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Sediment characterization and HSPF modeling in the Lower San Antonio River Basin, Texas

In cooperation with the San Antonio River Authority and Texas Water Development Board

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U.S. Geological Survey

Sediment in the Lower San Antonio River Basin

- Purpose of study is to better understand the complex suspended-sediment dynamics
  - What are the loads?
  - Where is sediment coming from/going to?
  - Needed to better understand sediment and nutrient loads to bays and estuaries

- Phase 1: Collect and analyze suspended-sediment, bedload, particle-size distribution, and turbidity data over a wide range of hydrologic conditions
  (Crow and others, 2013)

- Phase 2: Develop HSPF model simulating hydrology and suspended-sediment loads
  (Banta and Ockerman, 2014)

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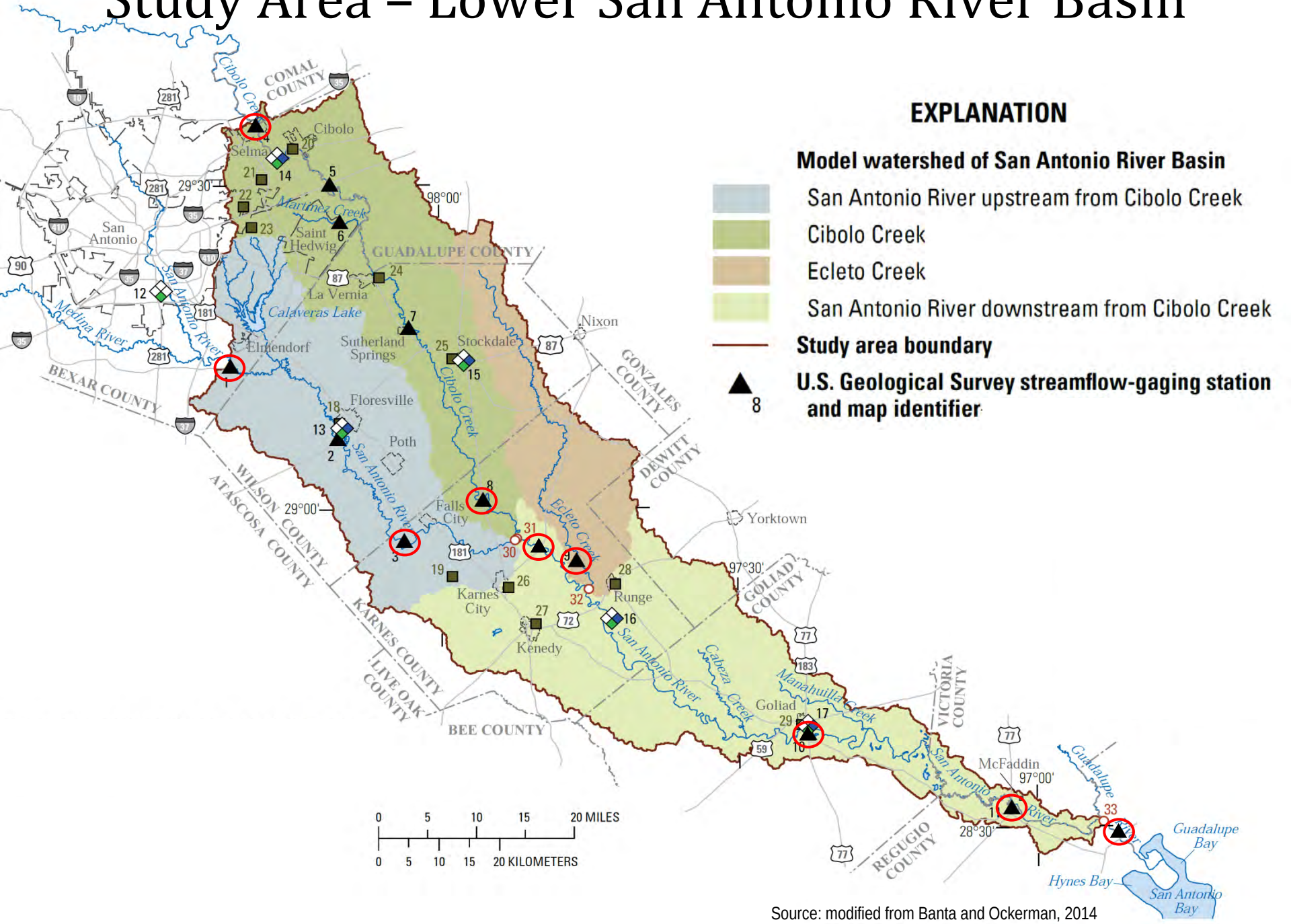
What is sediment?

- **Suspended sediment:**
  Sediment transported within the water column

- **Bedload sediment:**
  Sediment transported along the bottom of the streambed

- **Turbidity:**
  A measure of water clarity, often correlated to discrete measurements of suspended-sediment concentration (SSC) and the resulting relation is used as a surrogate for SSC

Study Area – Lower San Antonio River Basin



Source: modified from Banta and Ockerman, 2014

Methods to collect suspended-sediment and bed sediment samples

- All samples collected using standard USGS protocols (Edwards and Glysson, 1999; Davis, 2005)
- Suspended-sediment samples
  - When wadable, collected by hand (US DH-81 sampler), isokinetic equal width increment method
  - When too deep, collected from bridge or boat (US DH-2 sampler)

Photos: Crow and others, 2013; USGS

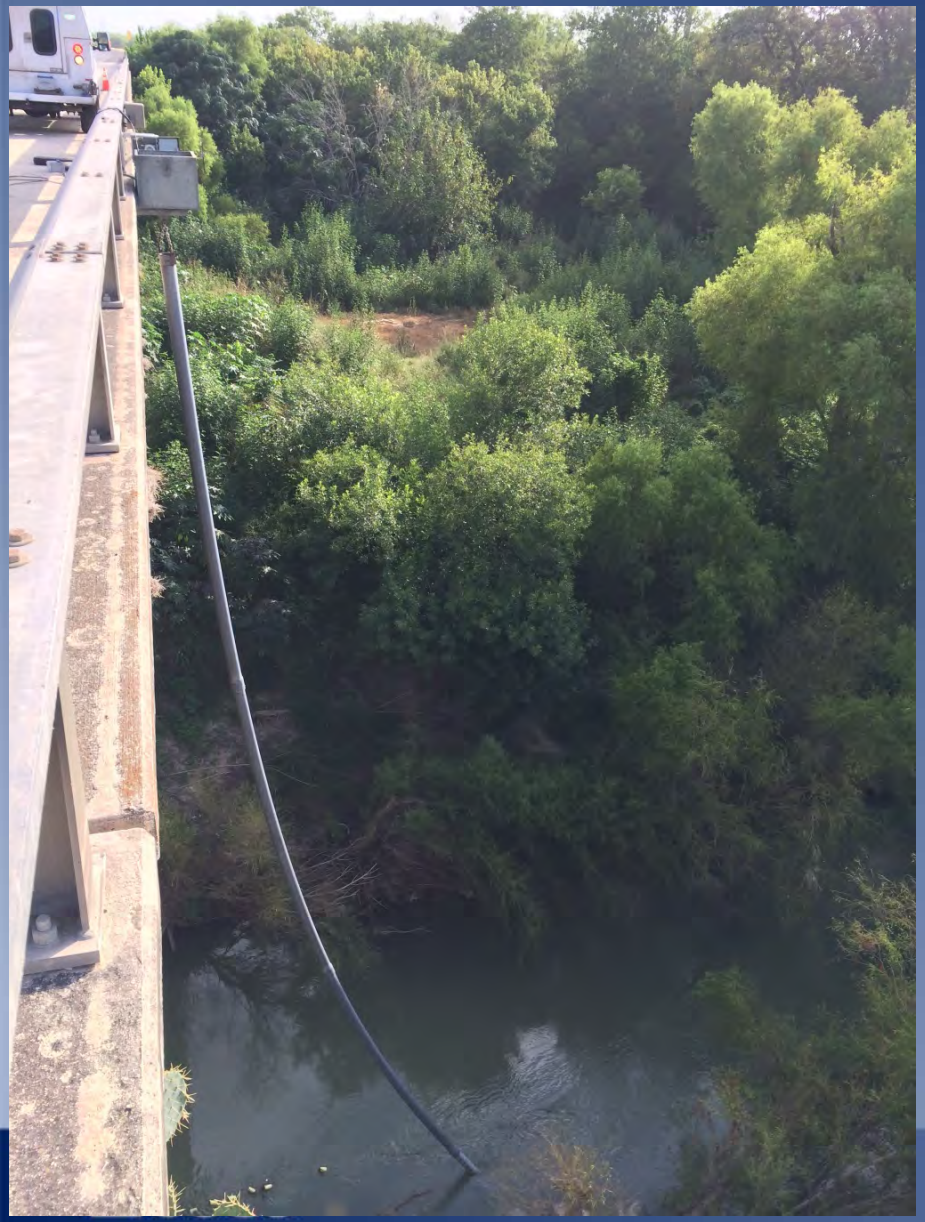
Methods to collect suspended-sediment and bed sediment samples

- All samples collected using standard USGS protocols (Edwards and Glysson, 1999; Davis, 2005)
- Bed sediment samples
  - Collected from bridge or boat (US BL-84 sampler)

Photos: Crow and others, 2013; USGS

Photo: San Antonio River near McFaddin, USGS

Methods to collect turbidity measurements



In-situ realtime time turbidity probe

(Wagner and others, 2006)

- Optical measurement of turbidity every 15 minutes
- Calibrated range from 0 – 1000 FNU

Photos: USGS

Estimating suspended-sediment loads

Suspended-sediment load (SSL) is calculated as:

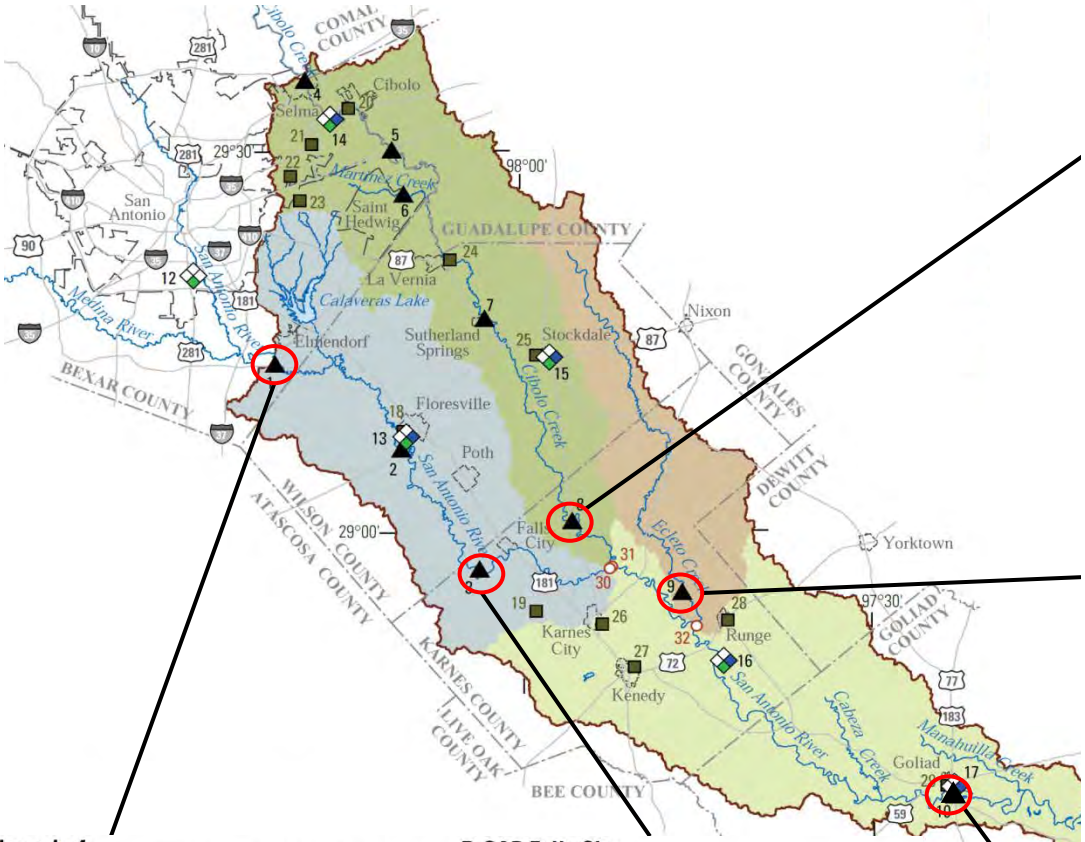
$$SSL = Q \times SSC$$

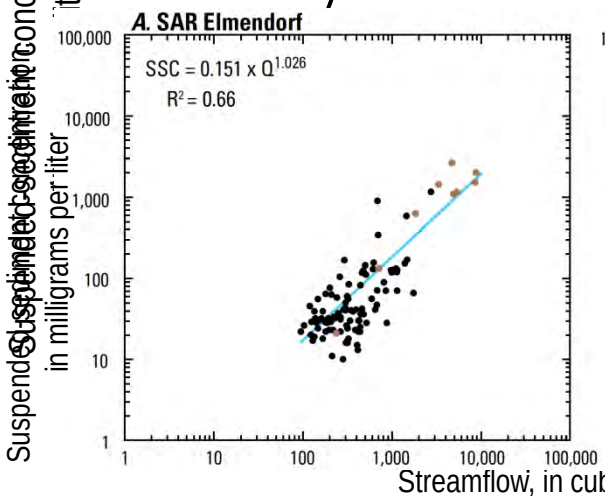
- (Q) Streamflow, (SSC) Suspended-sediment concentration
- Bedload was a small percent of the total sediment mass thus, not included in HSPF model.

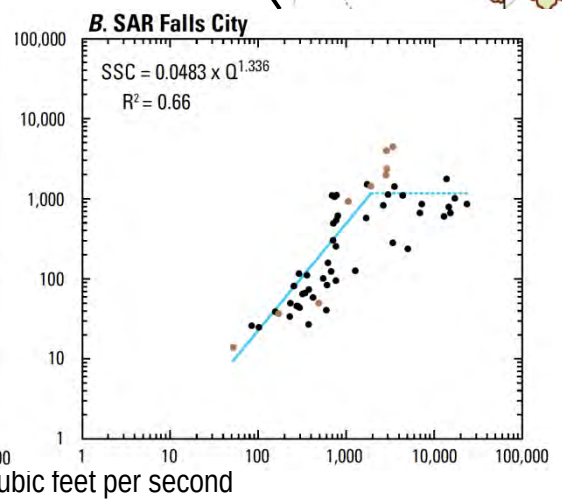
1) Develop relation between Q and SSC

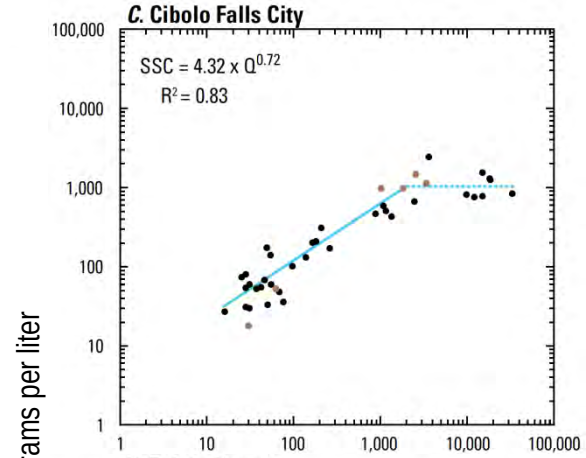
2) Use relation to estimate time series of suspended-sediment loads from streamflow
   - Caveat: previous studies have demonstrated that during stormflow events, SSL can peak prior to Q hydrograph peak.

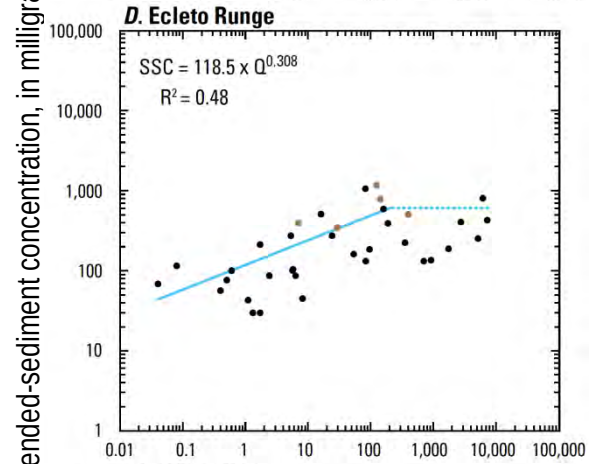
Regression Equation Development

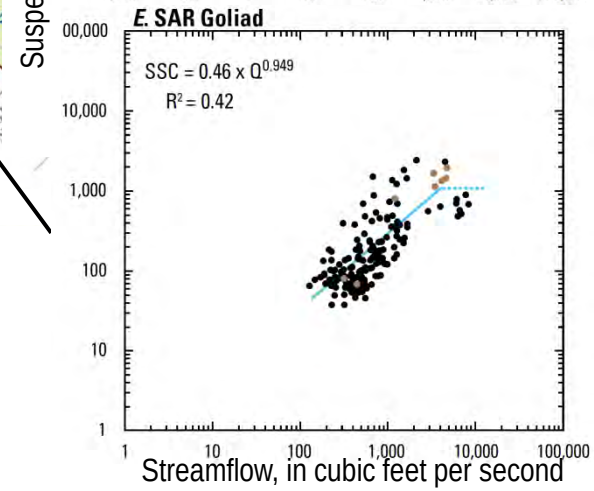






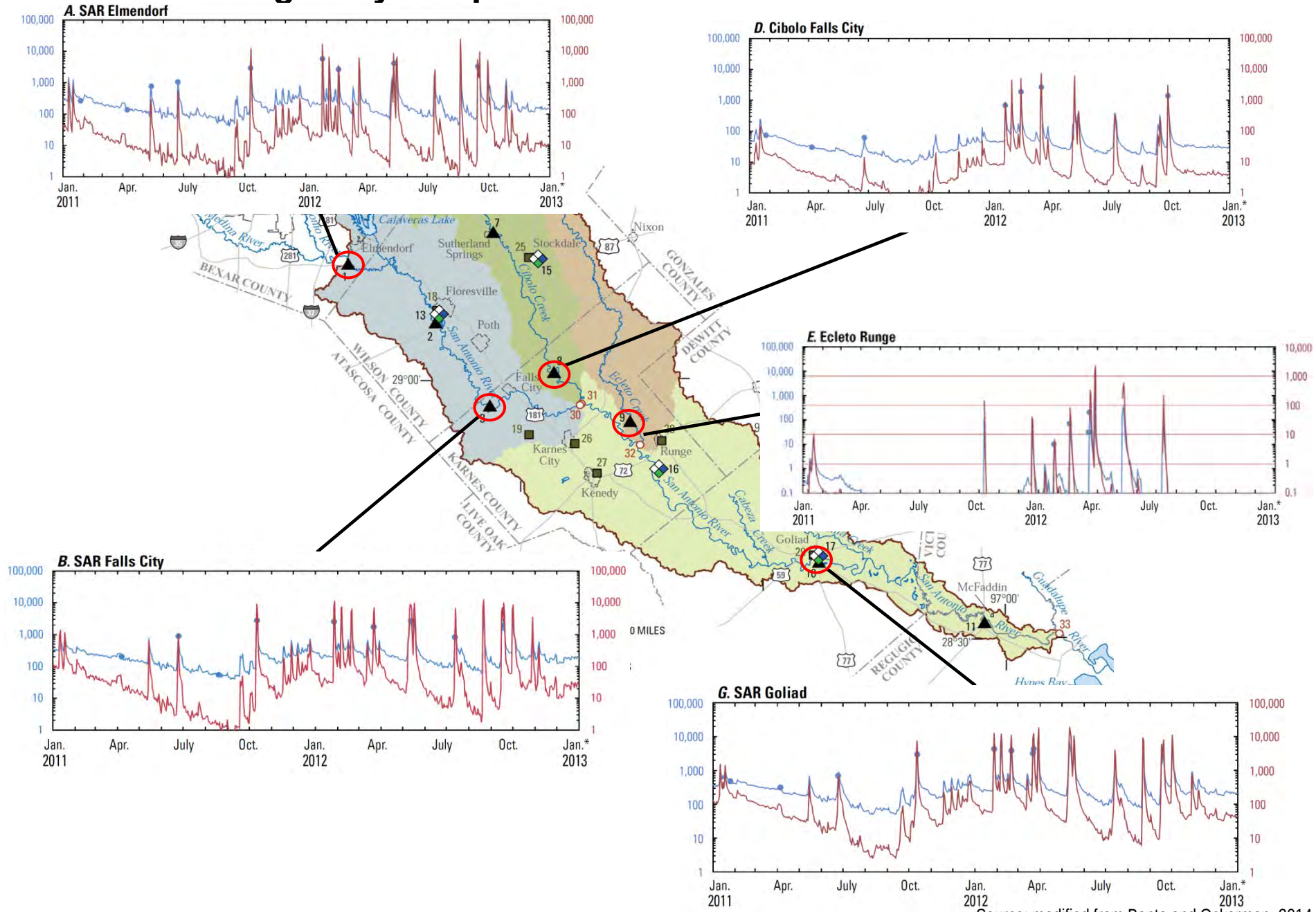






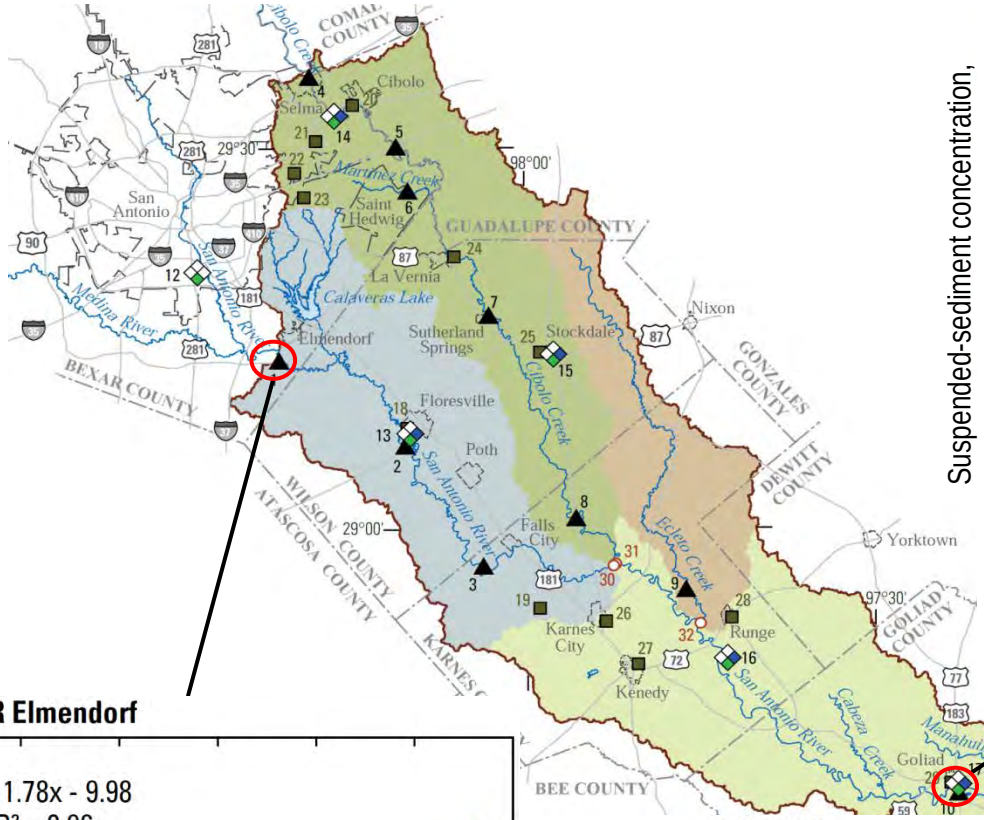
Source: modified from Crow and others, 2013

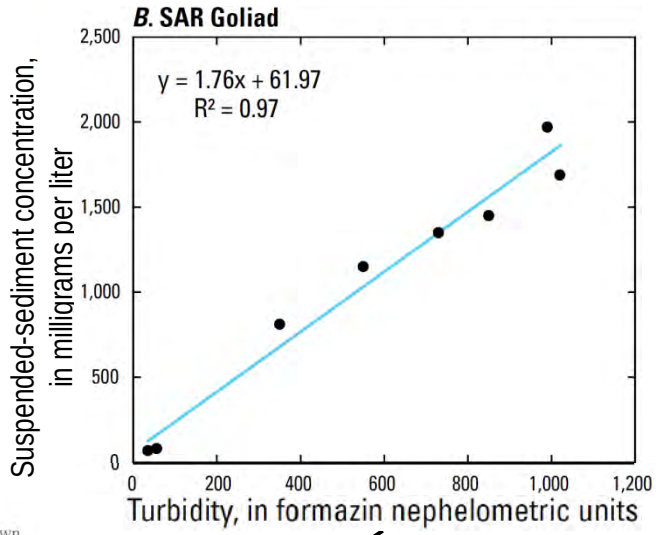
Estimating Daily Suspended-Sediment Loads

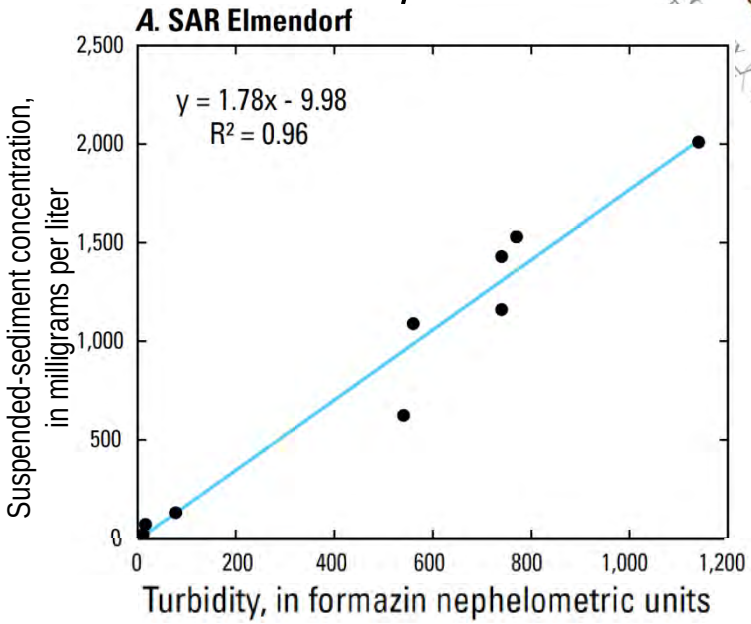


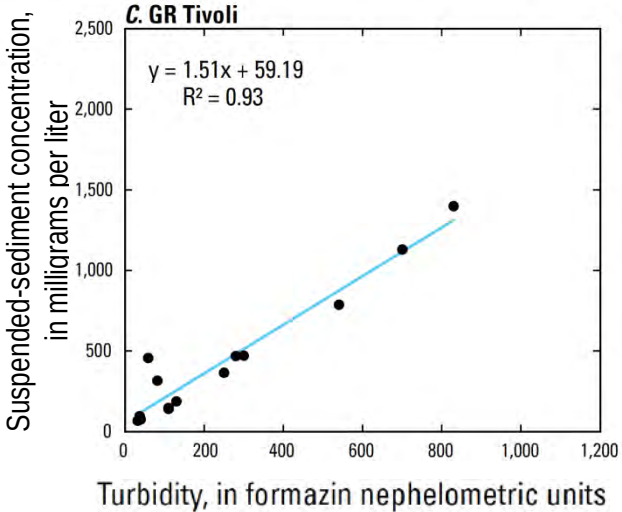
Source: modified from Banta and Ockerman, 2014

Estimating Suspended-Sediment Concentrations using Turbidity









Source: modified from Crow and others, 2013

HSPF Model Approach

- Step 1: calibrate hydrology
  - Model inputs
    - Streamflow at SAR Elmendorf and Cibolo Selma
    - Precipitation from DayMet (Oak Ridge National Laboratory)
    - Evapotranspiration from Basins 4.0
    - Discharges/withdrawals from WWTP, springs, pumping
    - Land cover type
  - Model parameterization
    - Adjust infiltration, deep storage, interflow, etc.
    - Generally consistent parameters between modeled watersheds.
    - Calibration sites in each model watershed

HSPF Model Approach

- Step 2: calibrate sediment
  - Model inputs
    - Estimated SSL at SAR Elmendorf and Cibolo Selma
    - Simulating suspended-sediment load only (no bedload)
    - Particle size distribution – mostly fines
  - Model parameterization
    - Adjust detachment and erosion rates, tau, etc.
    - Balance with hydrologic properties, consistent between model watersheds
- Use SAR Goliad as final calibration site for both hydrology and suspended-sediment simulations

Calibration Results

- Generally "good" to "very good" fits (Donigian, 2002; Moriasi et al., 2007)
  - Percent Difference
  - Coefficient of Determination (R^2)
  - Nash-Sutcliff Efficiency
  - RMSE-SD
- Ecleto Runge exception

Table 4. Evaluation criteria for Hydrological Simulation Program—FORTRAN (HSPF) model simulation results based on Donigian (2002) and Moriasi and others (2007).

[RMSE-SD, root mean squared error to standard deviation of observations ratio, also referred to as "RSR"; <, less than; >, greater than]

Performance rating	Daily mean streamflow percent difference	Daily mean suspended-sediment percent difference	Coefficient of determination[1] (R^2)	Nash-Sutcliffe efficiency[2] (NSE)	RMSE-SD[2] (RSR)
Very good	<10	<15	>0.80	>0.75	0.00–0.50
Good	10–15	15–30	0.70–0.80	0.65–0.75	0.50–0.60
Fair	15–25	30–55	0.60–0.70	0.50–0.65	0.60–0.70
Unsatisfactory	>25	>55	<0.60	<0.65	>0.70

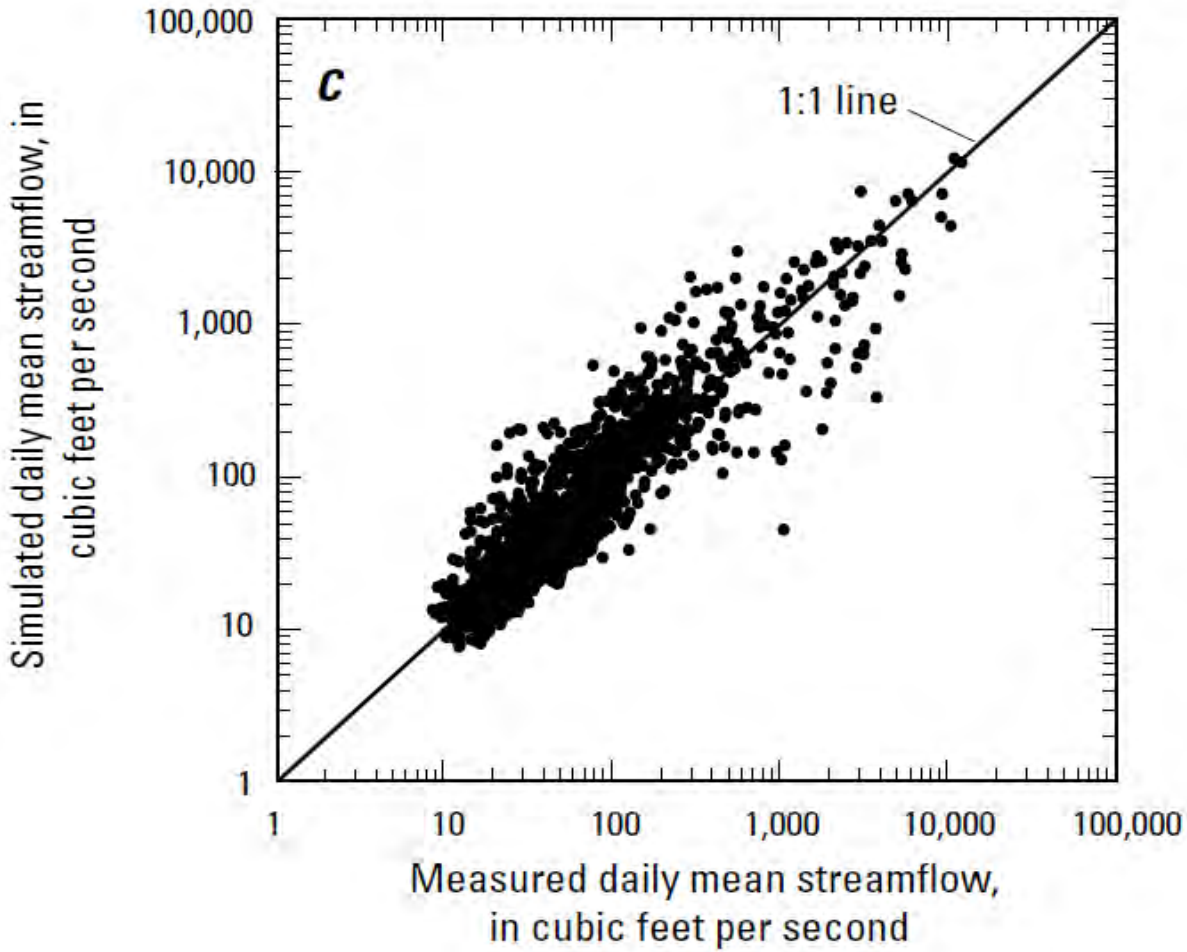
[1]Applicable to daily mean streamflow values.

[2]Applicable to monthly mean streamflow or monthly mean sediment values.

Source: Banta and Ockerman, 2014

Hydrology

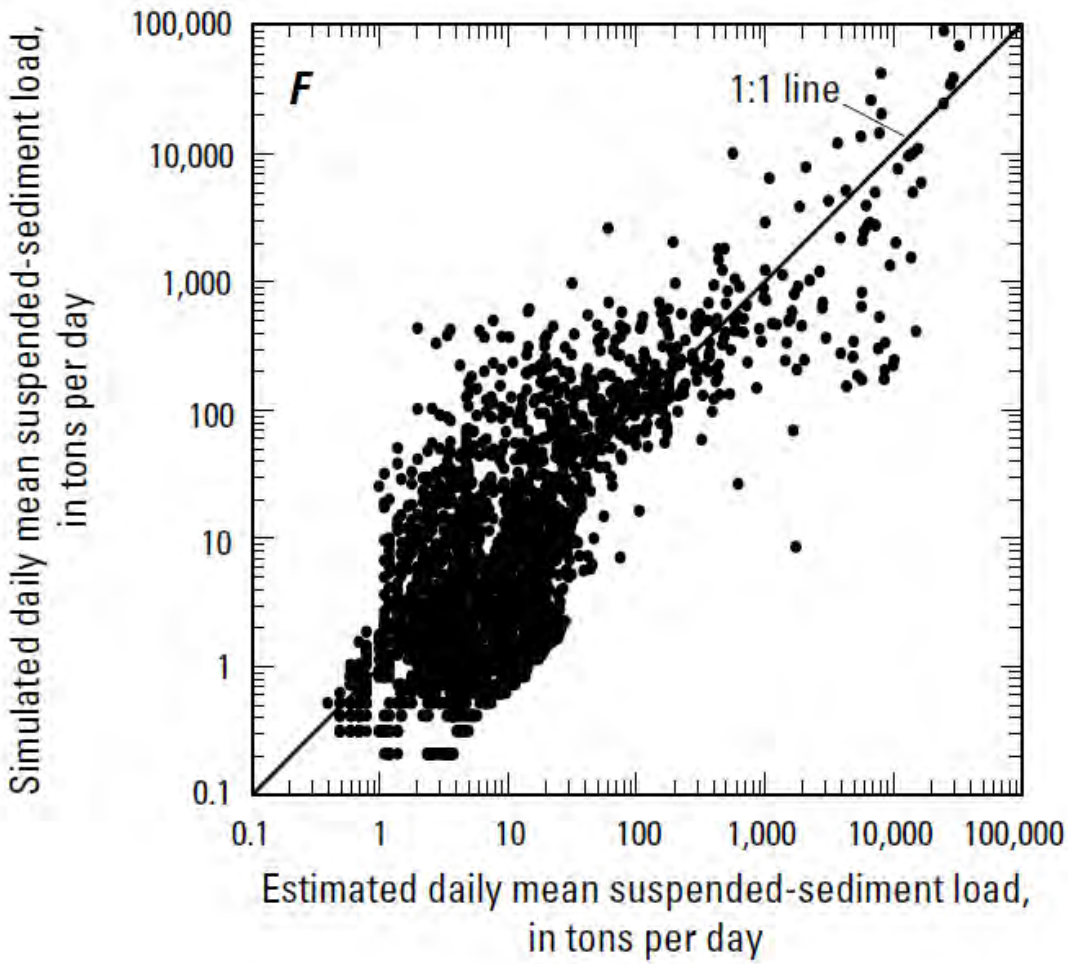
(Cibolo Creek near Falls City)



Source: Banta and Ockerman, 2014

Suspended-Sediment

(Cibolo Creek near Falls City)



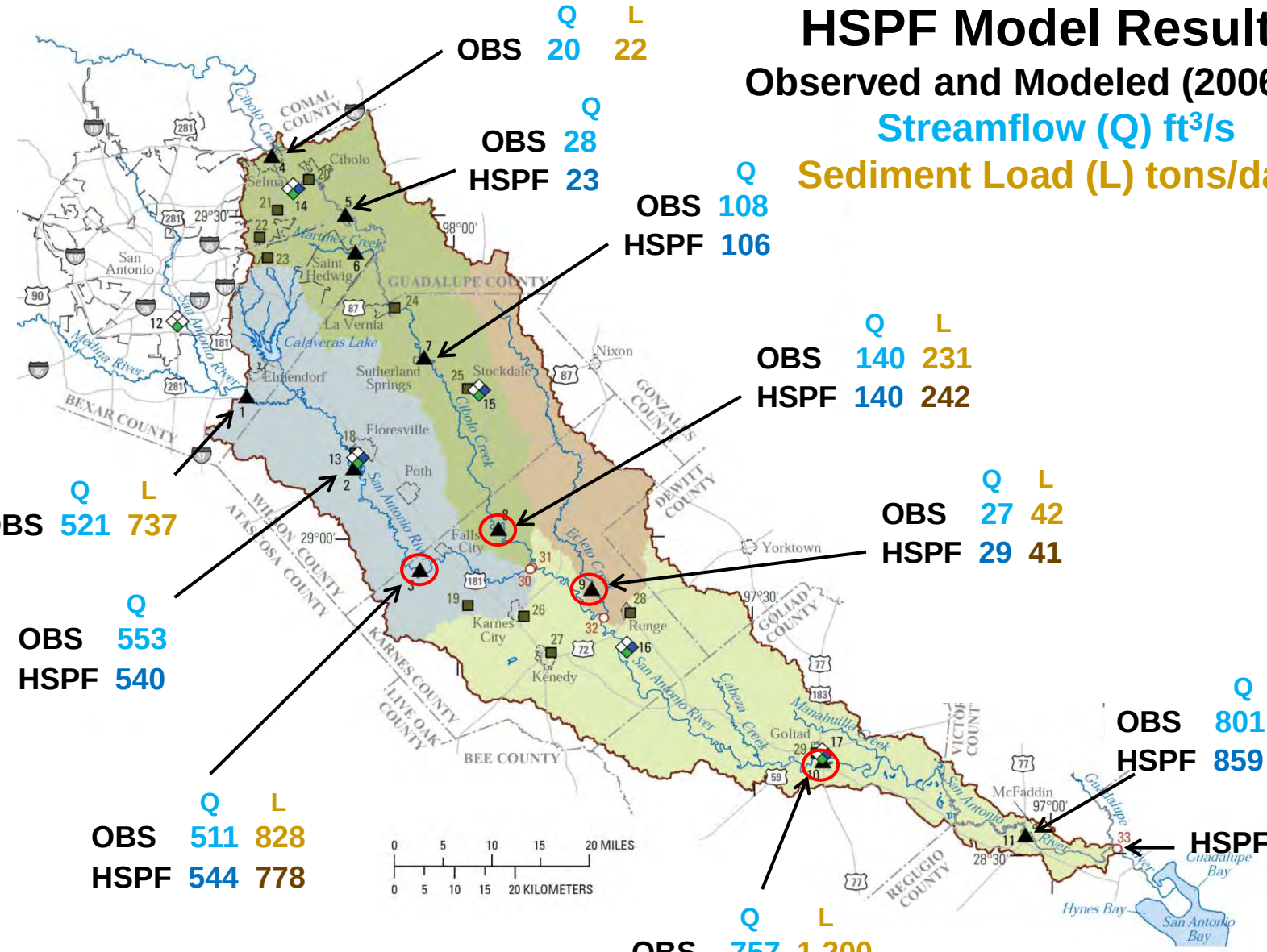
Source: Banta and Ockerman, 2014

HSPF Model Results

Observed and Modeled (2006–12)

Streamflow (Q) ft³/s

Sediment Load (L) tons/day



	Q	L
OBS	20	22

	Q
OBS	28
HSPF	23

	Q
OBS	108
HSPF	106

	Q	L
OBS	140	231
HSPF	140	242

	Q	L
OBS	521	737

	Q
OBS	553
HSPF	540

	Q	L
OBS	27	42
HSPF	29	41

	Q
OBS	801
HSPF	859

	Q	L
OBS	511	828
HSPF	544	778

	Q	L
HSPF	865	1,230

	Q	L
OBS	757	1,200
HSPF	820	1,180

Source: modified from Banta and Ockerman, 2014

HSPF Model Results

suspended sediment by watershed

Suspended-sediment entering study area fro upstream at Cibolo Creek at Selma, Tex., **22 tons per day.**

Suspended-sediment entering study area from upstream at San Antonio River near Elmendorf, Tex., **737 tons per day.**

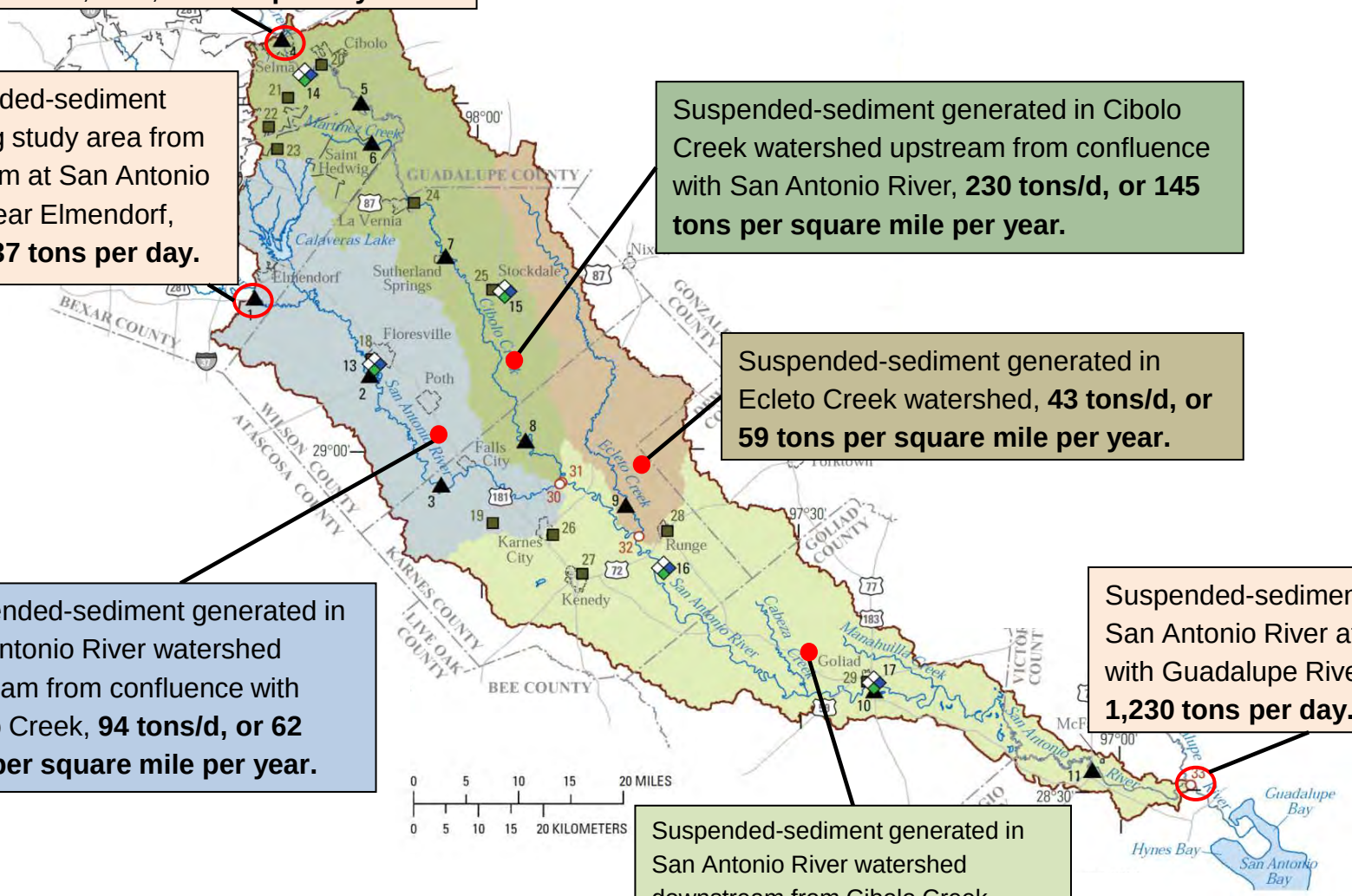
Suspended-sediment generated in Cibolo Creek watershed upstream from confluence with San Antonio River, **230 tons/d, or 145 tons per square mile per year.**

Suspended-sediment generated in Ecleto Creek watershed, **43 tons/d, or 59 tons per square mile per year.**

Suspended-sediment generated in San Antonio River watershed upstream from confluence with Cibolo Creek, **94 tons/d, or 62 tons per square mile per year.**

Suspended-sediment exiting San Antonio River at confluence with Guadalupe River, **1,230 tons per day.**

Suspended-sediment generated in San Antonio River watershed downstream from Cibolo Creek, **104 tons/d, or 51 tons per square mile per year.**



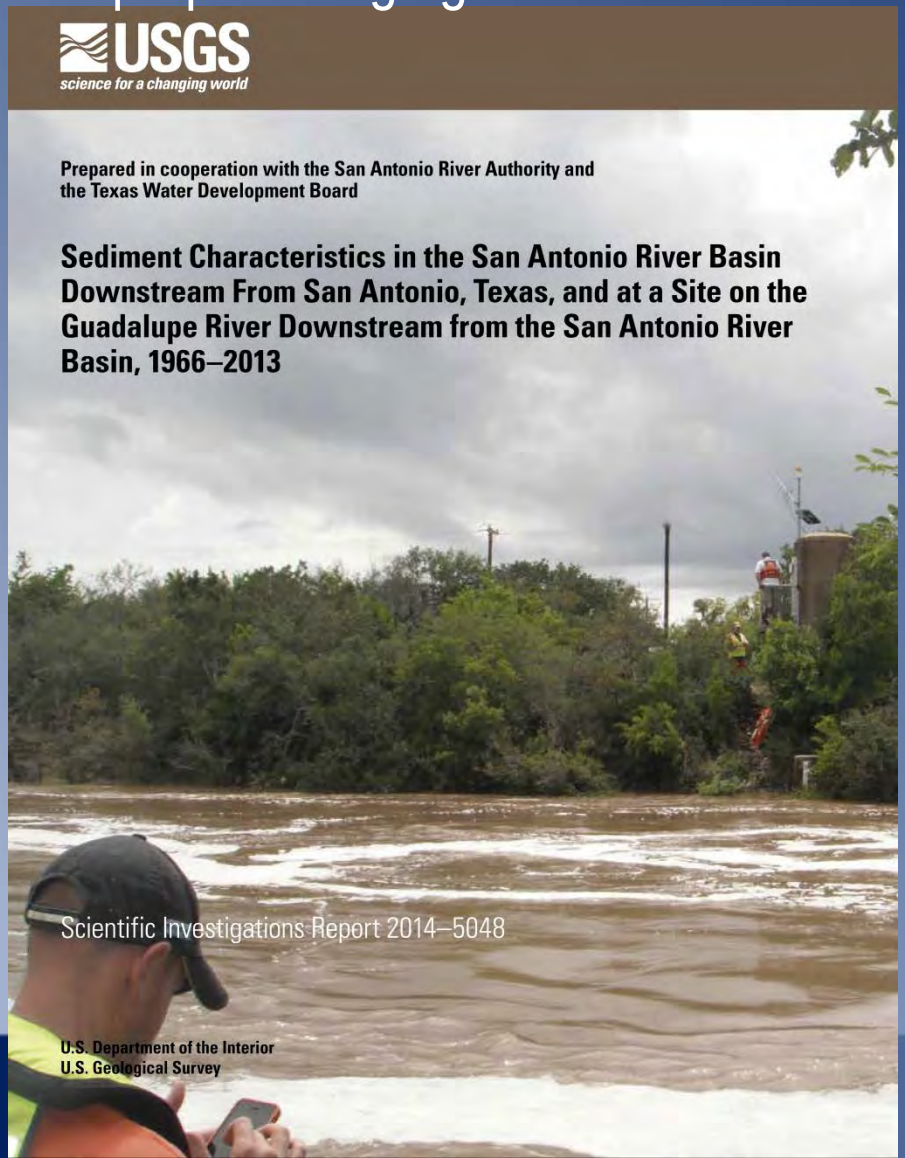
Source: modified from Banta and Ockerman, 2014

Summary

- Measured suspended-sediment and bed load in the Lower San Antonio River Basin over a range of hydrologic conditions
- Developed regression curves to estimate SSL
- Developed HSPF model to simulate SSL
  - HSPF model simulated environmental conditions reasonably well
  - Majority of suspended-sediment loads originated upstream from the study area
  - Cibolo watershed was the largest contributor of suspended-sediment from study area.

Publications Available Online

http://pubs.usgs.gov/sir/2014/5048/



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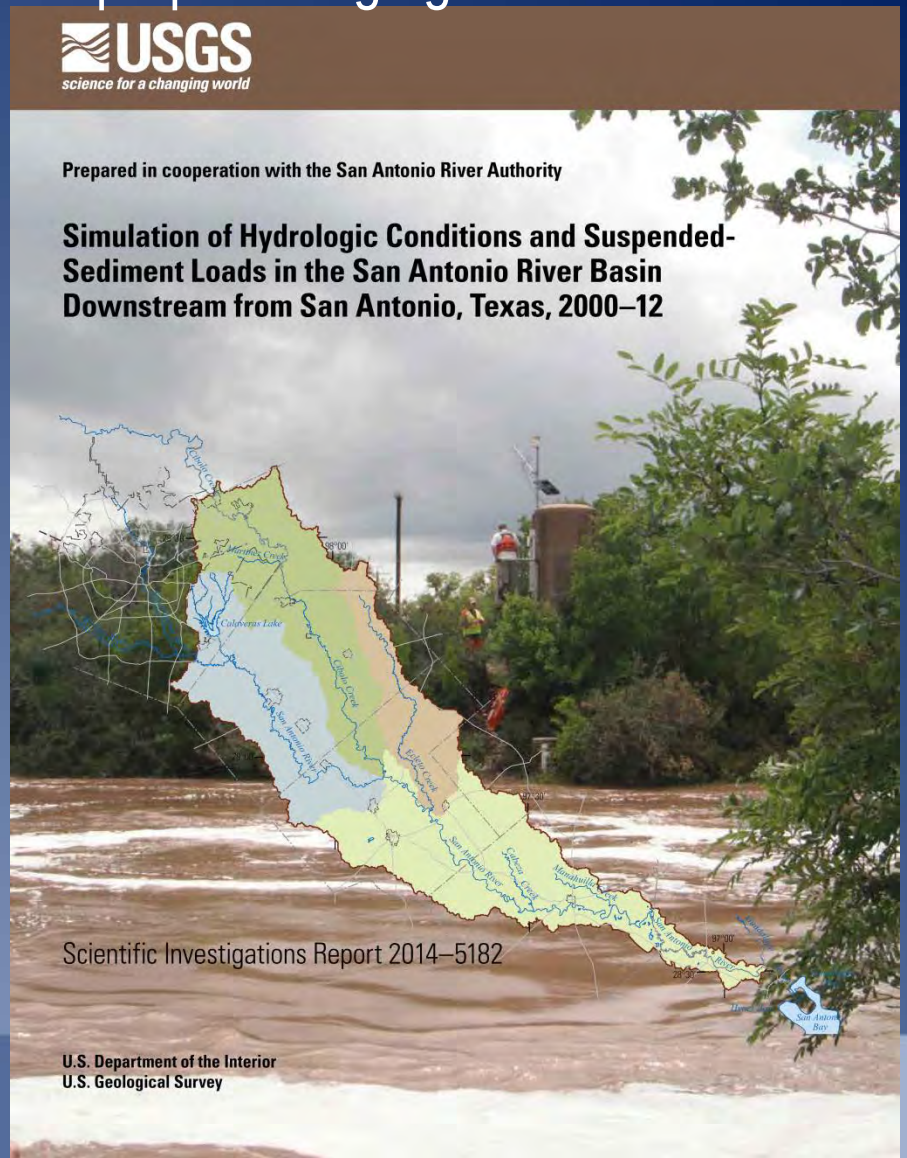

Questions?

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Photo: courtesy of San Antonio River Authority