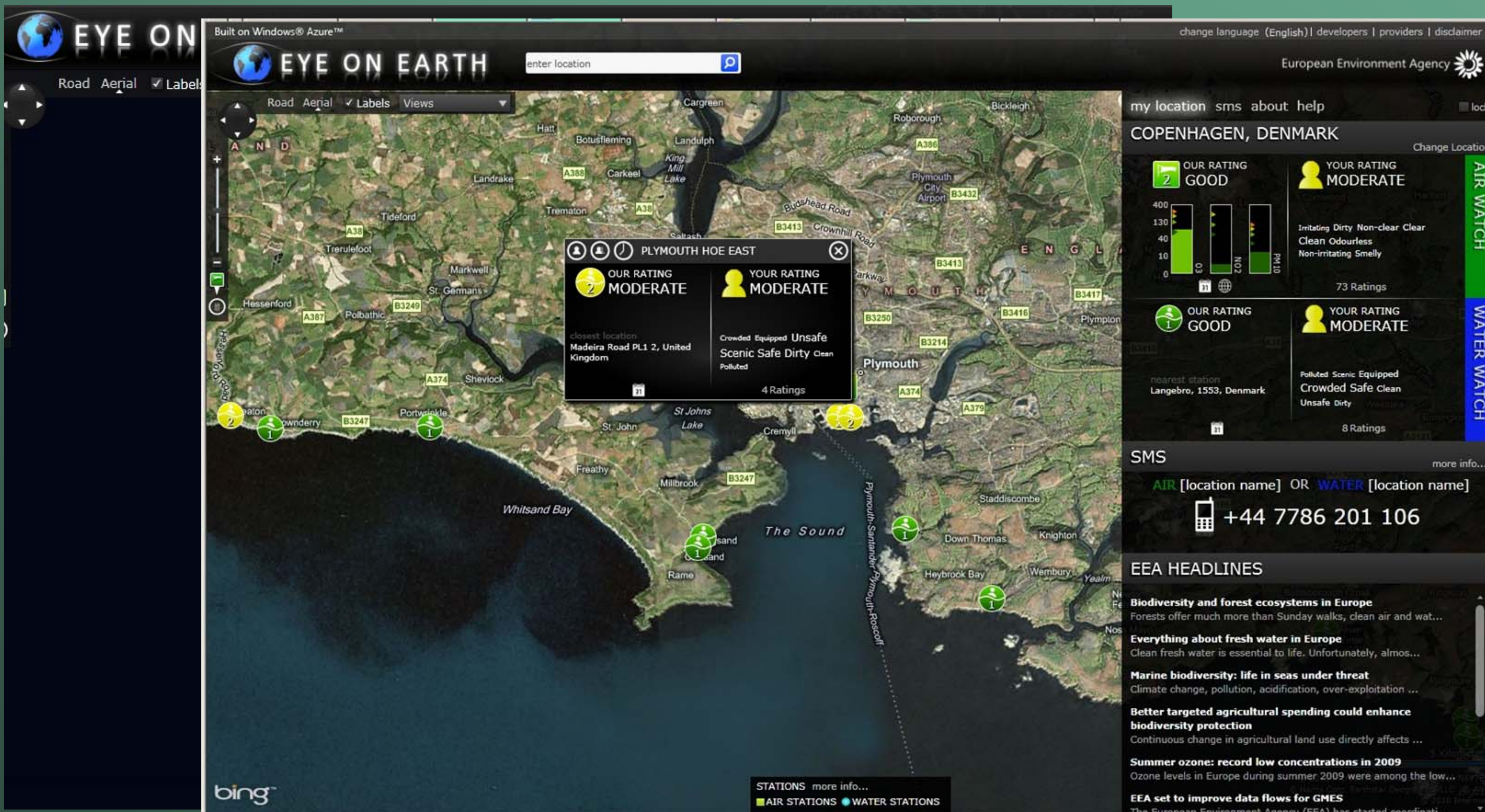
Eye-On-Earth European Union Air and Bathing quality



http://eyeonearth.cloudapp.net/

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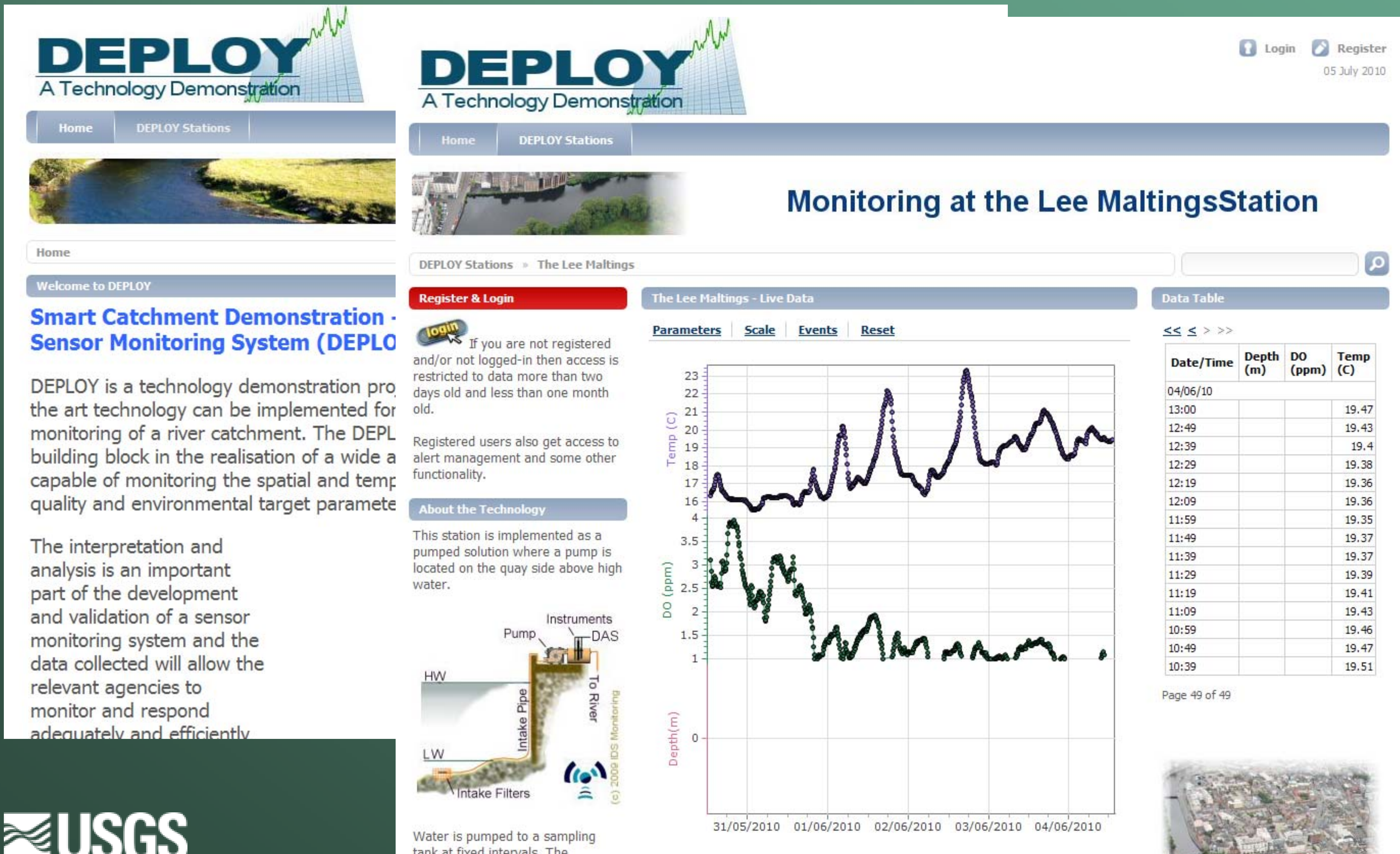
Deploy– Ireland
http://89.124.67.3/Deploy2/Default.aspx



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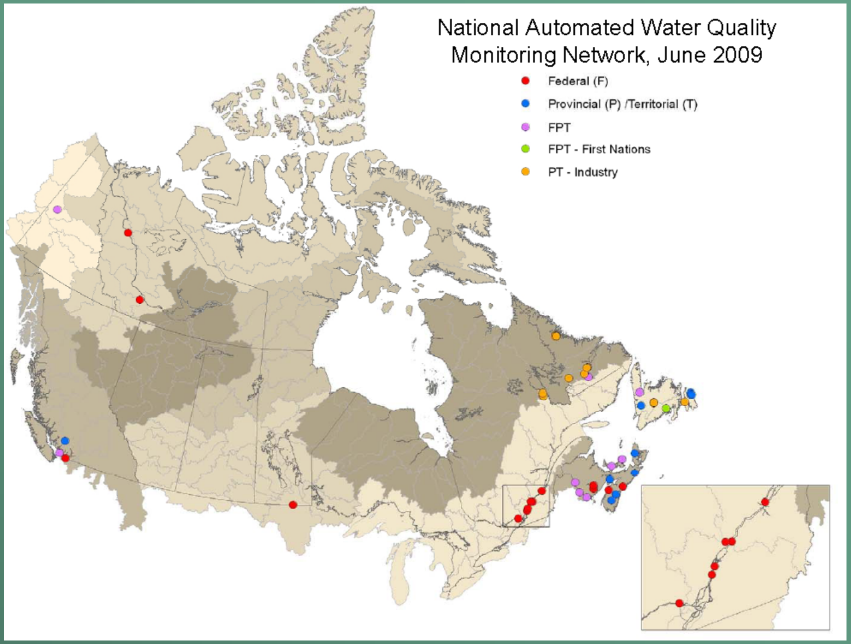
Canadian National Monitoring Network

- Goal—Bring together existing automated sites, implement new sites and expand with interested partners
- Maximizing integration with the hydrometric network
- Benefits:
  - Demonstrate technology, cost effective, primary water quality screening, early warning, background and trend data and provide real-time information to public and more rapid intervention



http://www.env.gov.nl.ca/env/Env/waterres/WQMA/RTWQM_Workshop_2009/Agenda_2009.asp

Towards a National Automated Real-Time Water Quality Monitoring Network - Geneviève Tardif (Environment Canada)
Real-Time Water Quality Monitoring Workshop 2009, St. John’s, NL

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Newfoundland-Labrador and Fraser

Environment and Conservation
Government of Newfoundland and Labrador - Canada

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Newfoundland Labrador

Newfoundland and Labrador Real-time Water Quality Monitoring Stations

Due to the volume and frequent updating of the data available on this Web site the streamflow and water quality data is PROVISIONAL and has not undergone quality control checks. These data may be subject to significant change.

Networks	Partners	Station Name	Installation Date
Industry Partners Network	Vale Inco Newfoundland and Labrador (Voisey's Bay, Labrador) and NL WRMD	NF03NE0009 - Reid Brook at Outlet of Reid Pond	July 2003
		NF03NE0010 - Camp Pond Brook below Camp Pond	July 2003
		NF03NE0011 - Lower Reid Brook below Tributary	July 2003
		NF03NE0012 - Tributary to Reid Brook	July 2006
		NF03NE0008 - Voisey's Bay - Well After Tailings Dam	July 2006 – currently not installed due to location conditions
	Vale Inco Newfoundland and Labrador (Long Harbour, Newfoundland) and NL WRMD	NF02ZK0023 -Rattling Brook below Bridge	December 2006
		02ZK007 - Rattling Brook Big Pond	December 2006
		NF02ZK0025 - Rattling Brook below Plant Discharge NEW!	October 2009
	Duck Pond Operations, Teck Cominco Limited (Central Newfoundland) and NL WRMD	NF02YO0190 - Tributary to Gills Pond Brook	May 2006
		NF02YO0192 - East Pond Brook	August 2006

Home

Fraser River Water Quality Buoy Overview

About the Project

Buoy Location

Buoy Instrumentation

Protocols

Data Online

Online Resources

Publications

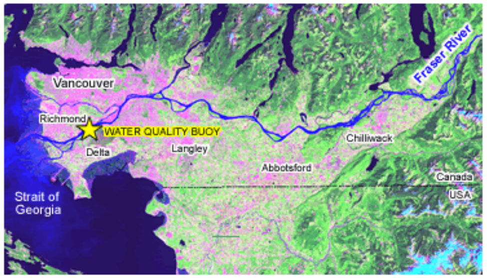
Photo Gallery

FAQ

BRITISH COLUMBIA

This buoy has been deployed in partnership with the British Columbia Ministry of Environment

Fraser River Water Quality Buoy
Federal-Provincial Automated Monitoring Station

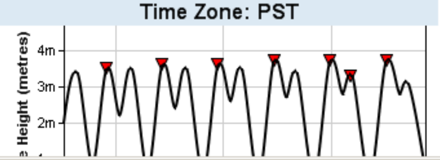


For more information on the location of the buoy click here

Environment Canada, in partnership with the BC Ministry of Environment, has deployed a new water quality monitoring and surveillance buoy in the Main Arm of the Fraser River. The buoy has a variety of instrumentation that will collect water quality, water quantity and meteorological information.

The data and information collected are transmitted via cellular telemetry and will be available to the public in real-time on this website. The data can also be viewed on your cellphone, Blackberry or other Internet-enabled mobile device at http://www.waterquality.ec.gc.ca/waterqualityweb/rtwq.aspx

Steveston
7 Days Tidal Prediction
Time Zone: PST



10/04/13 19:12

Live Image (Click to enlarge)

Real-Time Fraser River Buoy Readings

Water Quality Observations

Turbidity	10.8NTU
Specific Conductivity	229uS/cm
Water Temperature	7.63°C
pH	7.82
Dissolved Oxygen	103.5%

Water Depth and Flow

Water Depth	13.8m
Stream Velocity	0.15m/s (0.3kn) to SW (230.58°)

Meteorological Observations

Wind Speed	10.44km/h
Wind Direction	From E (73°)
Air Temperature	9.4°C
Relative Humidity	84.7%
Pressure	1017.62mb

From December 1st, 2009 till December 8, 2009 the water quality observations will be

http://www.env.gov.nl.ca/wrmd/RTWQ/RTWQ.asp

*www.**waterquality**.ec.gc.ca/**waterquality**web/**realtime**index.aspx*

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U.S.– lots of sites on-line in the last 6 years

- Our Lake—Central NY http://www.ourlake.org/index.html
- Near Real-Time Water Quality Monitoring and Data Distribution in the Central Valley http://www.centralvalleymonitoring.org/
- Mystic River http://www.mysticriveronline.org/
- Susquehanna River Basin Commission
- http://www.srbc.net/programs/remotenetwork.htm
- Eyes on Bay- Chesapeake
- http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm
- IOOS (Integrated Ocean Observing System)
- http://www.obsregistry.org/map.php
- Central & Northern CA
- http://www.cencoos.org/sections/conditions/waterquality.shtml
- Texas Commission on Environmental Quality
- http://tceq.net/cgi-bin/compliance/monops/water_monitors.pl

Neat sites and different approaches to presenting information
Check them out!

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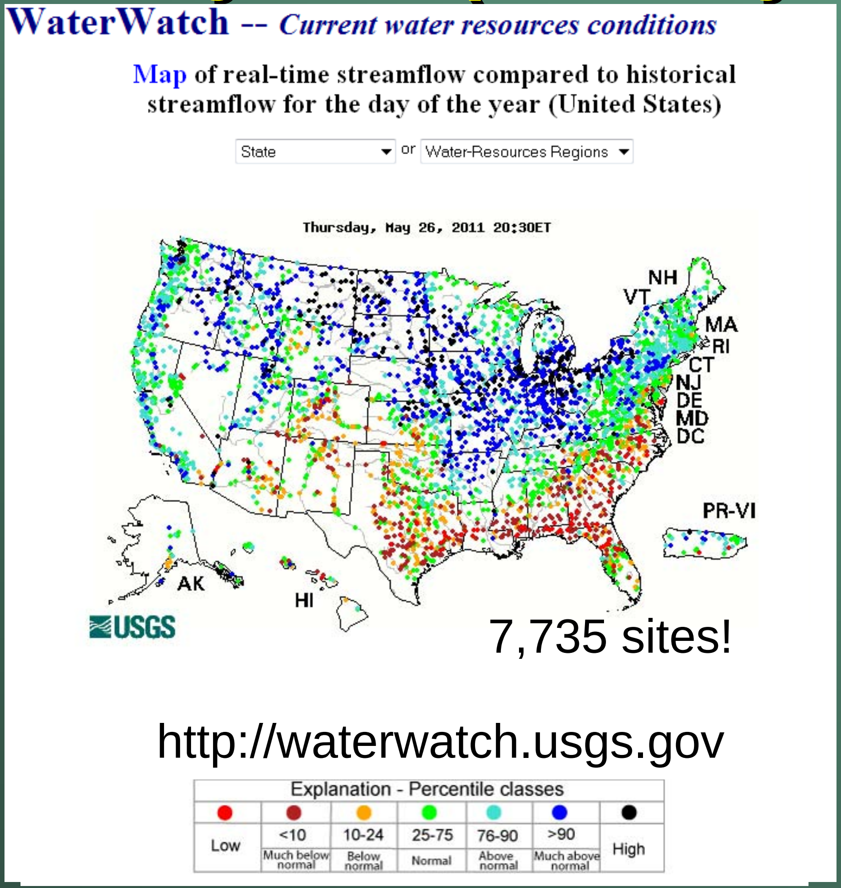
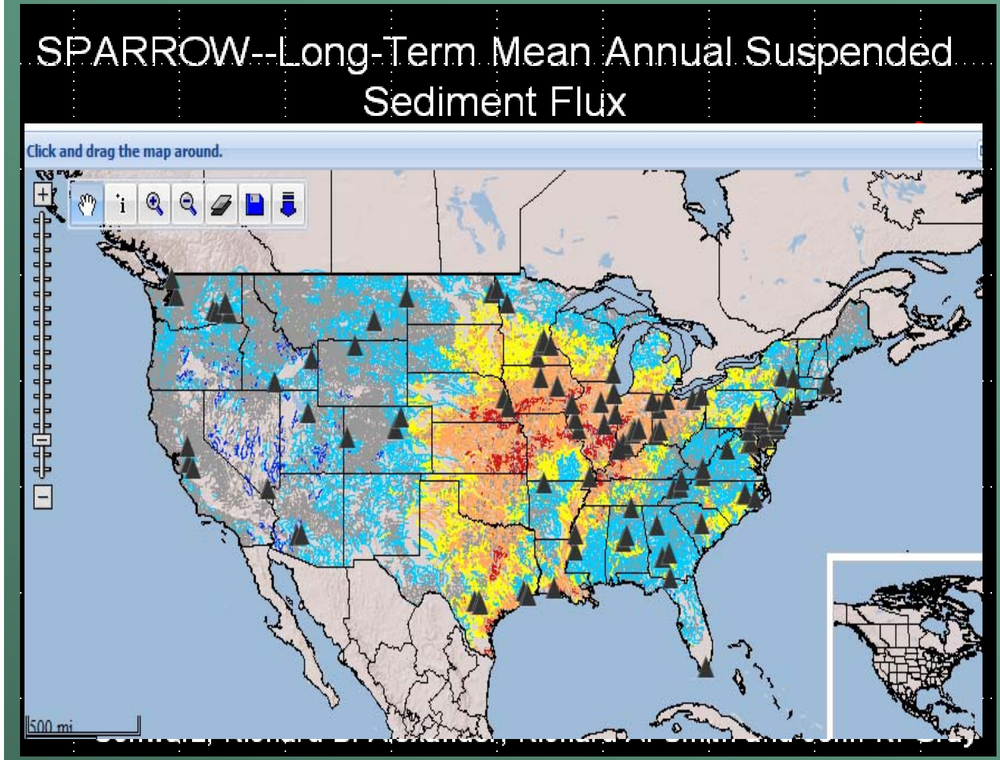
Vision: Water-quality information, anywhere at anytime (Thank you, Bob Hirsch!)





WARP http://infotrek.er.usgs.gov/warp/

Our goal should be to provide water-quality concentrations and loads with associated uncertainty on all time and spatial scales with a historical perspective … (and maybe even forecasting!)

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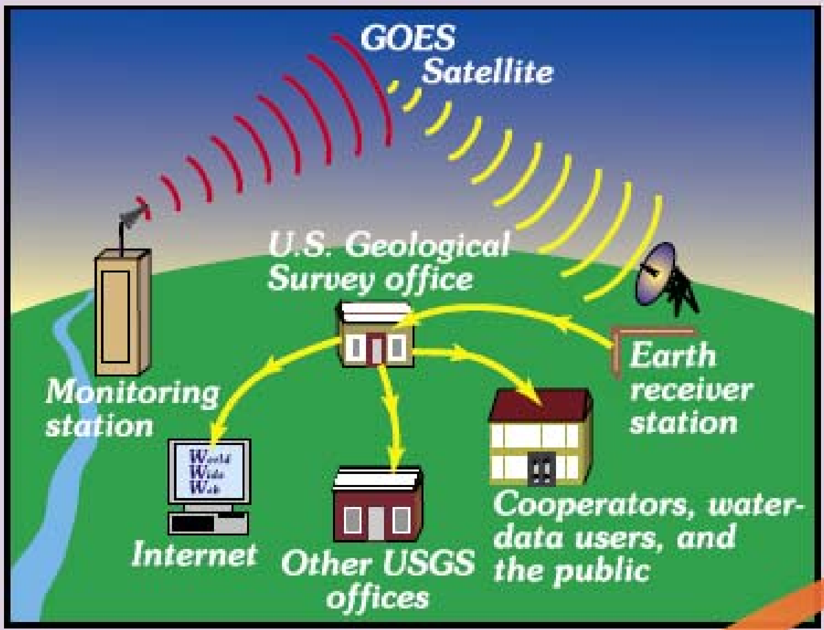
From stream to your computer!

Surface-water-monitoring stations record changes in streams or lake stage (gage height), then transmit that data via satellite to USGS offices.



http://ks.water.usgs.gov/pubs/fact-sheets/fs.060-03.html

USGS today

- WaterQualityWatch -- Continuous Real-Time Water Quality of Surface Water in the United States
  - http://waterwatch.usgs.gov/wqwatch/
  - Linkage to NWISweb data with some value added- Only current unit values are presented for last 120 days

- Data Grapher
  - http://or.water.usgs.gov/grapher/
  - Plots all data available for measured unit values with multiple sites and graph types

- NATIONAL REAL-TIME WATER QUALITY
  - http://nrtwq.usgs.gov/
  - Page to present all past and current computed “surrogate” and measured water quality for concentrations, loads, and model information

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USGS TODAY– Some examples of providing instantaneous continuous data and “surrogate” computations on the web

- CA- SF Bay- Sediment, etc. Since 1989 http://sfbay.wr.usgs.gov/sediment/cont_monitoring/index.html
- KS (1999)-MD, IA, MO, NE, SD, TX, and WI– bacteria, sediment, chloride, atrazine, geosmin, etc., http://nrtwq.usgs.gov/ks/
- CO- Total dissolved solids transport- http://co.water.usgs.gov/projects/ArkQW/index.cfm
- OH-beachwatch-bacteria- http://www.ohionowcast.info/index.asp
- MT/WY- Sodium absorption ratios- http://tonguerivermonitoring.cr.usgs.gov/

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NRTWQ– EXPANDING RAPIDLY!

1,553 temperature, 846 specific conductance, 337 pH, 413 dissolved oxygen, 291 turbidity sites (90 in 2000), nitrate (7)

http://nrtwq.usgs.gov/

http://waterwatch.usgs.gov/wqwatch

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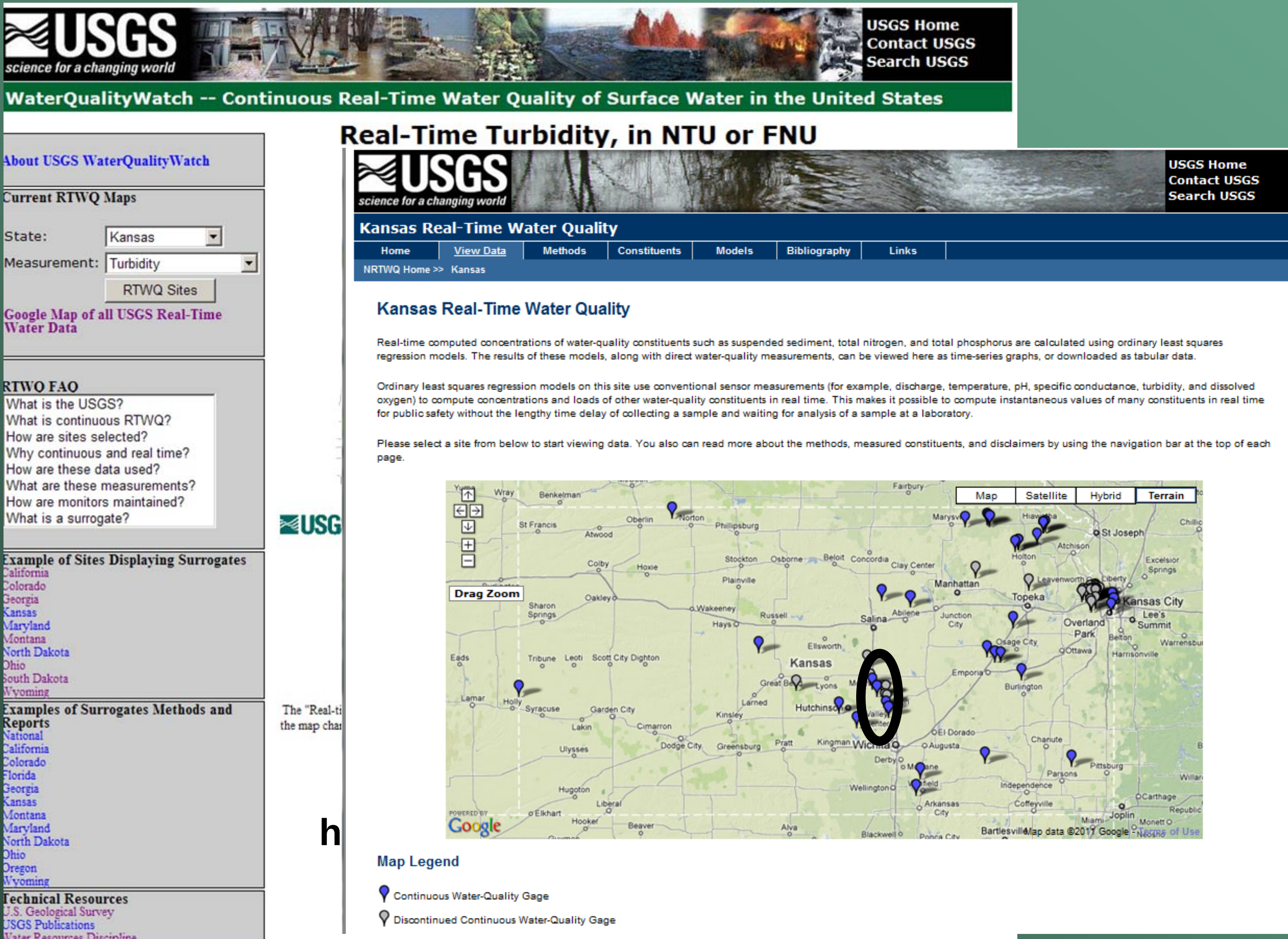

http://nrtwq.usgs.gov/ks/

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Little Arkansas River Basin

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Examples of Monitor Installations

Little Arkansas River near Halstead, KS

Lake Olathe

Kansas River at DeSoto, Kansas

Rattlesnake Creek near Zenith, KS

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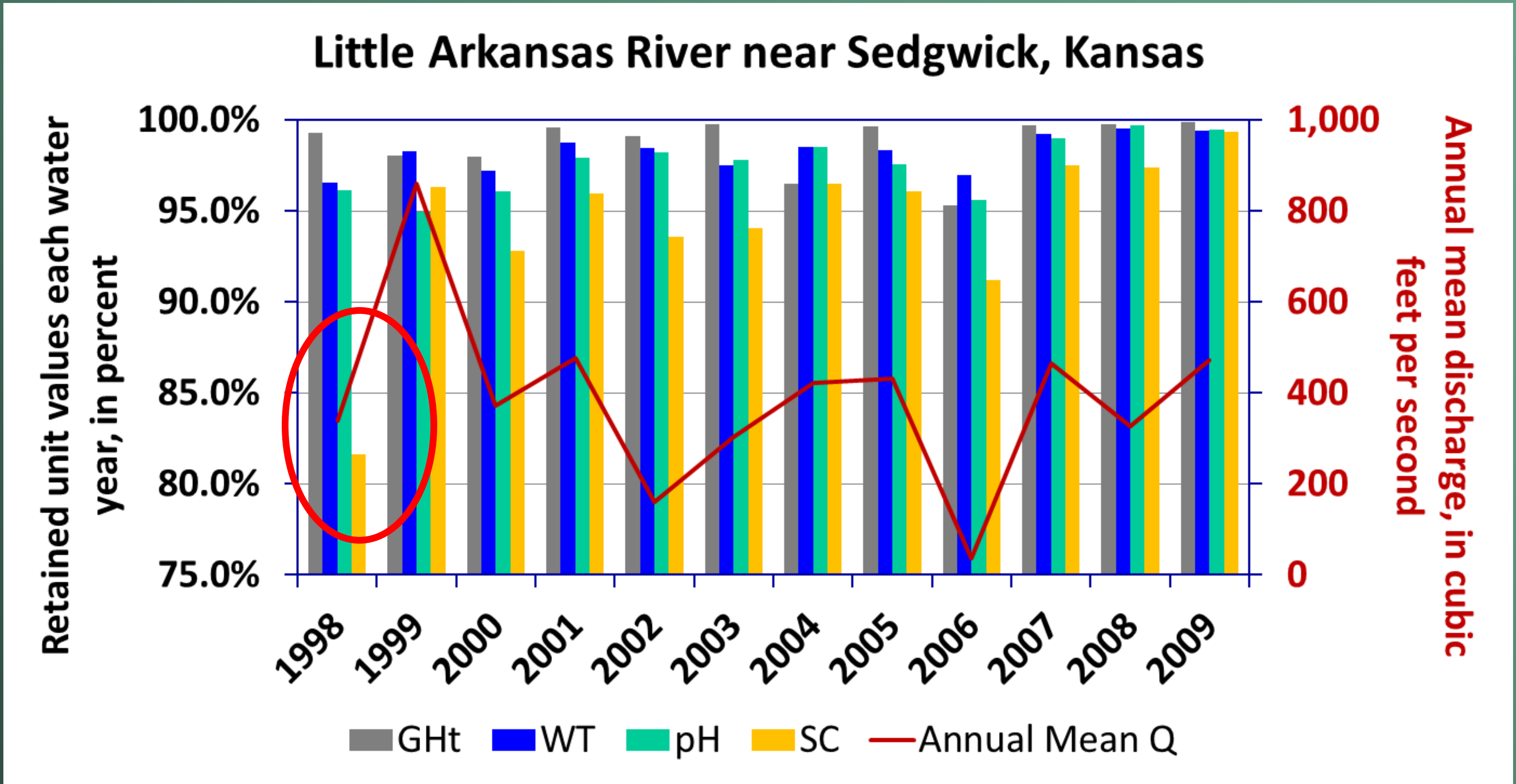
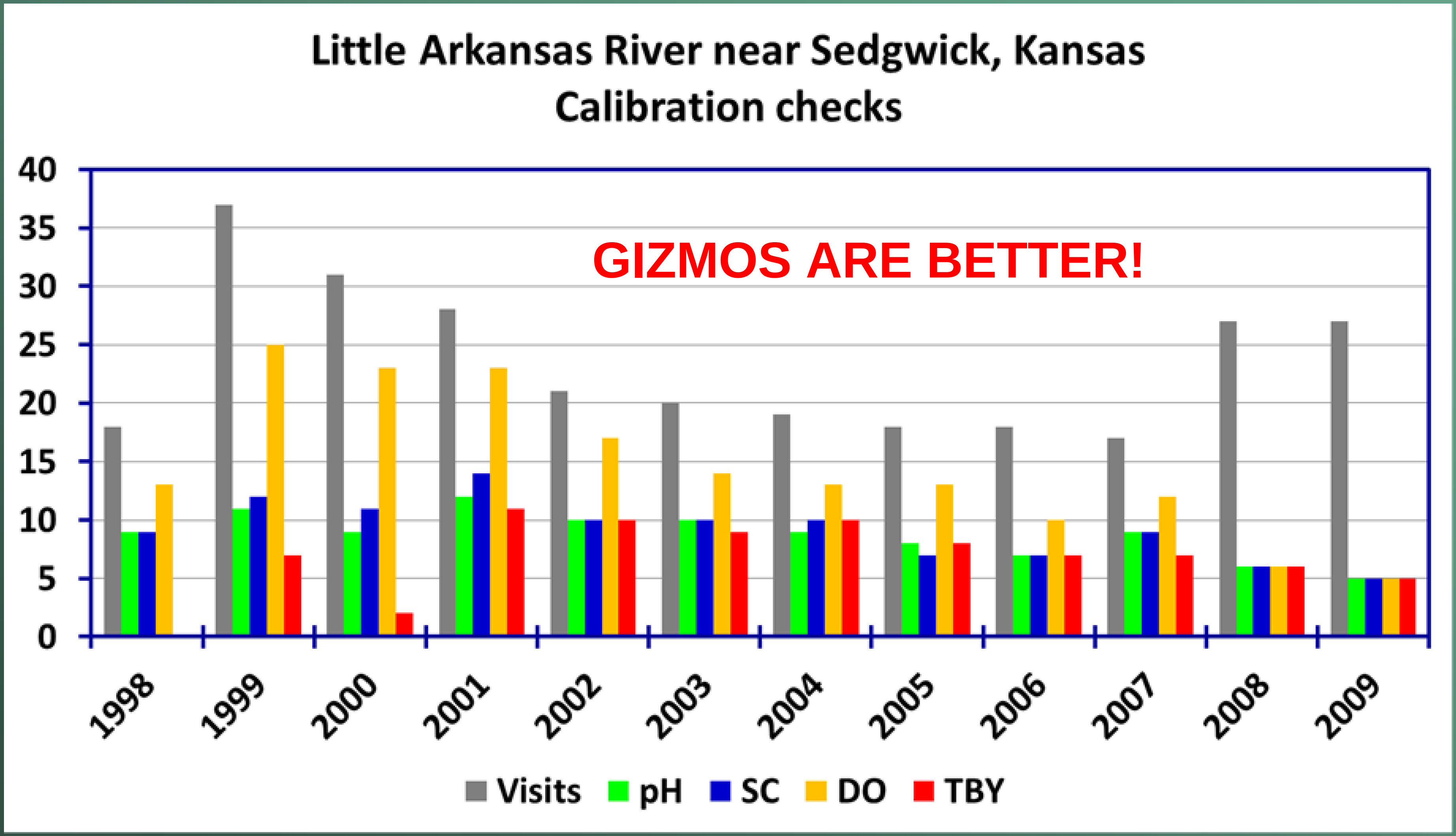
Bridge suspension dramatically increased retained data ('98-'99) for conductivity sensor at Sedgwick site



Bennett and others, NWQMC April 2010

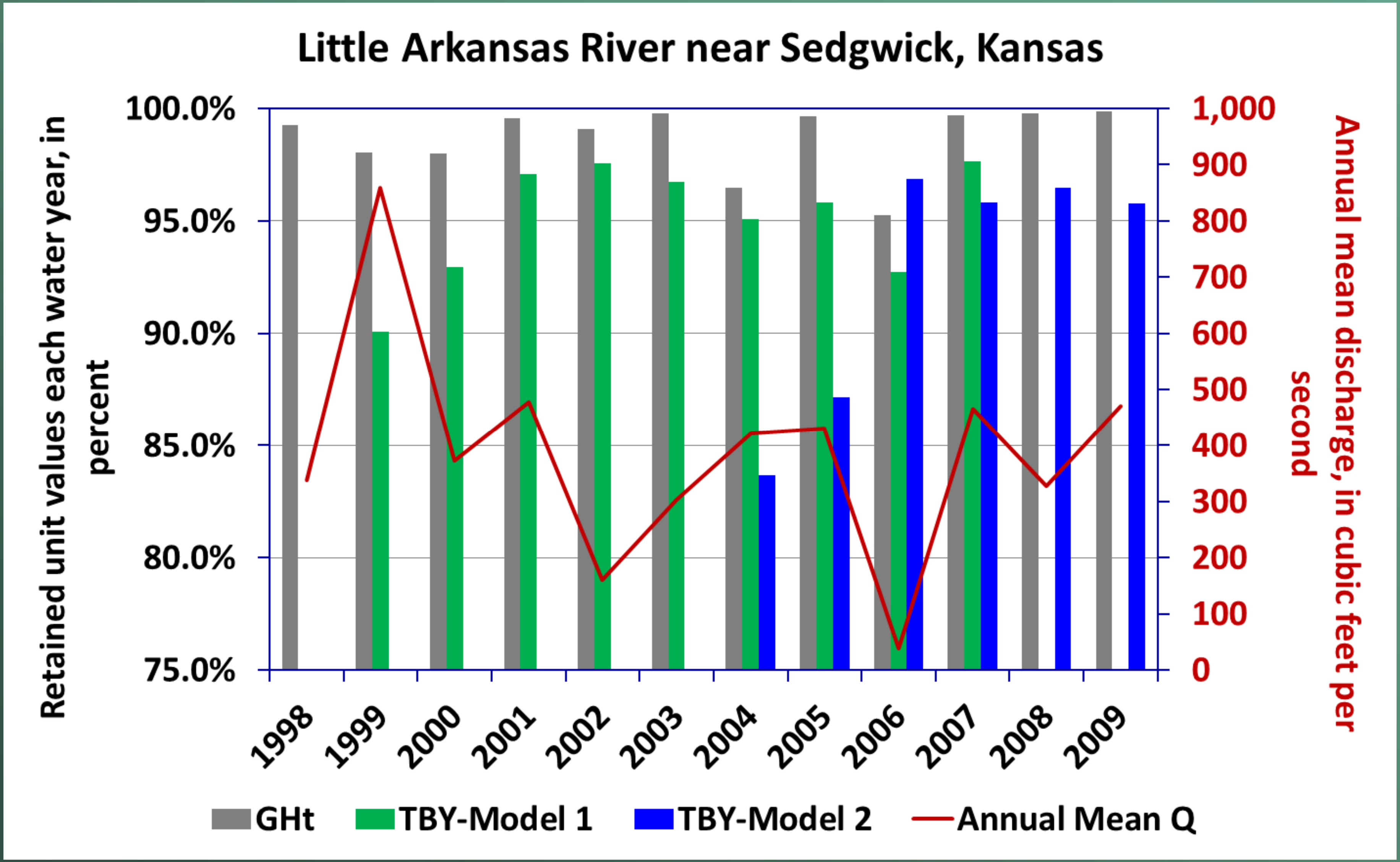
Downside of bridge suspension-- monitors getting caught in debris flow

Number of site visits for calibration checks have been decreased by 5x, but fouling…..



Bennett and others, NWQMC April 2010

Completeness varies but more than 95%



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Bennett and others, NWQMC April 2010

Goal is to automate the qa/qc of the data in real-time

- To streamline record work in Kansas
  - NWIS database
  - CHIMP
  - GRSAT/AQUARIUS
  - ADAPS
  - NWISWeb and NRTWQ
- Integrate AQUARIUS into our workflow

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Recommendations

- Committee on Streamgaging Costs and Support 2008
- Continuous Record Processing team 2008
- QW Monitor Value Engineering Study 2009
- SW Value Engineering Study 2010
- Improving Continuous Water-Quality Workflow 2010

All concluded that streamlining and automating records will improve quality and **reduce costs**

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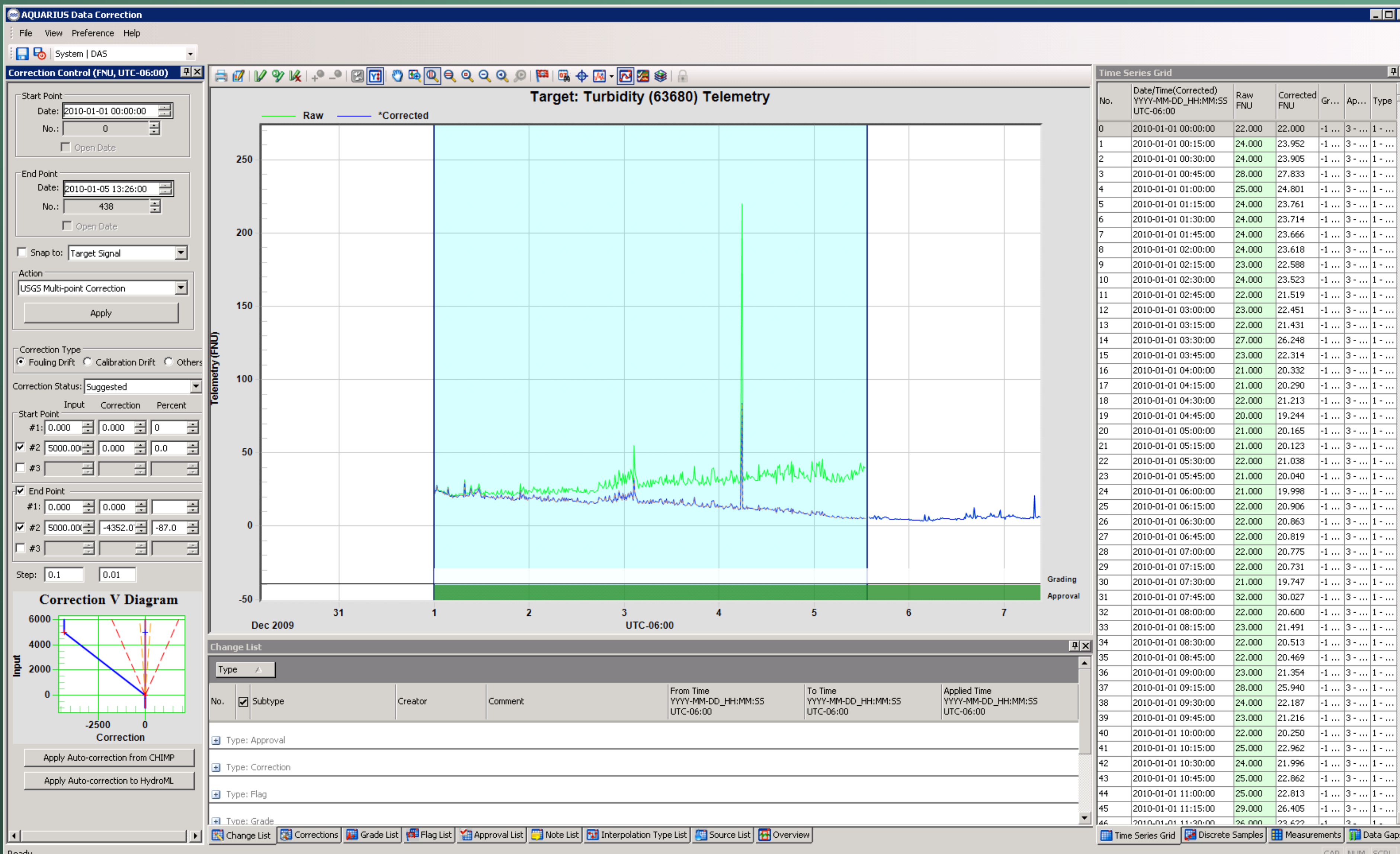
Data corrections in AQUARIUS



Benefits of “automated” records- QA/QC

- Rule-based approach provides objective and consistent data-correction computation

- Automating data-correction computation and application
  - eliminates transcription errors
  - saves time
  - replaces existing spreadsheets
  - illuminates the need for a checker

- Integration of graphical and tabular data display allows for efficient, intuitive record working, review, and approval
- Repetitive tasks in workflow are mostly eliminated, saving hydrographer’s time
- Enhances our ability to successfully QA and finalize data in real time

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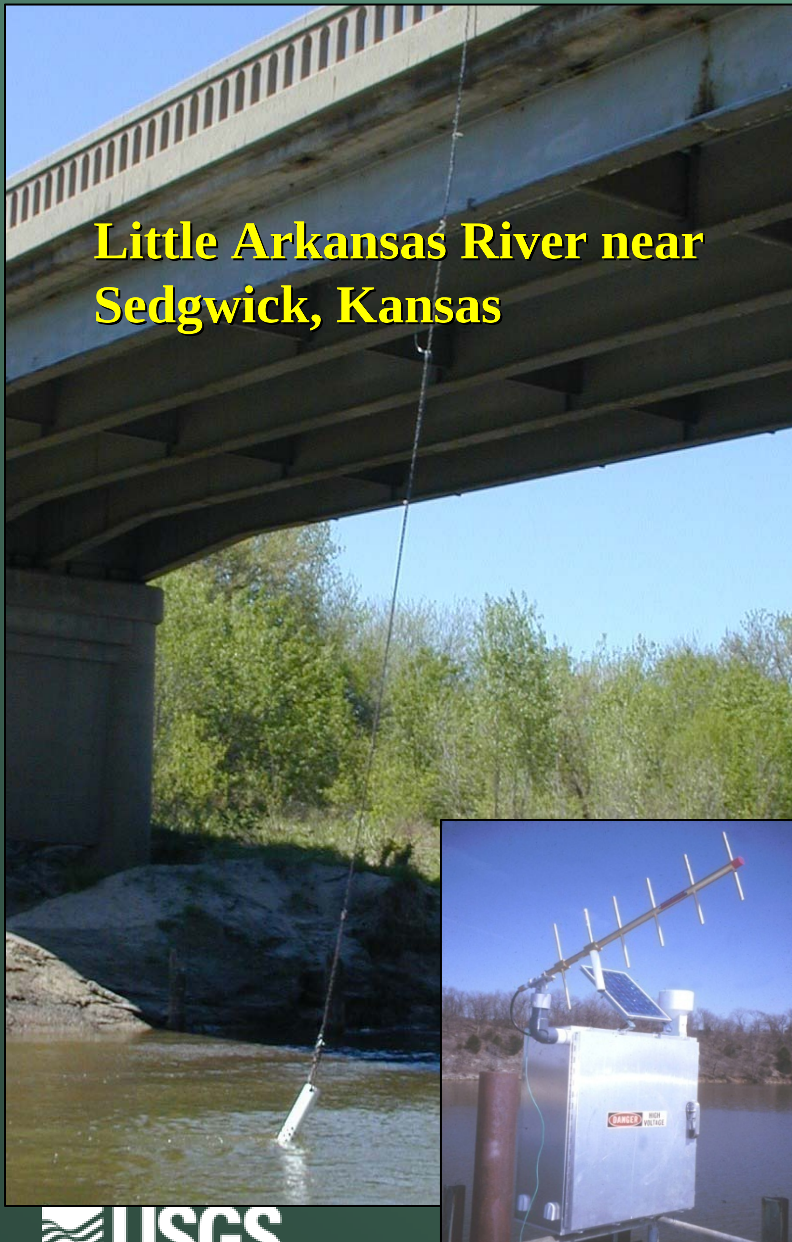
USGS Real-Time Water Quality Approach:



- Add water-quality monitors at streamgages and transmit data “real” time
- Collect water samples over the range of hydrologic and chemical conditions
- Develop site-specific regression models using samples and sensor values
- Compute concentrations and loads
- Publish regression models
- Display computations, uncertainty, and probability on the Web
- Continued sampling to verify models

Rasmussen, Gray, Glysson, and Ziegler, 2009, http://pubs.usgs.gov/tm/tm3c4/

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“Surrogates” are “calibrated” sensors

- Use in-situ measurements when direct measurement sensors are not available
- Calibrate the in-situ sensor with samples collected over range in conditions using statistics and develop models (the simpler, the better)
- Compute concentrations, loads, uncertainty, and probability of exceeding water-quality criteria and display on web

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Parameter Directly measured	Parameter Computed
Gage Height/Stage/velocity	Streamflow (discharge)
Specific Conductance	Chloride, alkalinity, fluoride, dissolved solids, sodium, sulfate, nitrate, atrazine
Turbidity	Total suspended solids, suspended sediment, fecal coliform, *E. coli*, total nitrogen, total nitrogen, total phosphorus, geosmin

Why do surrogates work?

Because there is a physical relation between the measured sensor value and the constituent of additional interest—

Sediment directly *causes* turbidity
Chloride directly causes specific conductance

In other cases, there is an *association* between the constituent of interest and the in-situ measurement—

Streamflow is computed based on the interrelation of water height, cross section, and velocity

Bacteria is associated with sediment and turbidity

Relations likely are site specific and robustness of relations depends on the consistency of sources of the constituents

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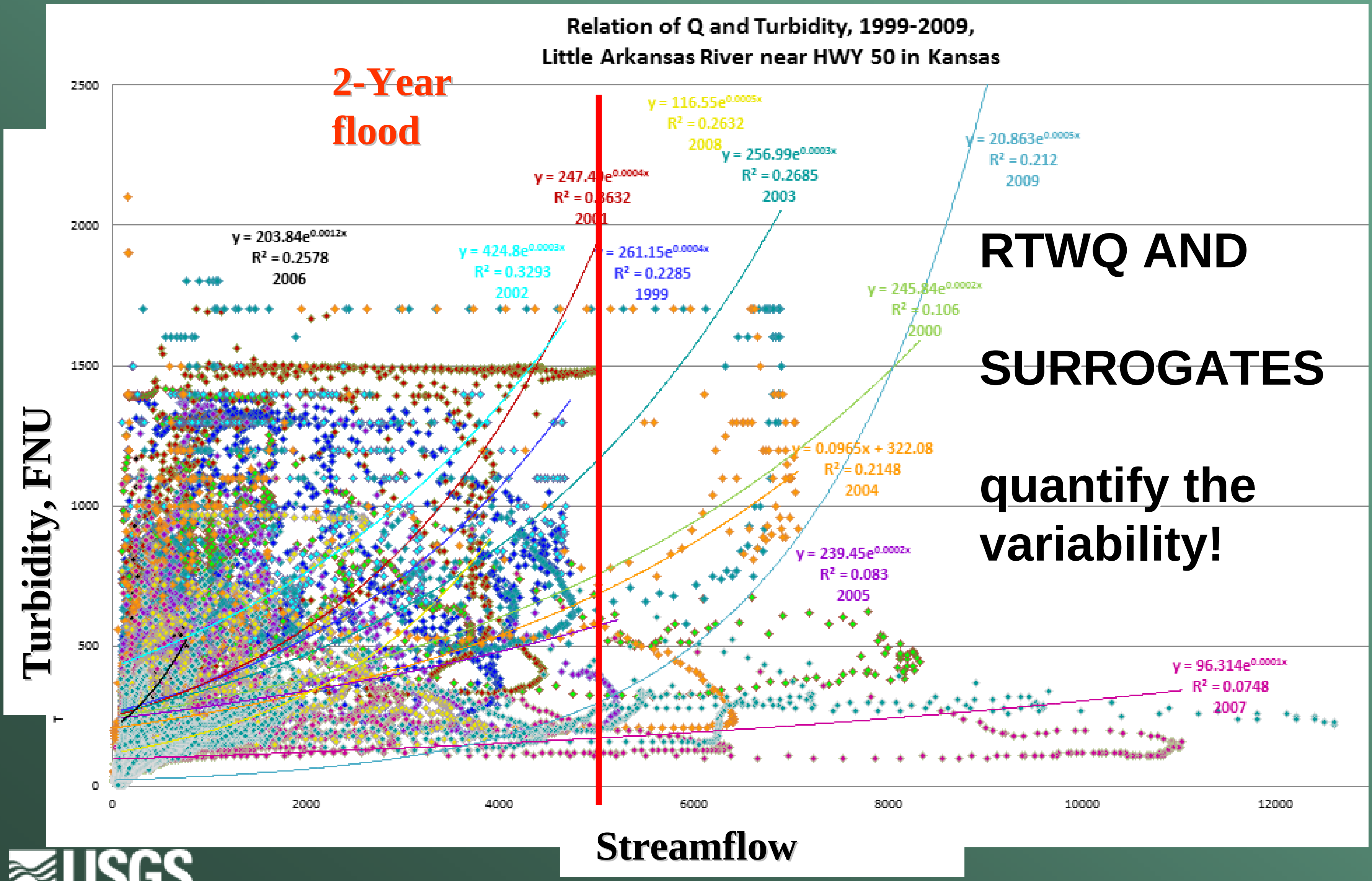
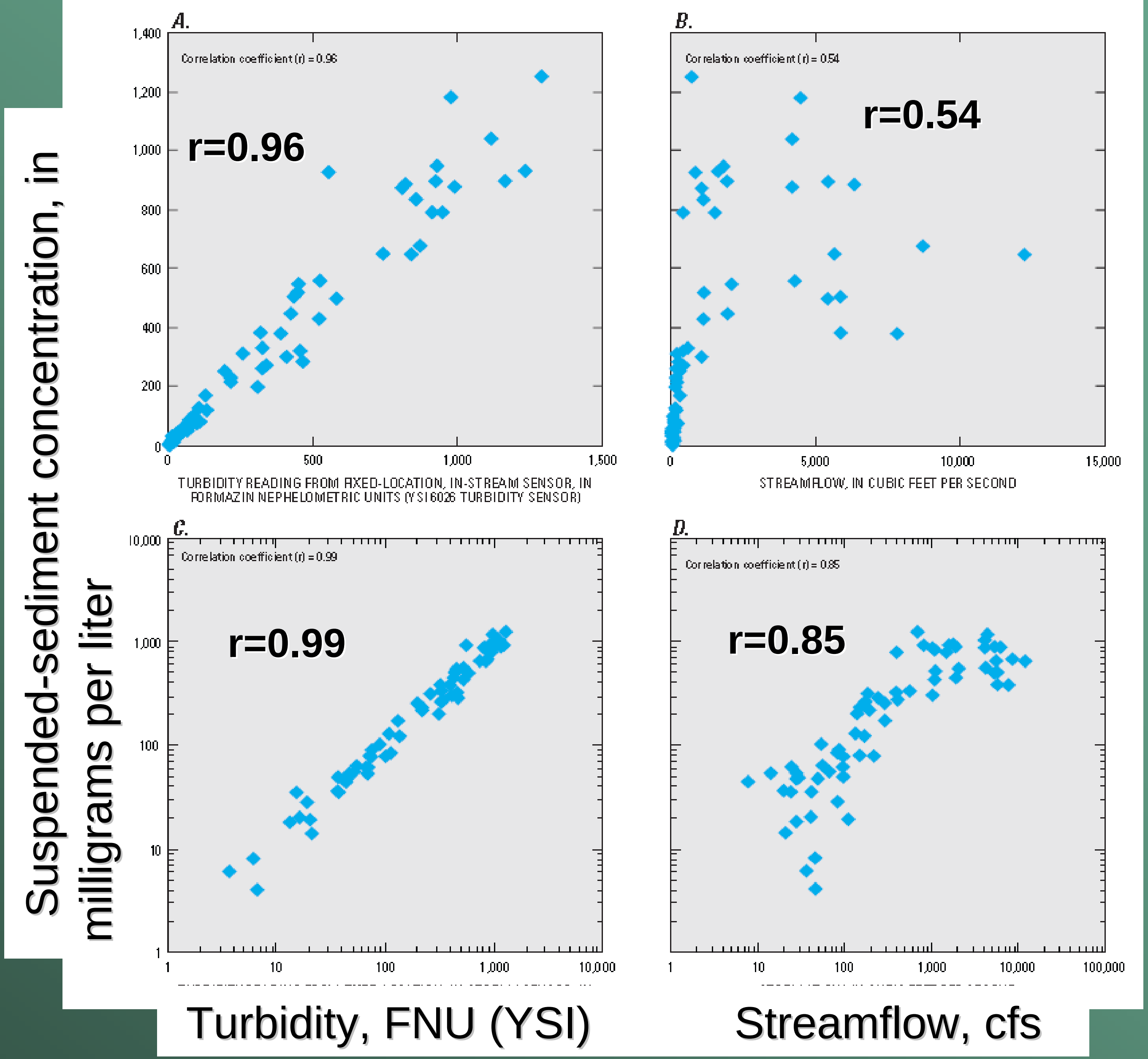
Streamflow relation to water quality is complex and variable

Can we capture, quantify, understand, and regulate this water-quality variability with 6 or 10 or 20 samples per year?



Turbidity

provides the best estimate of suspended-sediment concentrations



Rasmussen and others, 2009

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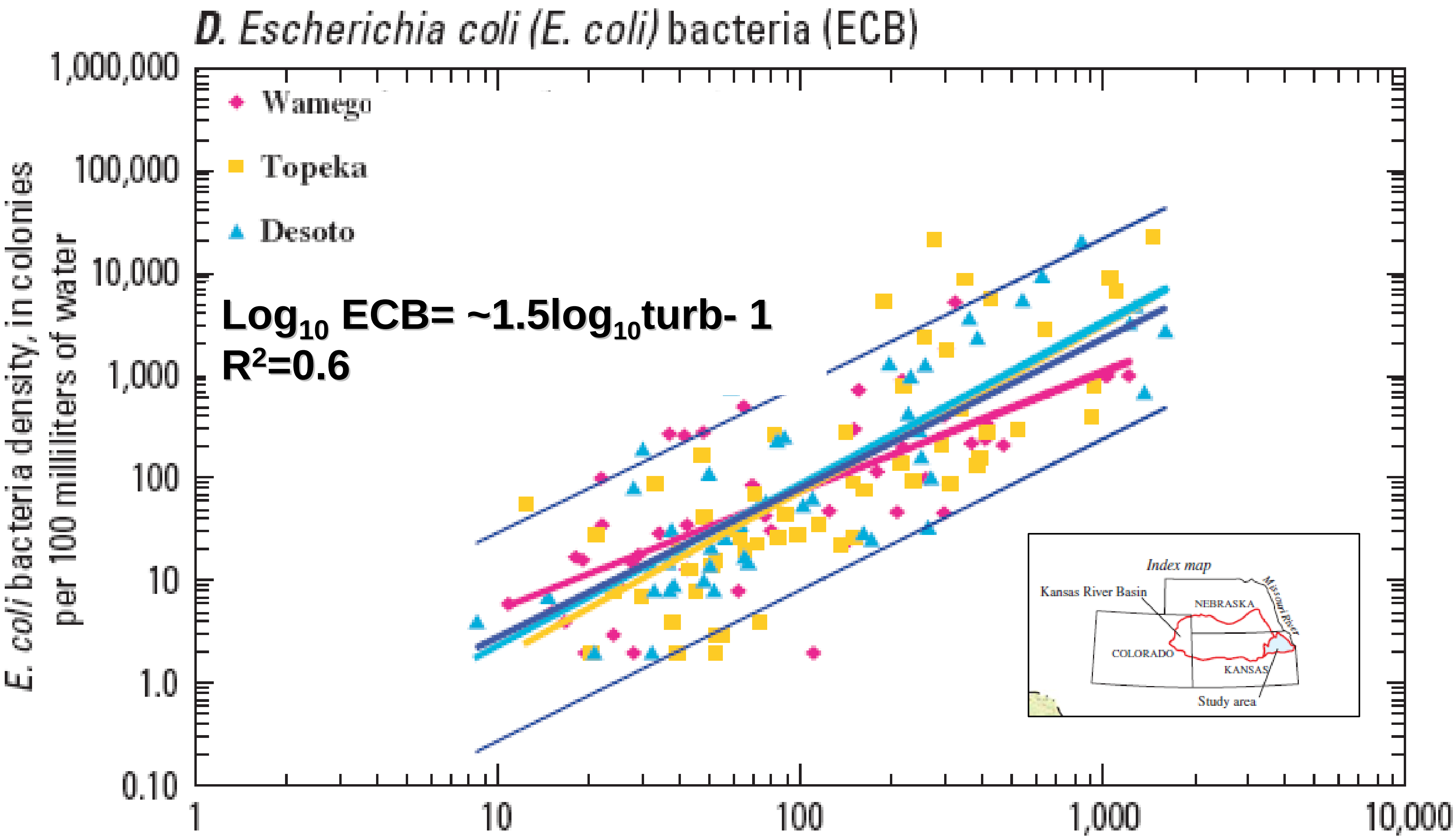
http://water.usgs.gov/osw/suspended_sediment/time_series.html

Turbidity estimates *E. Coli* reliably



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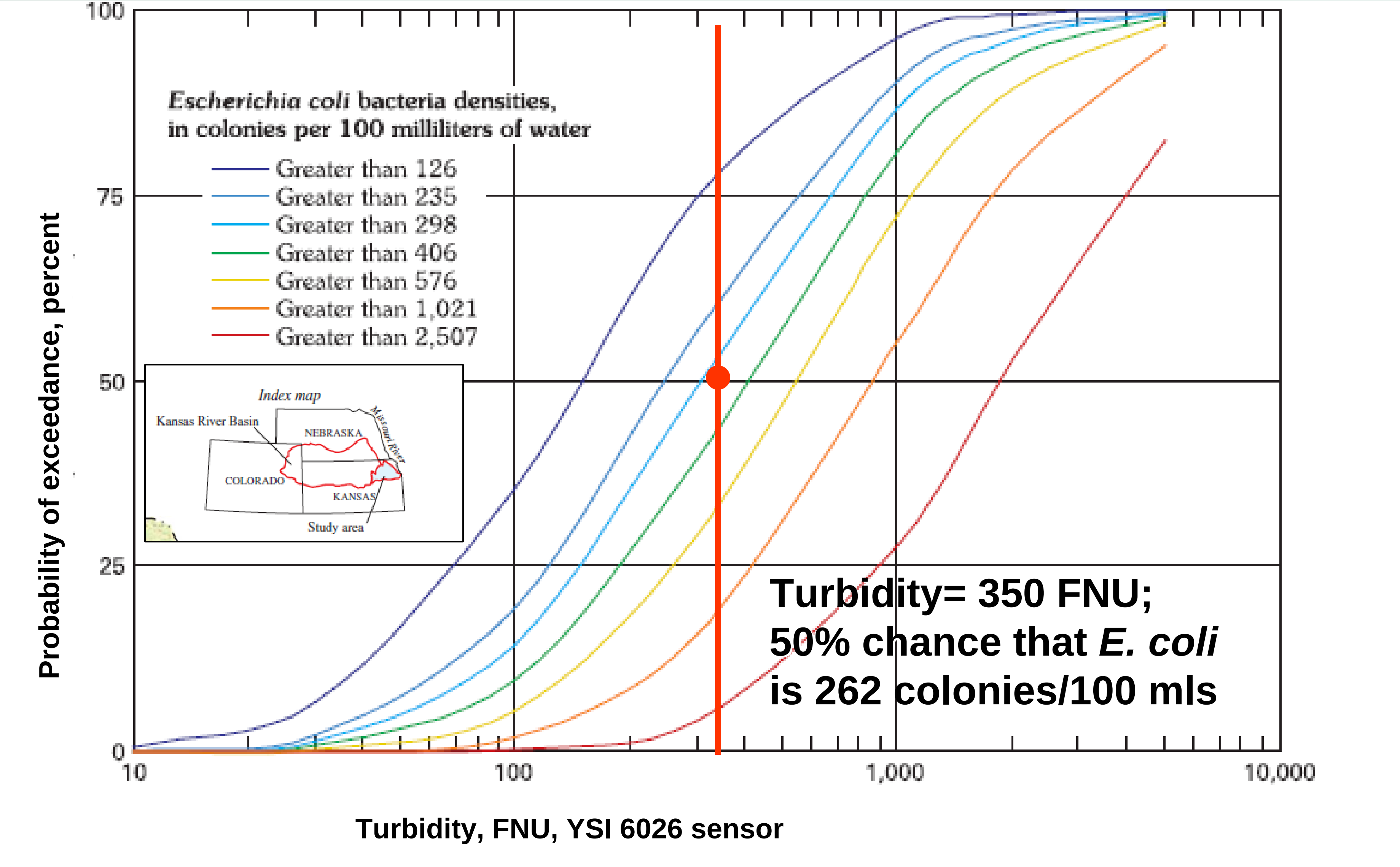
Rasmussen, Ziegler, and Rasmussen, 2005

Using turbidity to estimate probability of exceeding E. coli criteria



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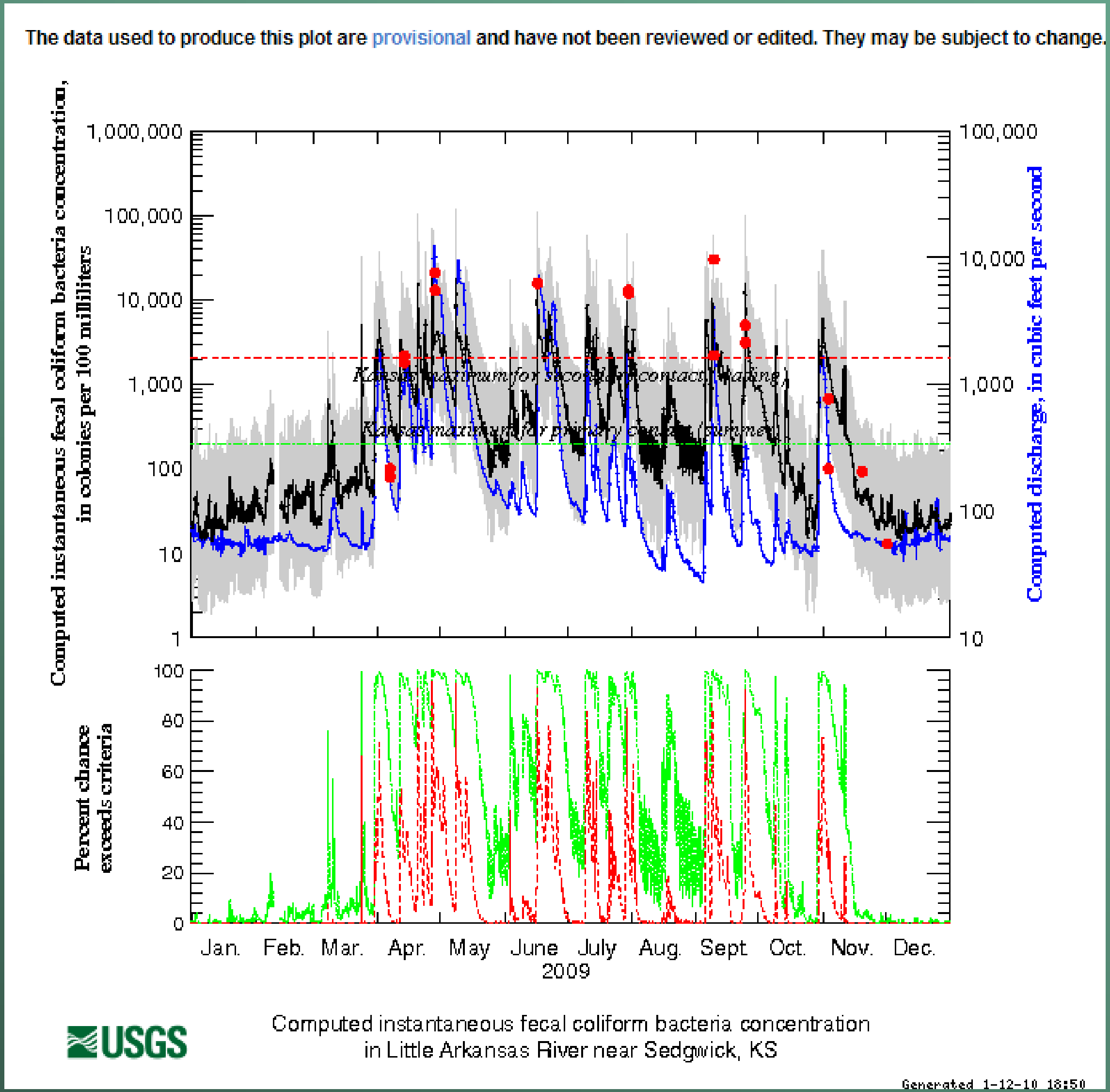
Rasmussen and Ziegler, 2003

Bacteria frequently exceed water-quality standards

Real-time computed concentrations of bacteria, uncertainty, and probability of exceeding WQ criteria

(look at the sample data….)

Aren't continuous surrogates better?

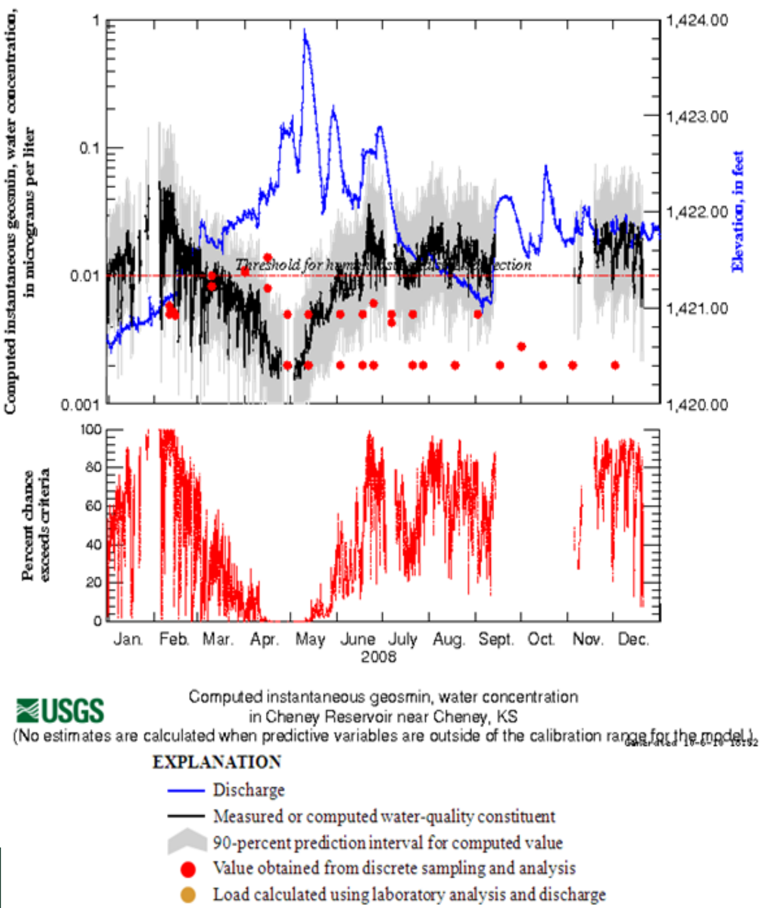


Concentration more important than load for health

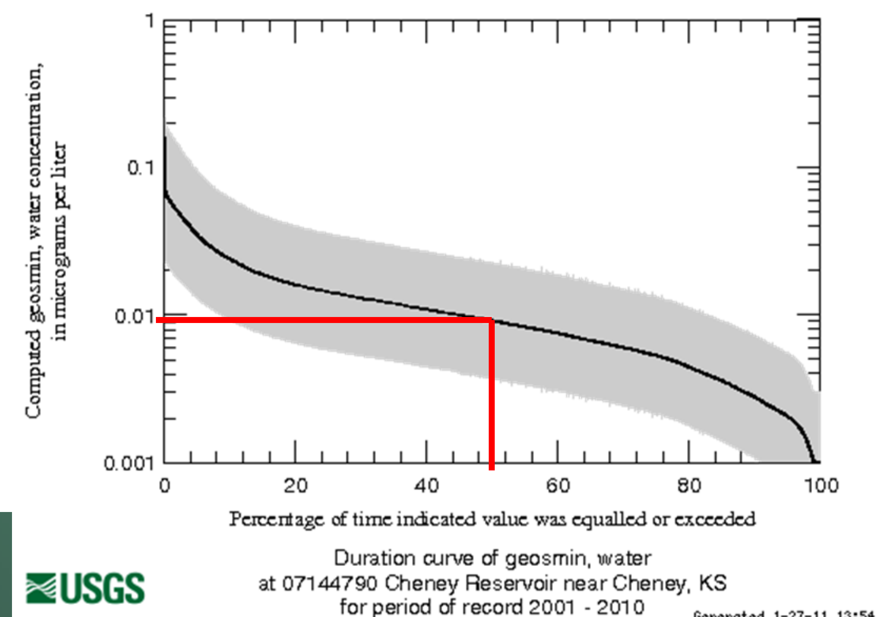
http://nrtwq.usgs.gov/explore/plot?site_no=07144100&pcode=31625&period=2009_all&timestep=uv

Early Detection - Geosmin concentrations in Cheney Reservoir exceed the human detection limit of 0.01 µg/L about 50% of the time

$\log10(Geo) = 7.2310 - 1.0664 \log10(Turb) - 0.0097\ SC$
$r^2 = 0.71$



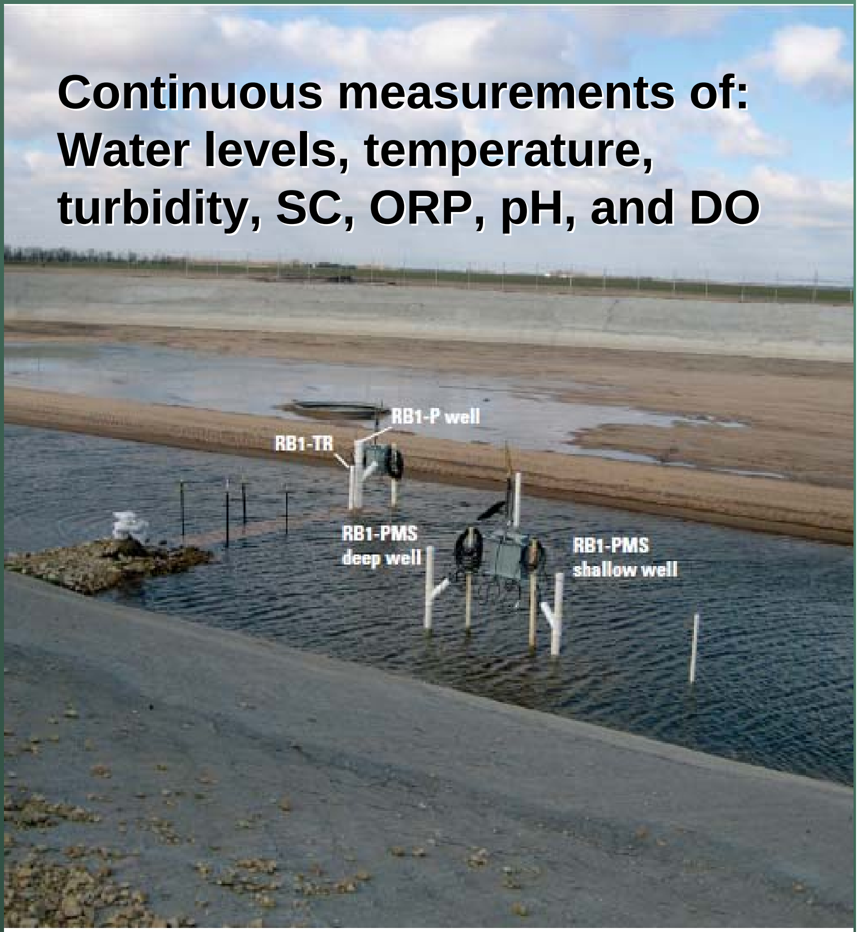
Estimates available from 2001-present



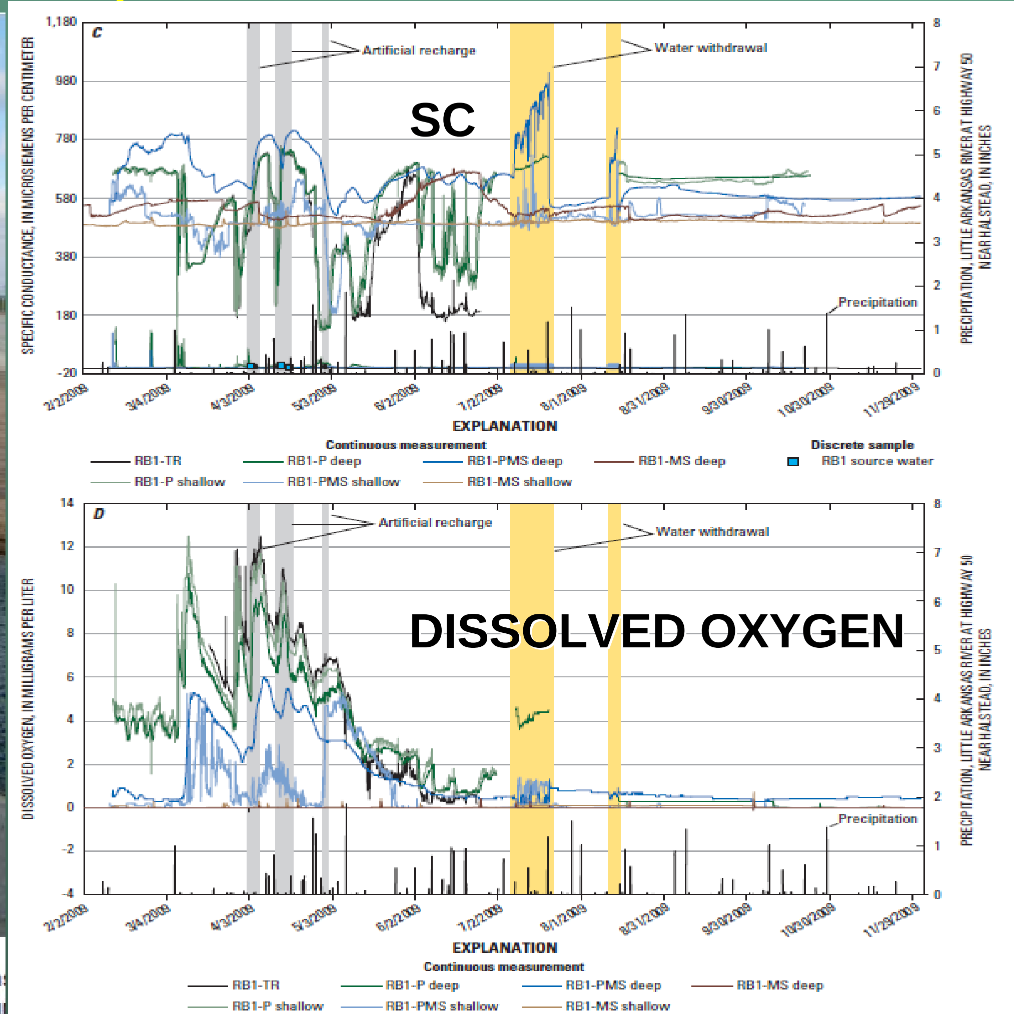
What About Groundwater?– Of Course!

Effects of experimental passive artificial recharge of treated surface water on water quality of the Equus Beds Aquifer near Wichita, KS 2009-2010

Continuous measurements of: Water levels, temperature, turbidity, SC, ORP, pH, and DO



1-TR, RB1-P well, and RB1-PMS wells installed along the eastern edge of the original RB1 ba
te. Photographed from a location northeast of the trench, RB1-P well and RB1-PMS wells du

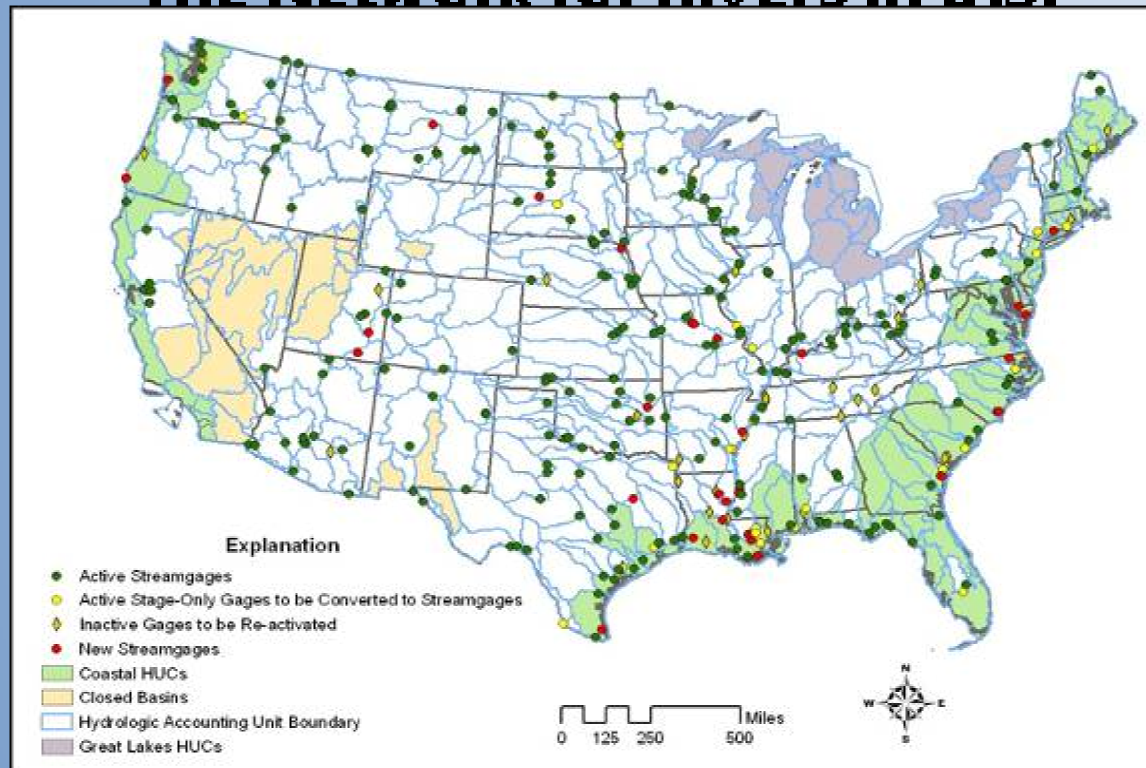


USGS SIR 2011-5070; Garinger, King, and Ziegler

Isn't it time for a National Continuous WQ network?

YES!

The Network for Rivers in U.S.



The Network for rivers is designed to assess:

- streamflow, contaminant loads, biological conditions at the outlet of each Hydrologic Accounting Unit at HUC6
- streamflow and constituent loads from coastal rivers.

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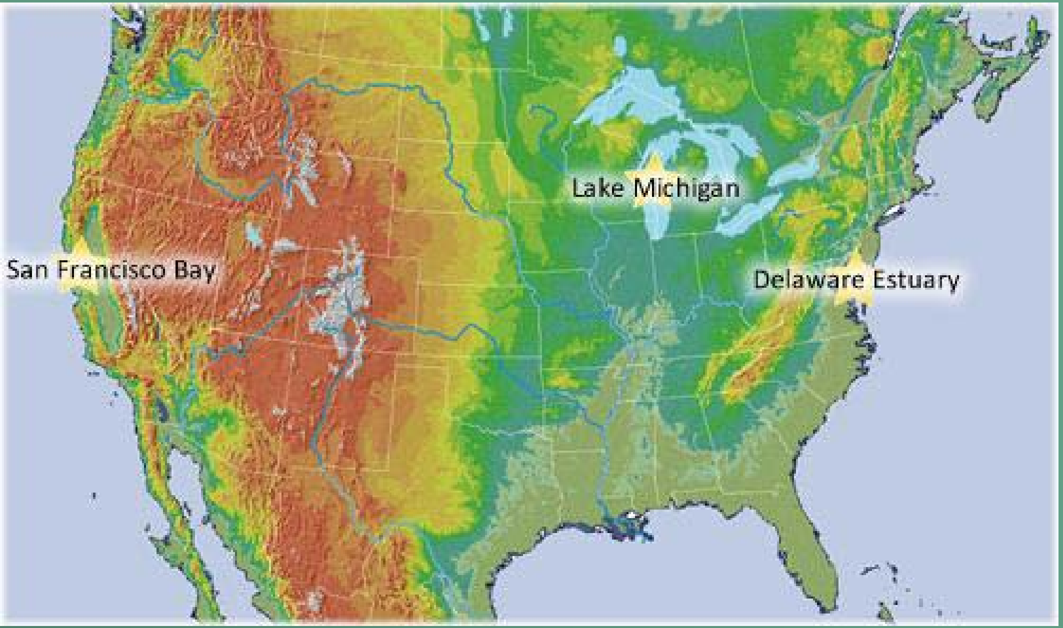
http://acwi.gov/monitoring/network/

NMN Pilots in Lake Michigan, Delaware, and San Francisco Bay



- Pilots represent 20 federal, state, local, academic, NGOs
- Fully implemented network will contribute to many of the most important resource management issues

http://acwi.gov/monitoring/

- Improvements in data management needed
- Gaps in numbers of sites, sampling frequency (nutrients) and need for additional analytes (chemicals related to fish consumption, nitrogen fluxes, effects of non-natives)

Annual estimated costs for each network estuary and its tribs would be in the range of $5-7 million each depending on size and complexity. Based on Lake Michigan, the costs for each Great Lake would be $12 million.

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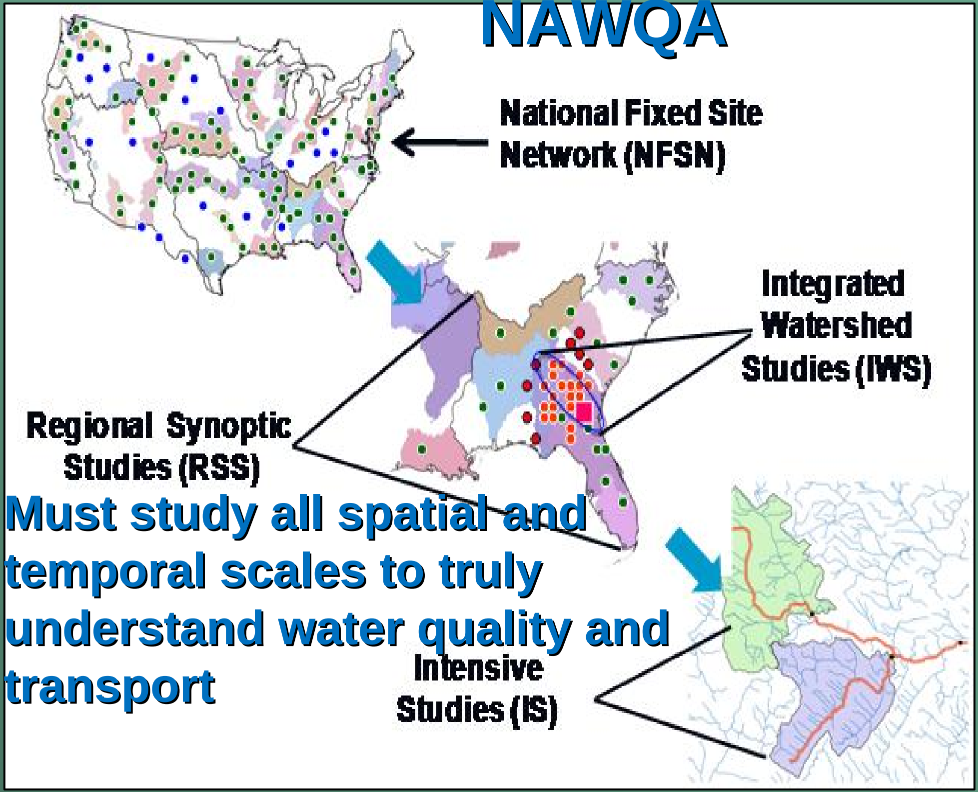
What do we gain from a National Continuous Water-Quality Network?

- Information to assess, describe, and understand water quality for all uses—drinking water, recreation, environment
- Infrastructure that measures water quality in very small to large river and estuaries-MS
- Use of today's technology rather than approaches developed 50 (or more) years ago that are only sufficient for annual loads—at best

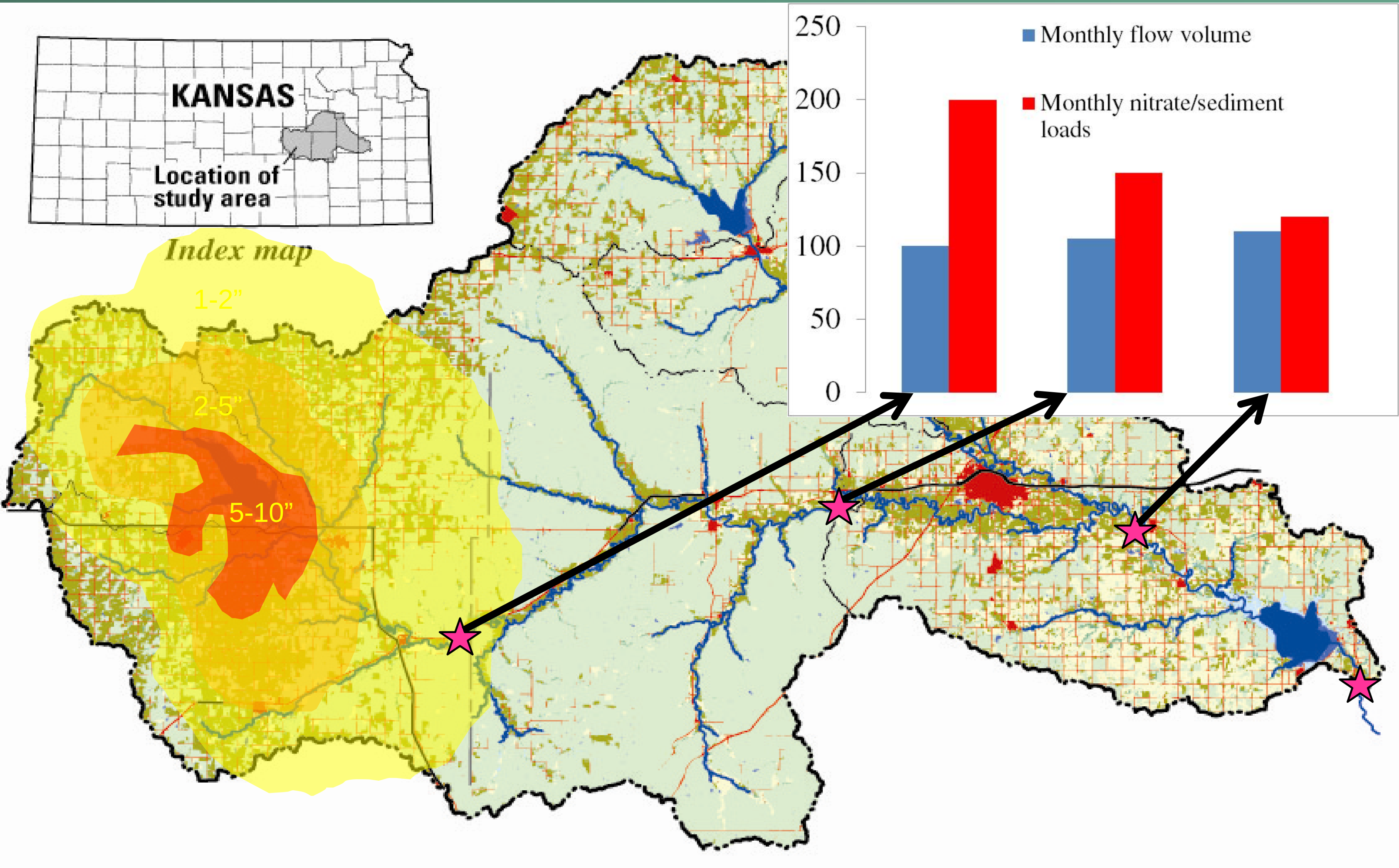
NAWQA



Must study all spatial and temporal scales to truly understand water quality and transport

▪Evaluation of the effectiveness in many and large and expensive programs (AG crop programs, EPA 319, …) designed or thought to improve water quality (but are these measurements made on the time scale that answers these questions?)

Continuous time-dense data to assess sources and transport



An example:
Vision: A National Sediment & WQ Monitoring Program

Establish a long-term, network-designed national monitoring program to generate sediment, nutrient, and sediment-associated chemical concentrations, loads, budgets and temporal trends that are integrated within existing networks.

Mississippi Basin proposed pilot program that grows into a national network

ftp://ftpext.usgs.gov/pub/er/va/reston/jrgray/mrb_proposal/

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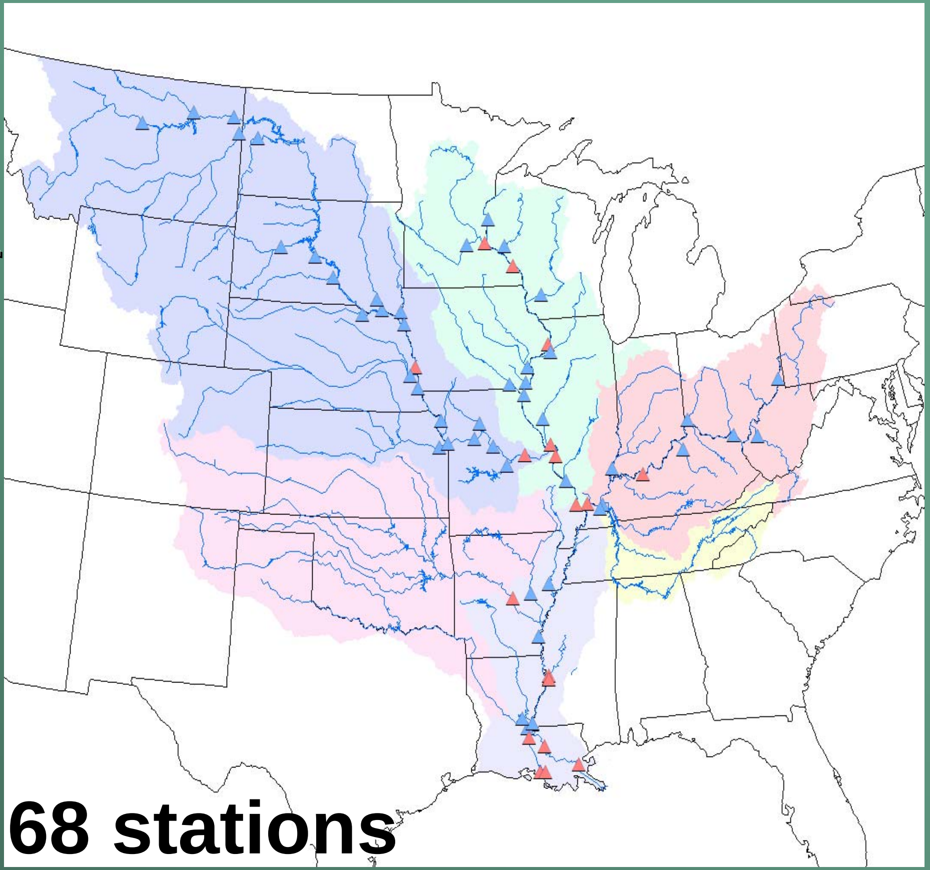
National Program Cost/Benefits

400-450 stations about $ 100 M annually

Pilot program in Mississippi River Basin proposed at $18M

National program cost is <1% of estimated sediment costs/damages annually

Not to mention the Gulf Hypoxia costs…….



68 stations

Max use of USGS gages & programs

20 sites Priority 1:
Large-scale processes

48 sites Priority 2:
Watershed proc./issues

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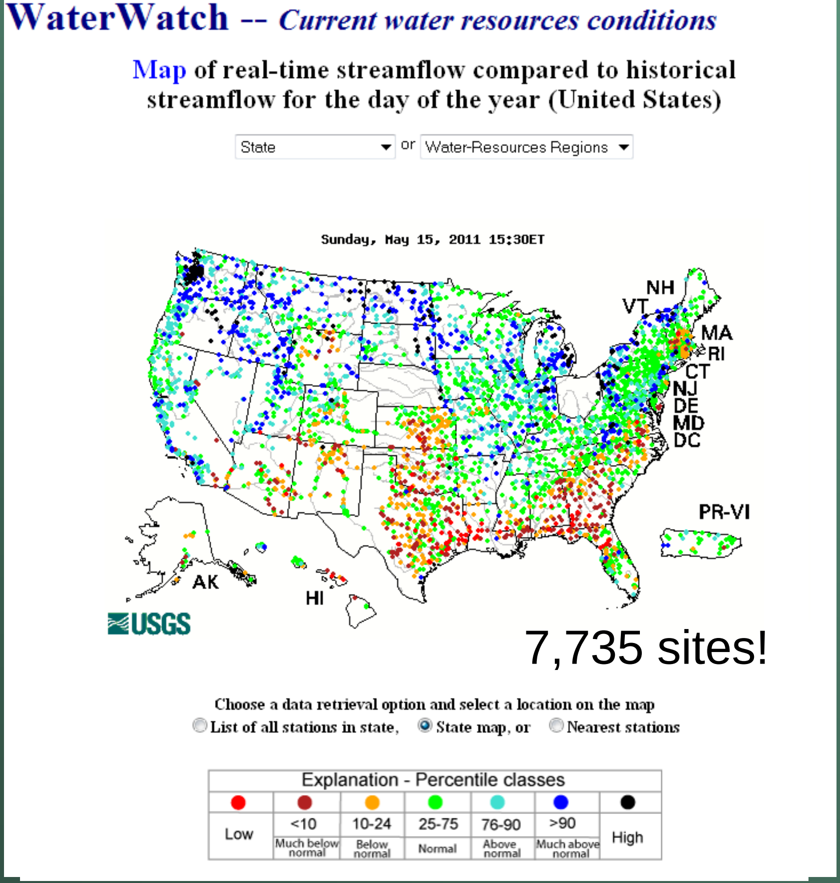
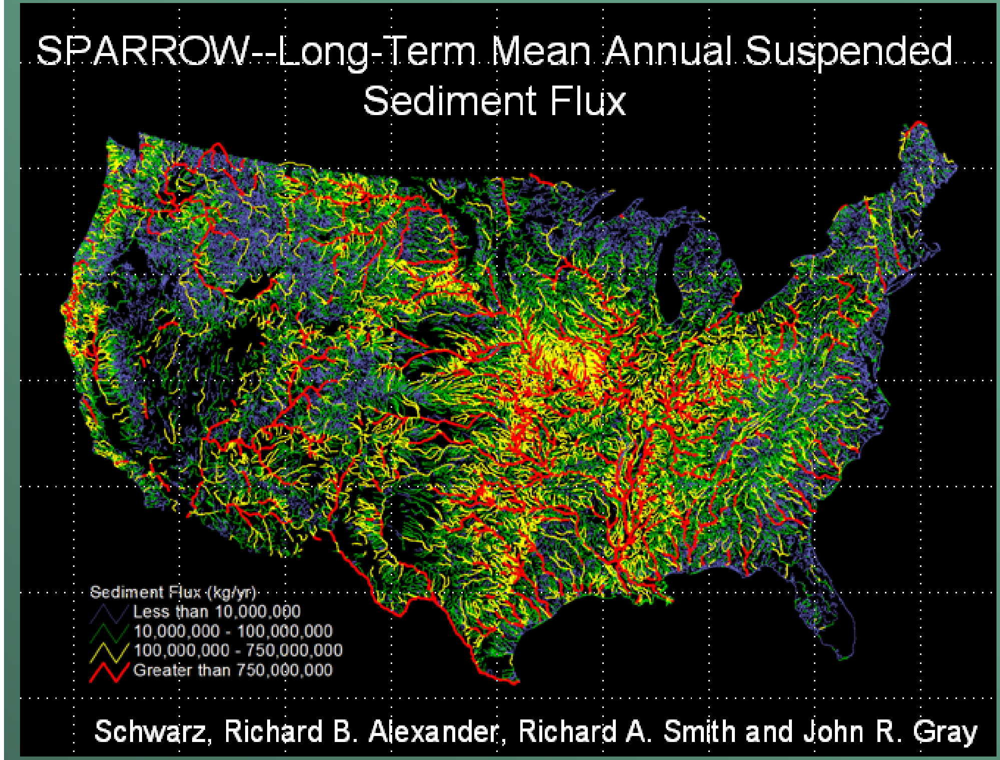
Vision: Water-quality information, anywhere at anytime (Thank you, Bob Hirsch!)





Our goal should be to provide water-quality concentrations and loads with associated uncertainty on all time and spatial scales with a historical perspective … and forecasting!

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Three Areas needed for the Future-

“Water Quality-anywhere anytime”

- Data and databases
- Statistics and models
- Information dissemination

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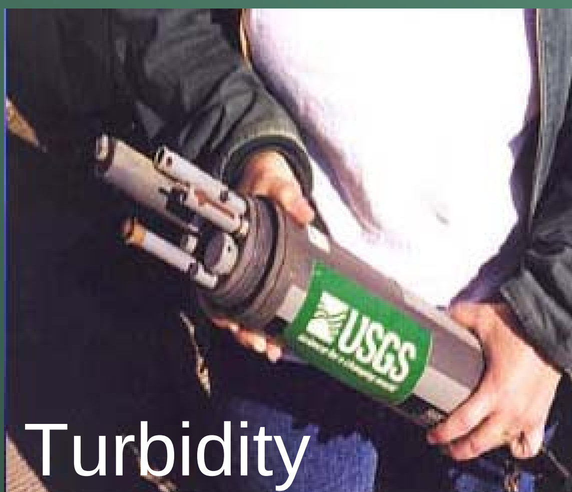
DATA--Improved Sensors!

- ***Streamflow, Turbidity*, *acoustic backscatter*, *ultraviolet nitrate, laser-based* sensors**



Laser-Based

But we need even better sensors

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Sensor needs—turbidity example

A sensor that:

- Reads values that are equivalent in an independent standard—not just formazin
- Ranges from <1 to more than 50,000 mg/L equivalent suspended-sediment concentrations with precision
- Has the ability to provide multi-scatter angles to infer or measure grain sizes of material
- Is unaffected by particle or fluid color
- Is self cleaning
- Transmits data wirelessly from the monitor to the gage for relay

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DATABASE--Value Engineering Report for Water Quality (Visited NC and KS; YSI and In-Situ)

1. Automate Data Entry and Record Processing

- Streamline data entry
- Automate data collection and analysis
- Consolidate functionalities of multiple software programs into one solution
- Improve yield in data processing

OBJECTIVE and CONSISTENT approaches

2. Reduce Wastes

3. Reduce Frequency of Visits to Field Sites

4. Continuous Improvement

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Future—Data and databases

- Use new technology-More sensors/direct measurement
- Low maintenance or self-cleaning sensors
- Sensors that work in groundwater/reducing conditions
- MCERTs—NWQMC– ASTM– some standardization
- National Network- start with sediment/nutrients
- Continued Nationally consistent protocols for;
  - O&M of sensors
  - Generic testing protocols for new gizmos
  - Data storage and method delineation
- Automated data entry– maybe even wireless!
- Automated record processing/working tools
- Storage of estimates/computations
  - National "surrogate" web page for estimates/computations and retaining the historical statistical models
- Acceptance of these Qaed data in regulatory enforcement

USGS-Pat Rasmussen focus is to automate the data processing to enhance the quality and save time

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Future: Statistics and models

- National Consistency
  - T&Ms for instantaneous constituent concentrations and loads
    - Ohio bacteria
    - KTR line
    - LOADEST– (annual)
    - Instantaneous Turbidity/sediment protocol- Pat Rasmussen and others, 2009
  - Generic T&M protocol for computation of any constituent

- Automated statistical calibration model development done consistently with specific numeric criteria-

- Scenario testing/ future water-quality prediction– Recreational forecasts, Water-treatment forecasts, etc.

- Marriage of instantaneous point estimates with spatial models- Water Quality anywhere, anytime

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Future: Information transfer

- THINK, collect DATA, MODEL, PUBLISH, and repeat
  - Is more data more better? What do we need to know – process studies, customer needs, …..
- NRTWQ-National real-time computations web page:
  - Past, current, and eventual forecasts of water quality
  - Provides consistency of stats and display of uncertainty, probability, duration curves, ….
  - Comparison to water-quality criteria and probability of exceeding environmentally-relevant criteria
  - Dynamic user-specified comparisons in addition to static informational displays

If we can think of it, we can do it !

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Achieving click anywhere anytime?

- **Balance between:**
  - **Field data collection (discrete and continuous)—**

MORE SITES—National Network!

Process studies to improve our understanding—
MORE THINKING

Statistical and spatial modeling estimates (qualified with the uncertainty) to extrapolate/interpolate our information

MORE MODEL APPLICATIONS

Information dissemination to our customers

MORE NATIONALLY-CONSISTENT WEB DISPLAY AND "AUTOMATED" REPORTS

Progress is being made, but the pace must increase to meet our information needs.

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Continuous Water Quality Pledge!

- I (state your name), pledge to look for any and all opportunities to install, improve, and promote continuous water-quality monitors at more sites to develop national and international networks, applications meeting regulatory needs, and look at and think about these data to improve our understanding of the environment.

- Short version:

RTWQ—*REALLY (Just) Do It!*

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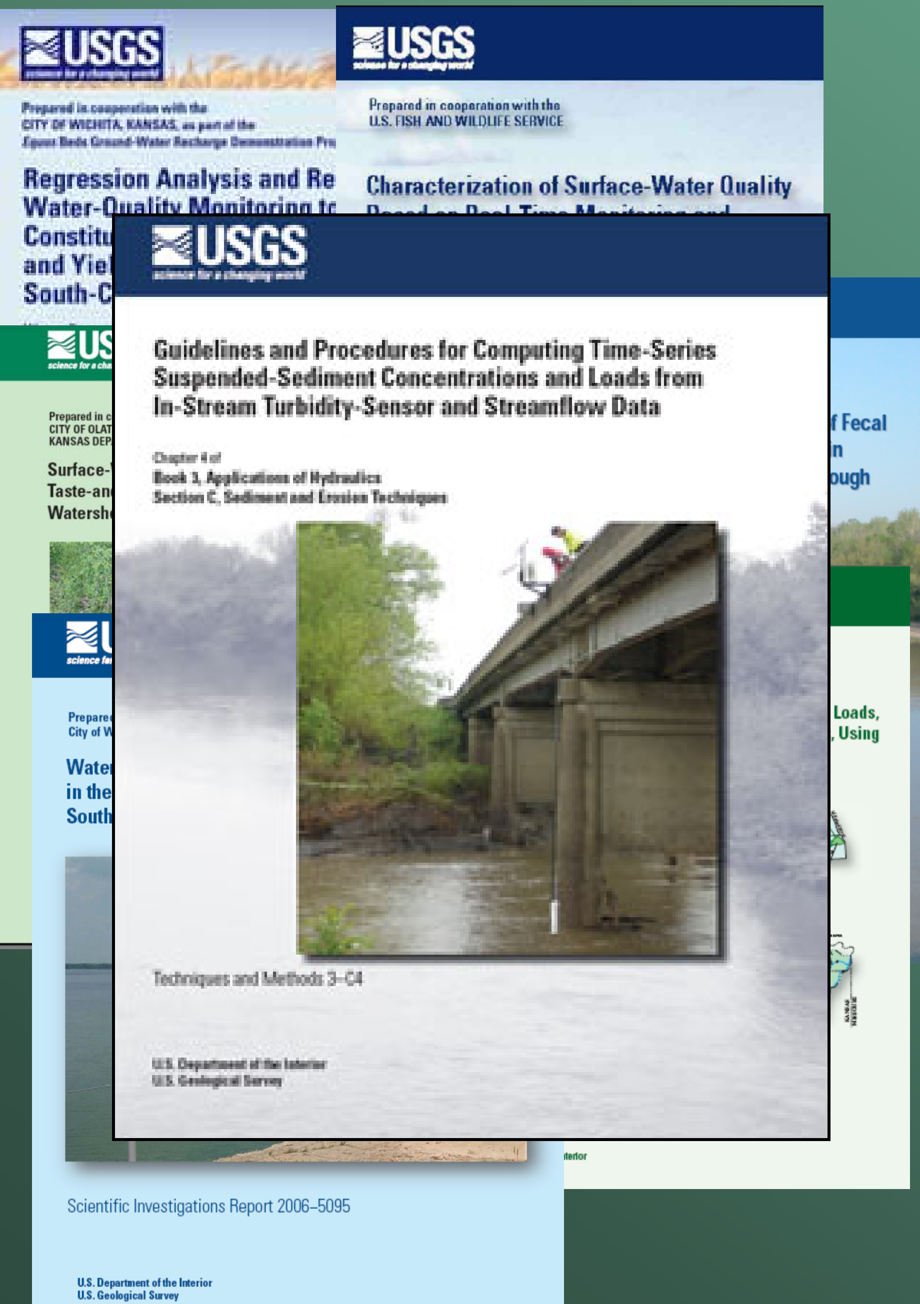
Kansas Real-Time Web Page and Reports



For more information:

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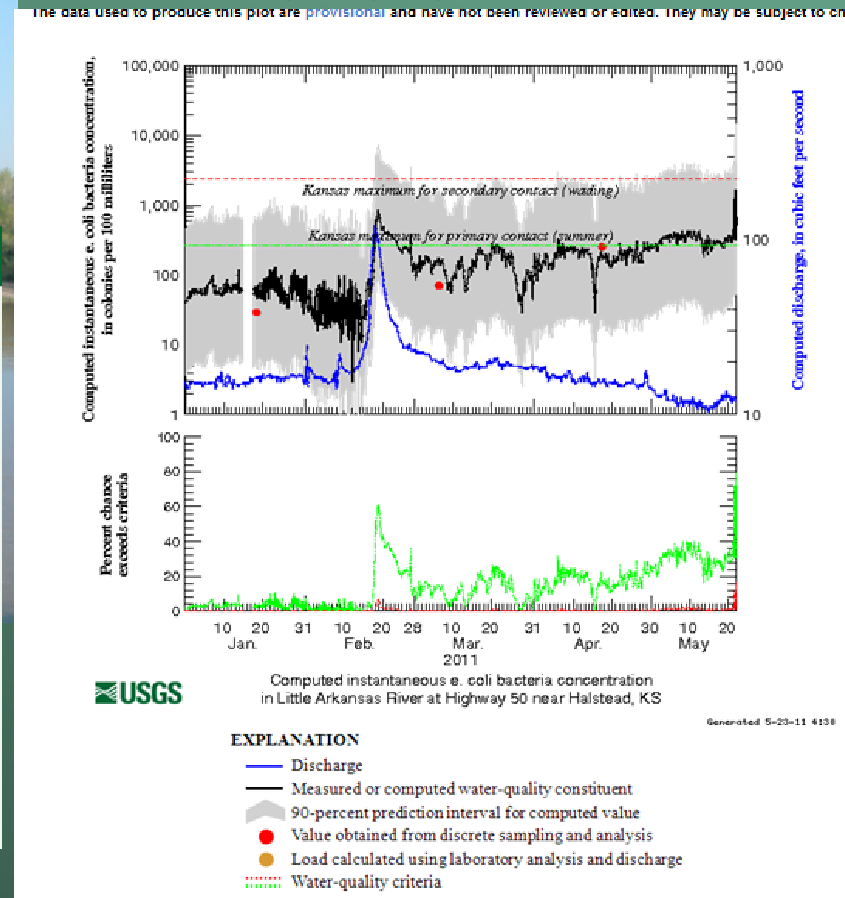

http:// nrtwq.usgs.gov/ks/

Selected Real-Time Water Quality Publications

- **Helsel and Hirsch, 1992, (2002),** Statistical Methods in water resources —Hydrologic Analysis and interpretation: Techniques of Water Resources Investigations of the U.S. Geological Survey, chap. A3, book 4, 510p.

- **Christensen, V.G., Jian, Xiaodong, and Ziegler, A.C., 2000,** Regression analysis and real-time water-quality monitoring to estimate constituent concentrations, loads, and yields in the Little Arkansas River, south-central Kansas, 1995–99: U.S. Geological Survey Water-Resources Investigations Report 00–4126, 36 p.

- **Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006**, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at *http://pubs.water.usgs.gov/tm1d3*

- **Rasmussen, P.P and Ziegler, A.C., 2003,** Comparison and continuous estimates of fecal coliform bacteria and *Escherichia Coli* bacteria in selected Kansas streams, May 1999 through April 2002, Water Resources Investigations Report, 03-4056, 97p.

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More Real-Time Water Quality Publications

- **Runkel, Robert L.; Crawford, Charles G.; Cohn, Timothy A., 2004**, Load estimator (LOADEST): a FORTRAN program for estimating constituent loads in streams and rivers: U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p.

- **Francy, D.S., and Darner, R.A., 2006,** Procedures for Developing Models To Predict Exceedances of Recreational Water-Quality Standards at Coastal Beaches: U.S. Geological Survey Techniques and Methods 6–B5, 34 p.

- **Granato, G.E., 2006,** Kendall-Theil Robust Line (KTRLine -version 1.0)__A visual basic program for calculating and graphing robust nonparametric estimates of linear-regression coefficients between two continuous variables: Techniques and Methods of the U.S. Geological Survey, book 3 chap. A7, 31p.

- **Rasmussen, Patrick P.; Gray, John R.; Glysson, G. Douglas; Ziegler, Andrew C., 2009,** Guidelines and Procedures for Computing Time-Series Suspended-Sediment Concentrations and Loads from In-Stream Turbidity-Sensor and Streamflow Data: Techniques and Methods of the U.S. Geological Survey, book 3 chap. C4, 54p.

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Discussion for Real-time water quality

- Where do we need to go (what is needed for instruments, protocols, databases, etc.)?
- Why aren’t we there? What are the technical and other impediments?
- How do we fill these gaps and get where we need to go?

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