The USGS Streamgaging Program

ACWI Subcommittee on Hydrology
July 24, 2014
Robert Mason

Watauga River at Sugar Grove, NC

Presentation Outline

USGS -Who are we? What we do?

Gage Site Selection/Network Design
- Federal “backbone” (~3,200 gages)
- Non-Federal network (~4,800 gages)

Streamgaging process
- Stage monitoring
- Flow measuring
- Rating/shifts to compute flow records
- The Future

Data Dissemination

USGS

Streamgages ≈
Follow the flow
-Core Systems
-Energy and Minerals
-Ecosystems
-Climate and Landuse
-Environmental Health
-Natural Hazards
-Water
U.S. GEOLOGICAL SURVEY
USGS
science for a changing world
River Flow Monitoring Station
USGS
U.S. Department of the Interior
U.S. Geological Survey

Water Community –Who We Are

- A workforce of about 3,000 people
- Diverse technical capabilities
- Located in all 50 states at a total of 179 locations
- Sate office report though regions
- Technical oversight by three tech offices: Groundwater, Water Quality, and Surface Water

USGS

Water Community –What we do

- Interact with 1,400 Federal, State, and local agency partners
- Operate hydrologic networks, interpretive hydrologic data, and develop hydrologic science
- Topics studied include quantity and quality of water in both both surface water and ground water

USGS

USGS Real Time Monitoring Sites -7/22/14

Number of sites	Name
10,841	Gage height
8,134	Discharge
3,339	Precipitation
2,048	Water temperature
1,832	Ground-water Level
1,087	Specific conductance
815	Lake/Res elevation
632	Dissolved oxygen
492	Stream velocity
466	Air temperature
523	pH
323	Turbidity
179	Wind speed
159	Salinity
144	Wind direction

Number of sites	Name
119	Reservoir storage
60	Soil temperature
52	Air pressure
50	Relative humidity
39	Soil moisture
25	Chlorophyll
19	Pressure, diss gases
15	Barometric pressure
14	Solar radiation
10	Sodium adsorption ratio
13	Tide elevation
7	Redox potential
5	NO2+NO3
5	Cyanobacteria

USGS

USGS NWISWeb Database

Total monitoring sites	1.5 million
Real-time sites	11,000
Real-time ground water	958
Daily values	286 million
Ground-water levels	8.0 million
Water quality samples	4.5 million
Water quality analyses	69.4 million
Peak discharges (floods)	750,000

August 1, 2007

USGS

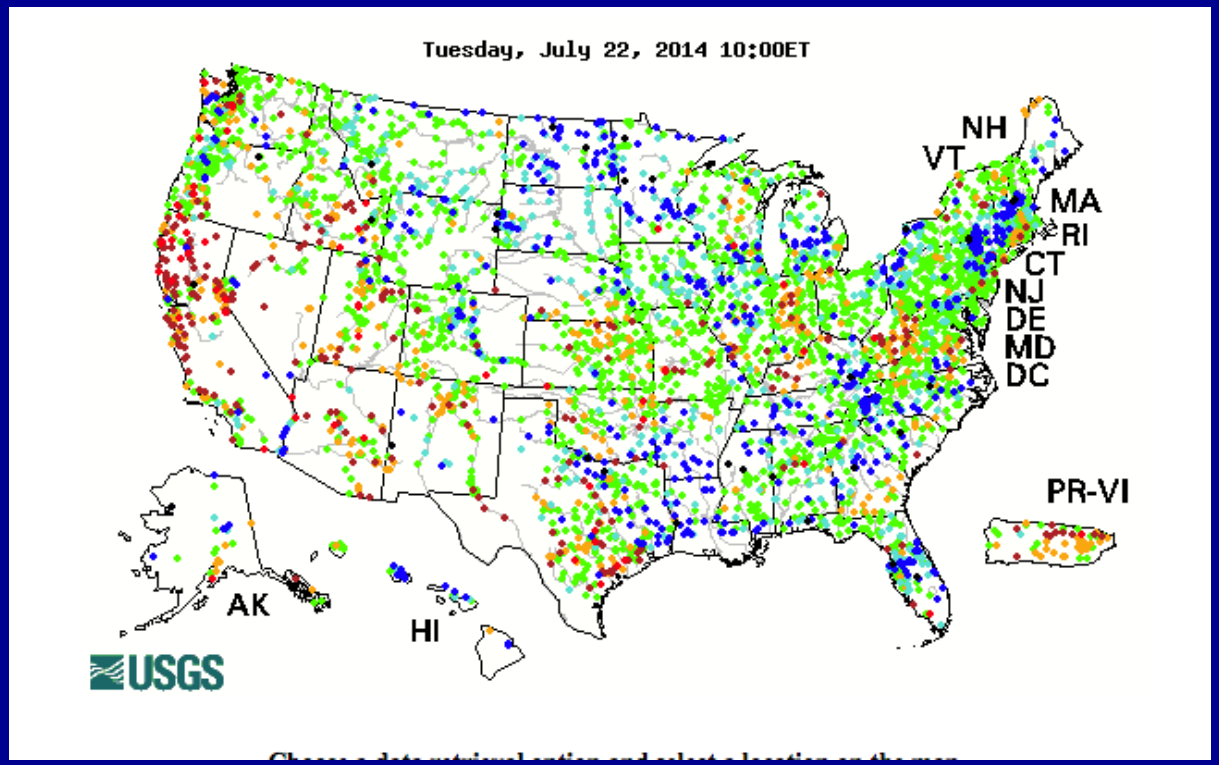
The USGS Streamgaging Network

Streamgages

8,134 gages
99 % real-time
All on web

Network Costs

$162M per year
850+ Partners



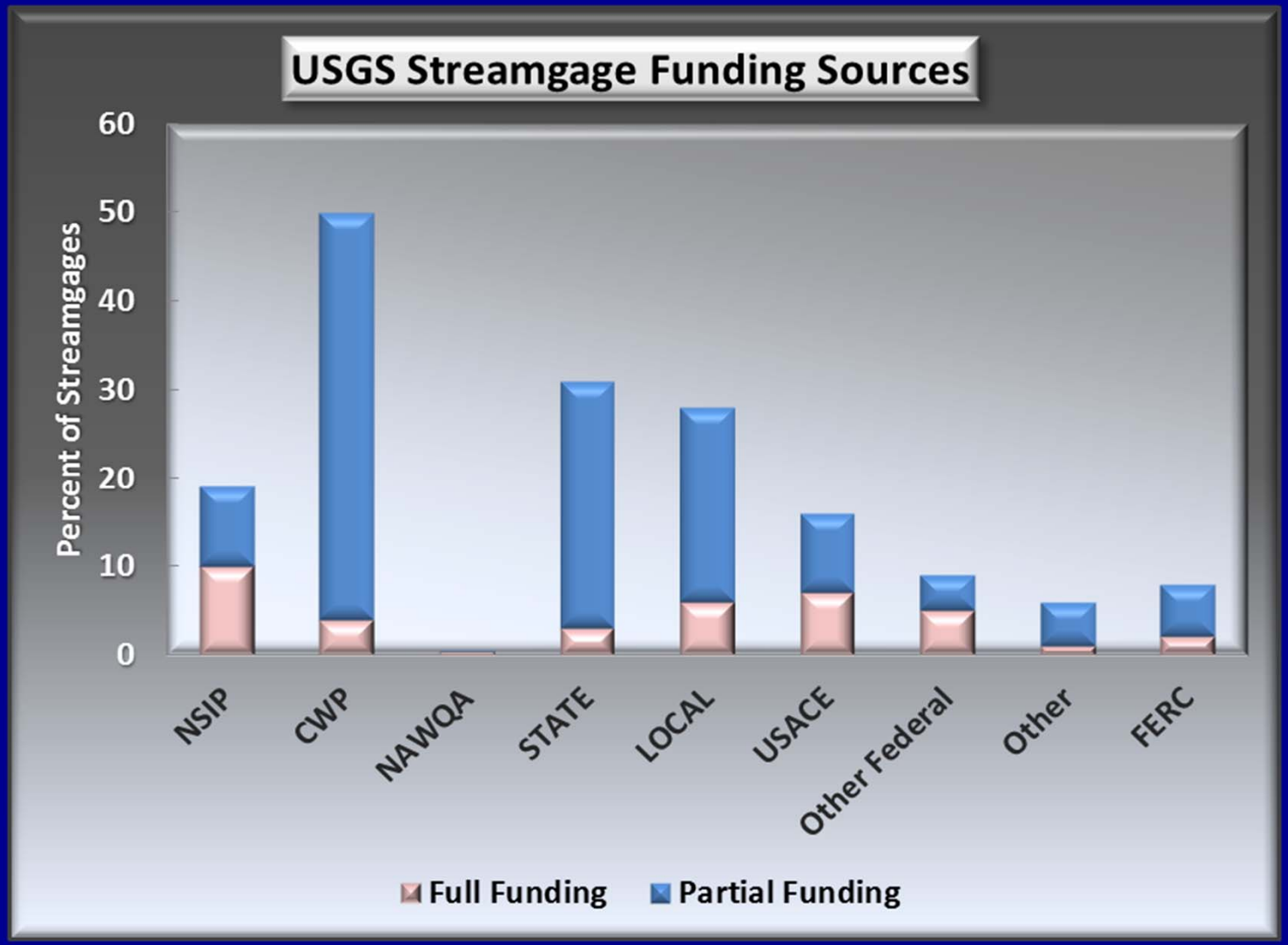
Funding Sources

State / Local Agencies	$79M	49%
Other Federal Agencies (OFA)	$27M	17%
USGS Cooperative Program (CWP)	$28M	17%
USGS Nat Streamflow Info Program	$28M	17%

USGS

2013

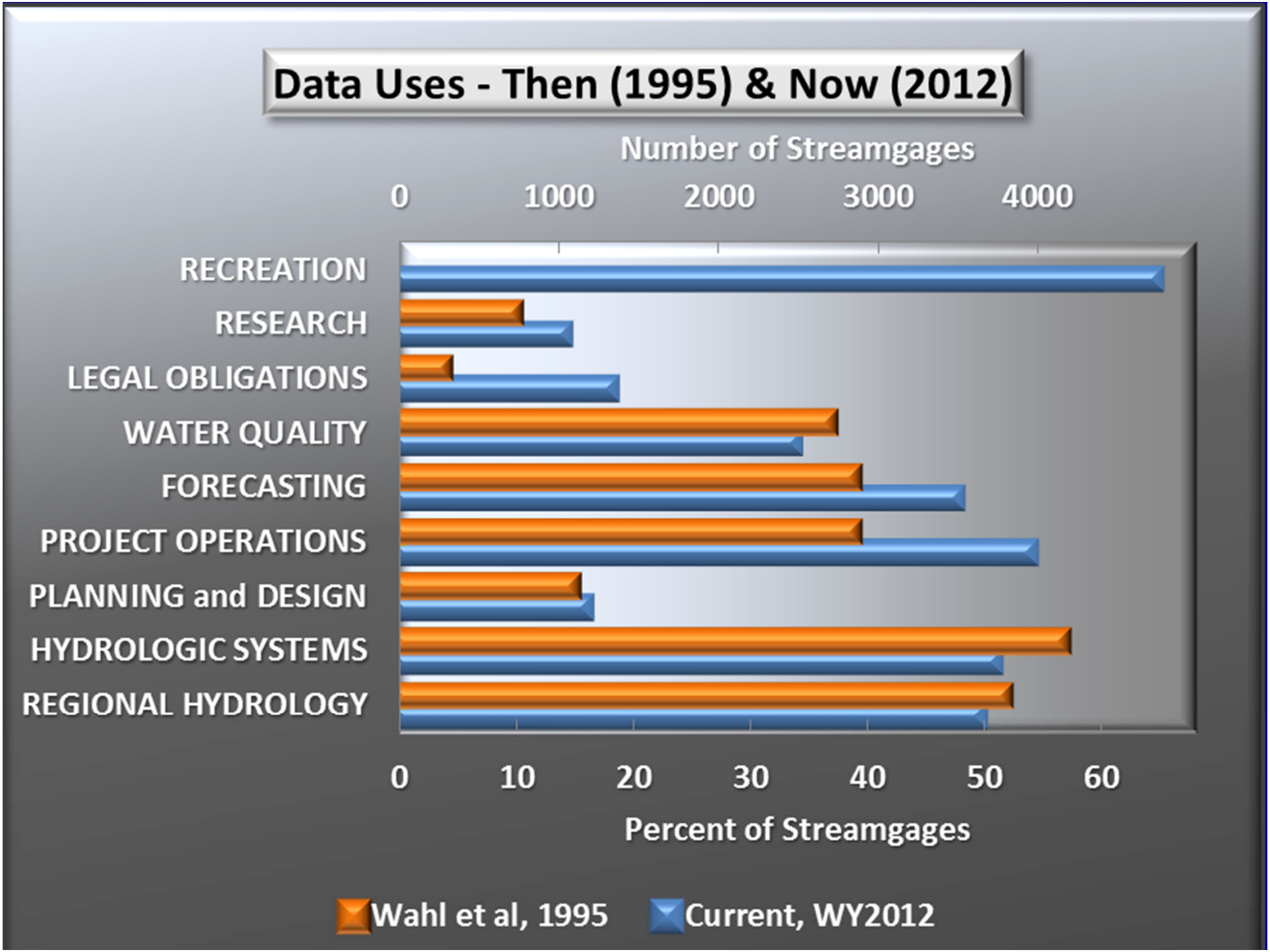
Shared Funding is Most Common



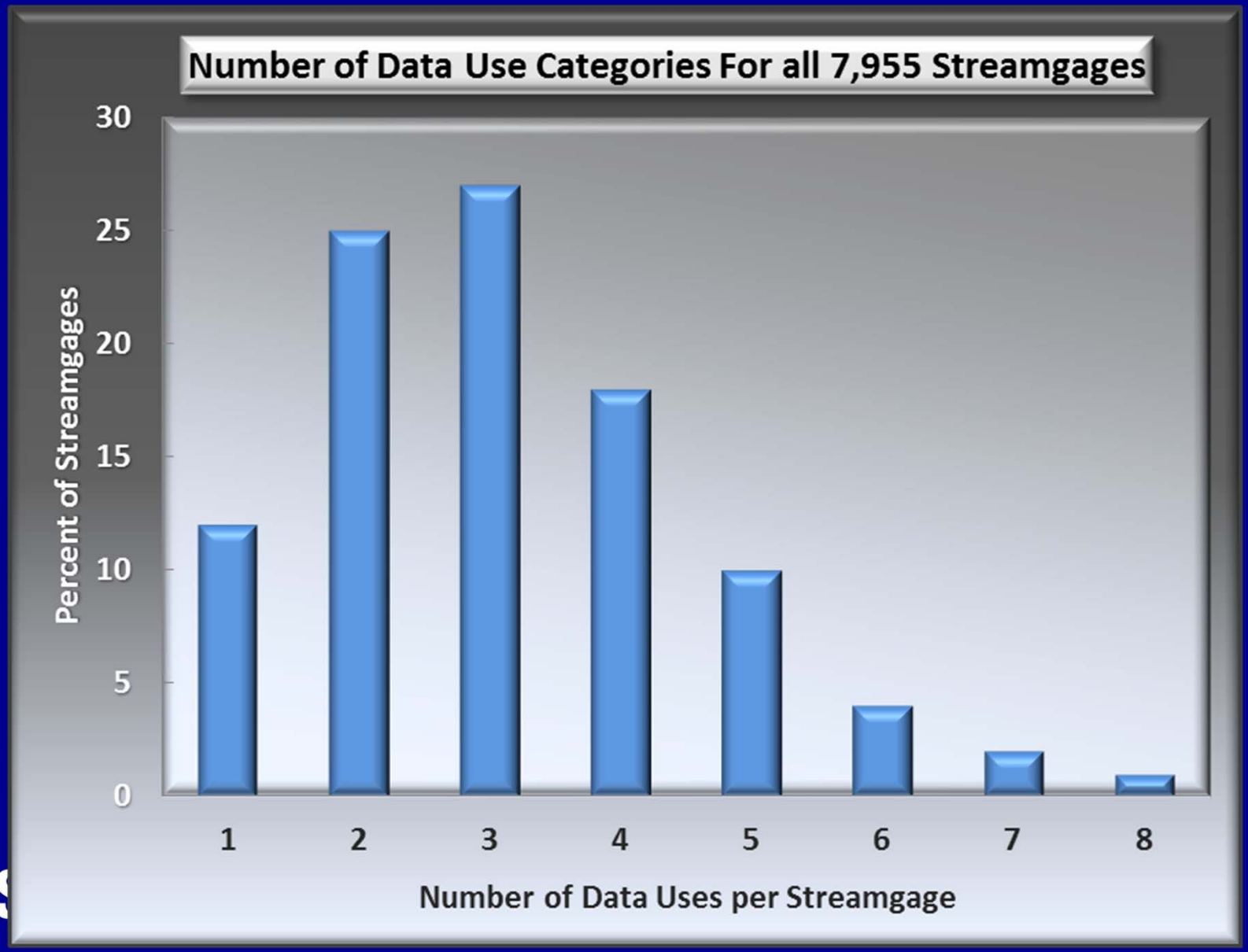
USGS

Streamflow Information is Essential

Engineering Design	–Corps, BOR, States, locals
Flood Reservoir Operations	–Corps (2,478 sites), BOR, TVA
Hydroelectric Power Ops	–FERC, Utilities
Streamflow Forecasting	–NWS (3,900 sites)
Water-Quality Regulation	–EPA, States (TMDLs, etc.)
Water/Wastewater Treatment	–Local and State
Irrigation	–BOR, water purveyors
Floodplain Mapping	–FEMA (NFIP)
Evacuation Planning	–FEMA (Hazus)
Recreational boating	–Outfitters, individuals
Research	–NAWQA, NRP, CWP, EPA, NOAA, universities


Data Uses - Then (1995) & Now (2012)
Number of Streamgages
0
1000
2000
3000
4000
RECREATION
RESEARCH
LEGAL OBLIGATIONS
WATER QUALITY
FORECASTING
PROJECT OPERATIONS
PLANNING and DESIGN
HYDROLOGIC SYSTEMS
REGIONAL HYDROLOGY
0
10
20
30
40
50
60
Percent of Streamgages
Wahl et al, 1995
Current, WY2012

Gages Often Support Multiple Uses



NSIP Federal Needs (Backbone) Network

- Priority considerations
  - Legal responsibilities
  - Public safety
  - Systematic sampling and monitoring for long-term comparisons
  - Long-term records for reference conditions
- Priority Needs
  - State and international boundaries
  - River forecasting
  - River basin accounting
  - Water-quality monitoring
  - Basin sentential watersheds

http://water.usgs.gov/nsip/pubs/Ries_EWRI_2001.pdf

http://water.usgs.gov/nsip/reviews.html

Prioritization Criteria For Cooperatively Funded USGS Streamgages In Colorado

Goal 1--Quantify Streamflow in Major Colorado Watersheds

Goal 2--Support Colorado Flood and Water-Supply Forecasting

Goal 3--Support Colorado Water Administration and Management

Goal 4--Support Streamflow Gages for Determination of Trends in Flow

Goal 5--Support Water-Quality Networks in Colorado

USGS

Prioritization Criteria For Cooperatively Funded USGS Streamgages In Colorado (Con't)

Goal 1--Quantify Streamflow in Major Colorado Watersheds

3 points--Gages on major rivers (North Platte, South Platte, Arkansas, Rio Grande, San Juan, Animas, Dolores, Gunnison, Colorado, White, and Yampa) that have a > 20% change in annual flow from downstream gage(s)

2 points—-One gage on small tributaries (tributary flow is > 5% of the mainstem flow upstream from the tributary).

1 point--One gage on small tributaries (tributary flow is > 5% of the mainstem flow upstream from the tributary).

0 points--All other gages**.**

Prioritization Criteria For Cooperatively Funded USGS Streamgages In Colorado (Con't)

Goal 2--Support Colorado Flood and Water-Supply Forecasting

3 points--Gage is an NWS, COE, USBR, State, or local flood forecast gage.

2 points--Gage is an NRCS or NWS water-supply forecast gage.

1 point--Gage is a State or local water-supply forecast gage.

0 points--All other gages.

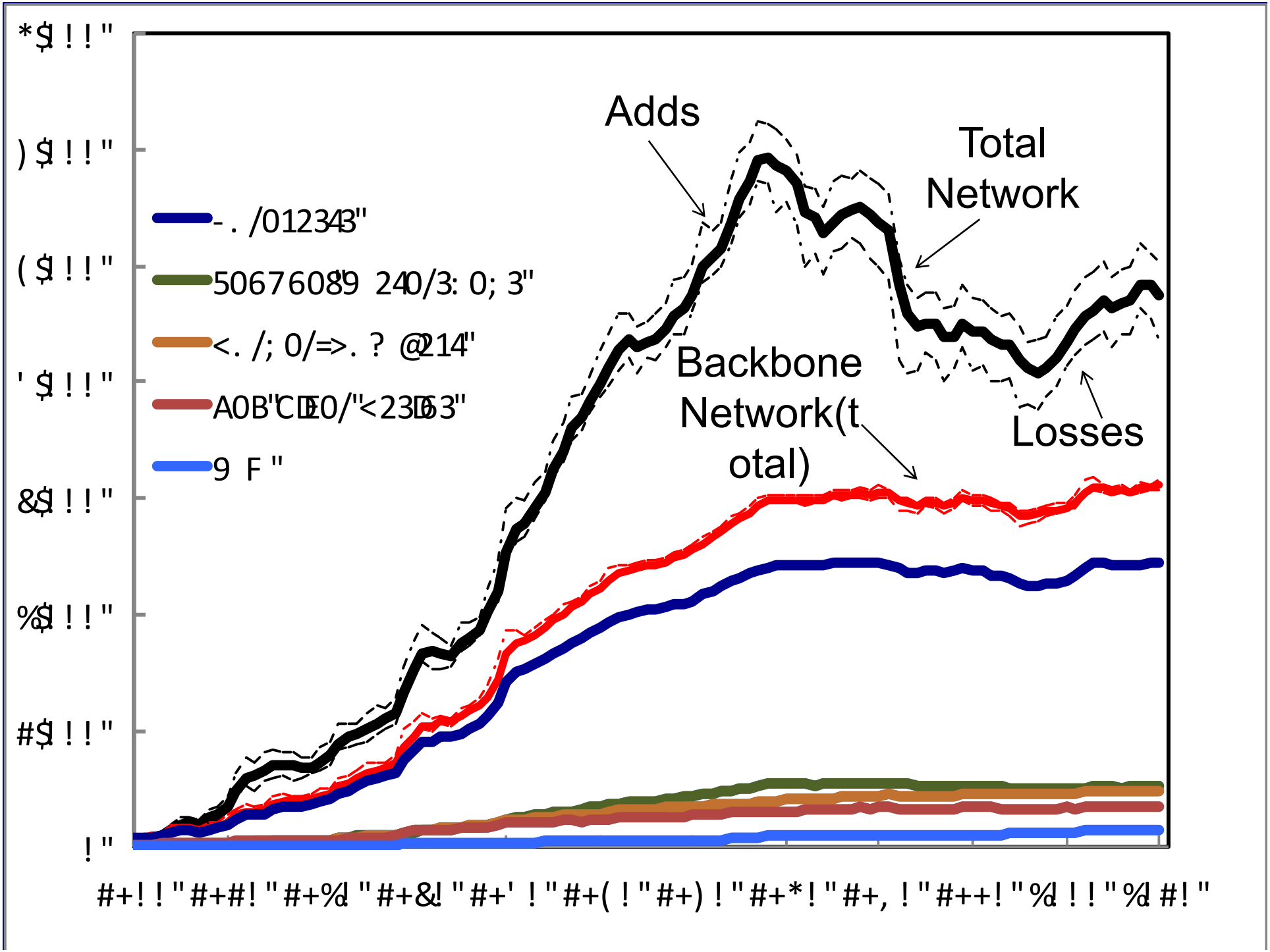
USGS

CWP FMF Final Allocation Ranking

Ranking Scores and Associated FMF Rates--2011 Fiscal Year:

- 0-1 points Very Low Ranking 0% FMFs
- 2-3 points, Low Ranking 12% FMF
- 4-7 points, Medium Ranking 40% FMF
- >7 points, High Ranking 46% FMF

USGS


Adds
Total Network
Backbone Network(total)
Losses

USGS Streamgaging Process and Standards

- Consistent, high-quality methodology
- Long--term data collection and archival
- Funded by many partners
- Data freely available
- Field-intensive
- Needs technology infusion

Gage Site Selection

- Purpose/Needs drive site selection
  - Physical proximity to project/resource
  - Representative sampling/coverage (geography, geology, hydrology, or land use)
  - Purpose/Needs evolve and multiply continually; Difficult to anticipate new needs
  - Easy, safe access

USGS

Proffered site characteristics

- Uniform hydraulics for measurement section
- Straight approach, even flow lines
- Smooth uniform bed and banks, firm, even substrate

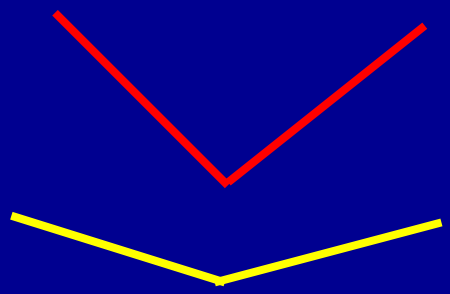
South Toe River at Celo, NC

Hydualic Control
South Toe River at Celo, NC

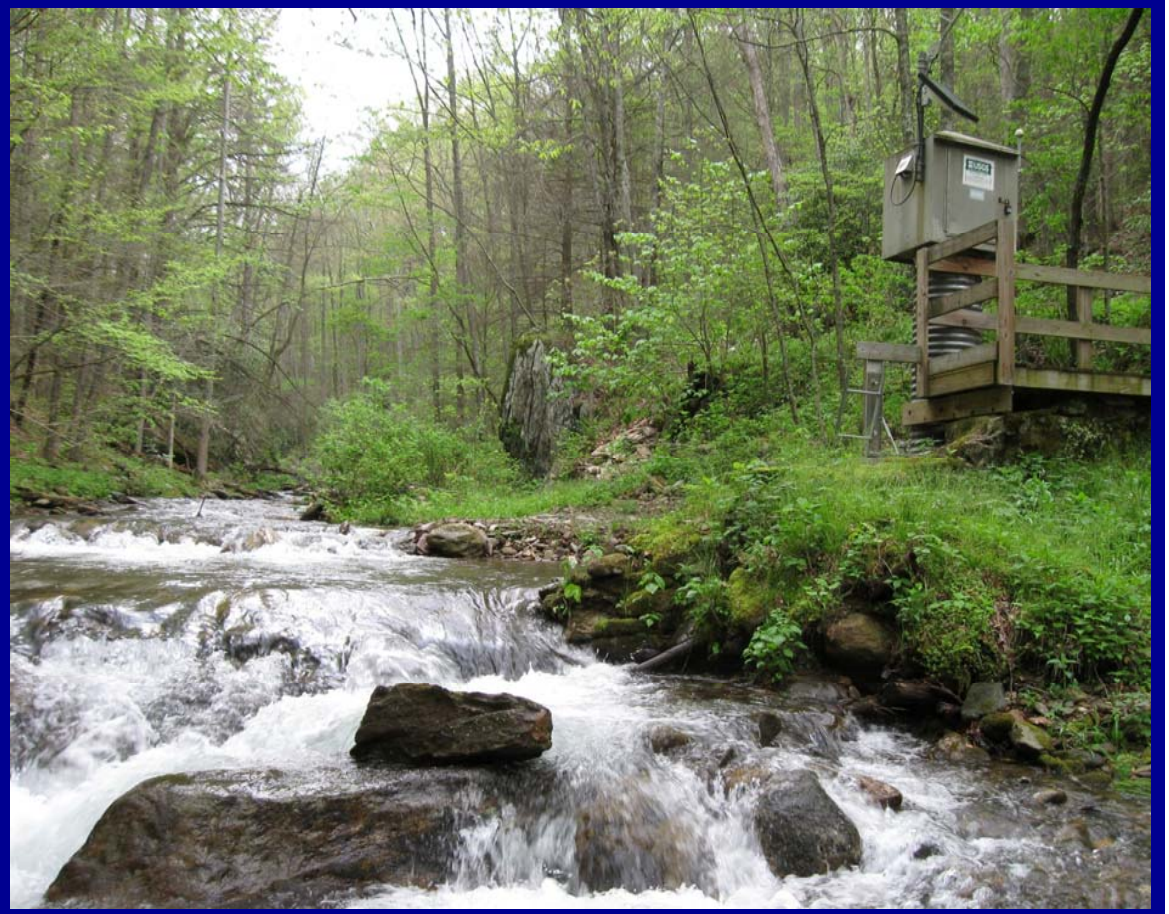
Proffered site characteristics –Con't

- Stable control (rock ledge, concrete v-notch)
- Avoid shifting, sandy controls
- Sensitive controls (tight "V".)

Sensitive

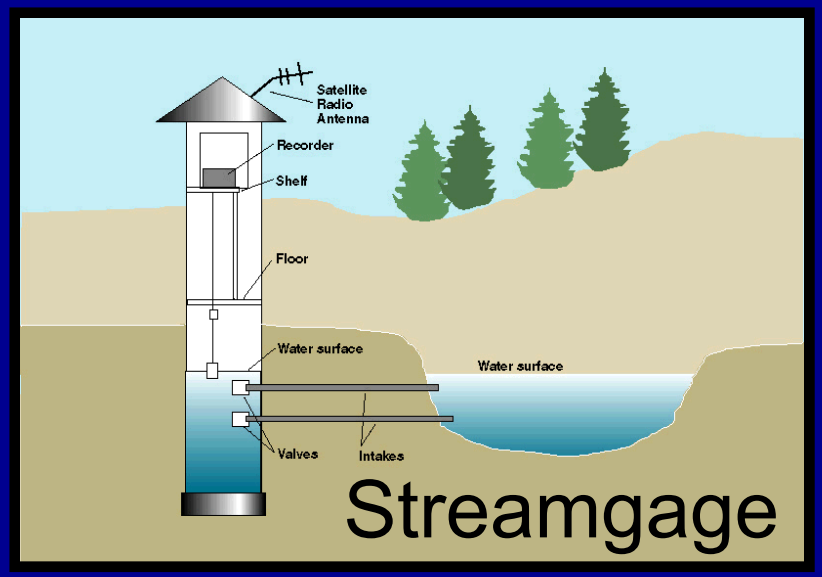


Insensitive

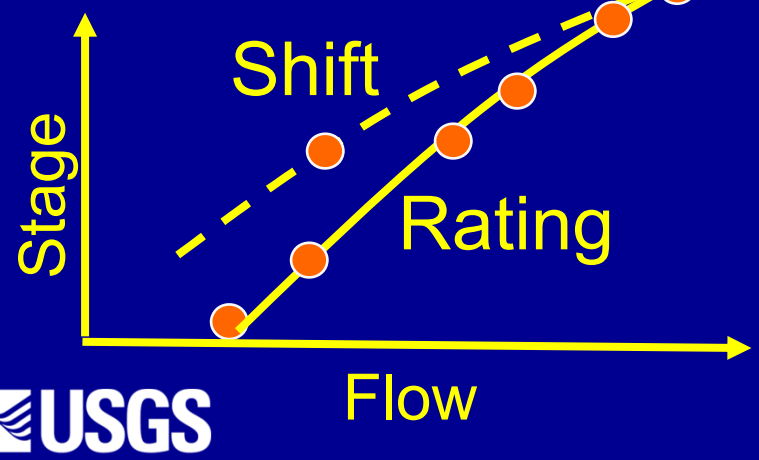


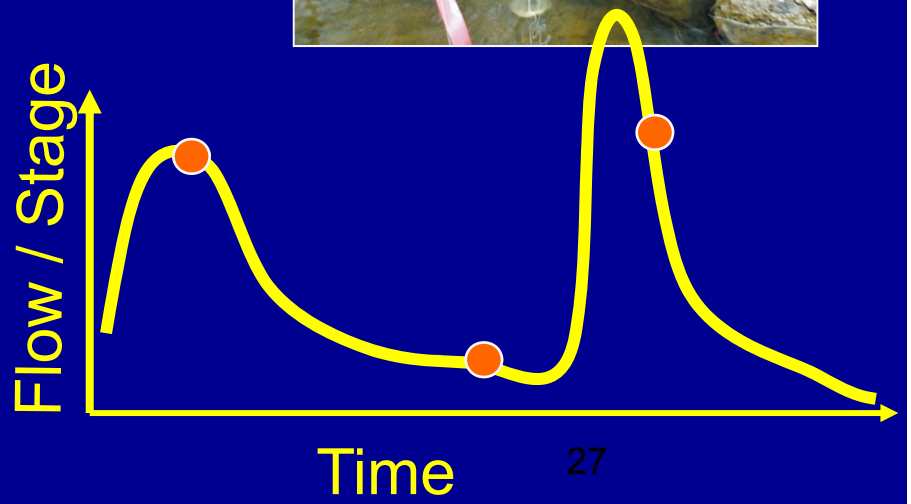
Beetee Creek nr Swannanoa, NC

The Streamgaging Process



Flow Measurements





USGS

Inside a Gage

USGS

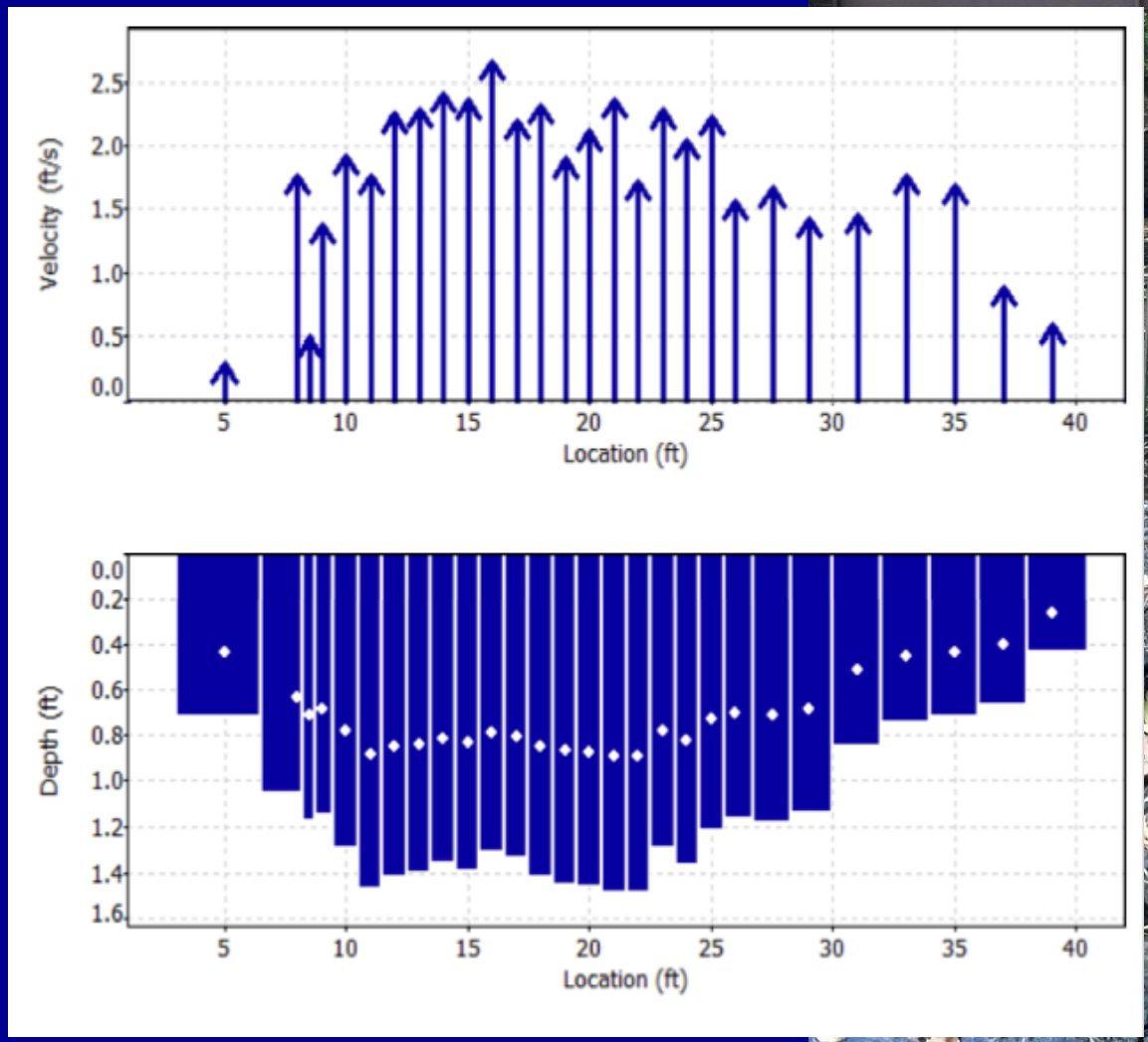
Monitoring Stage

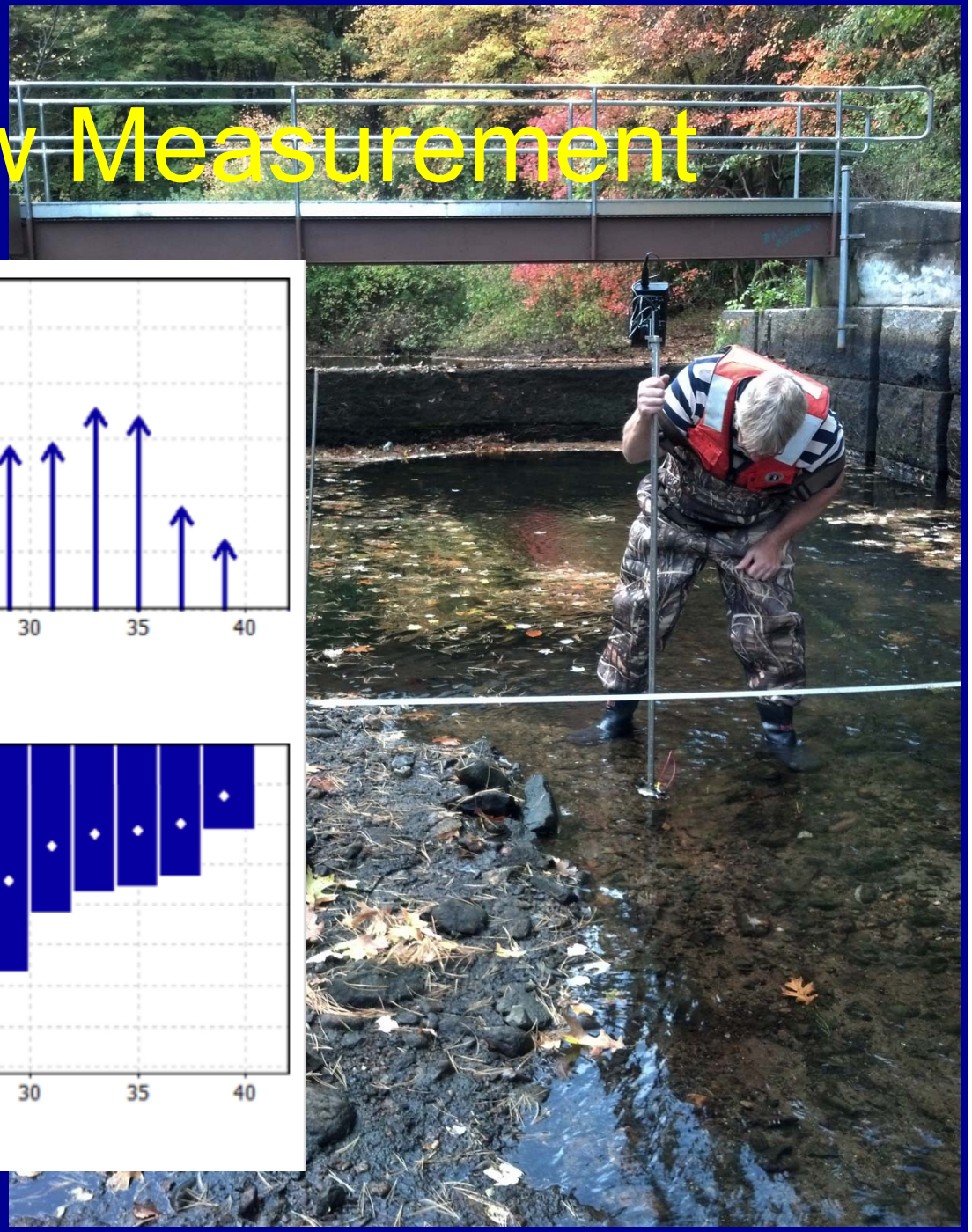
- Verified by direct readings
- Record adjusted accordingly
- New technologies reduced costs

+/- 0.02 ft. or 2% of range

Monitoring Stage

Making a Flow Measurement





Flow Measurements

Before Acoustics (1991)

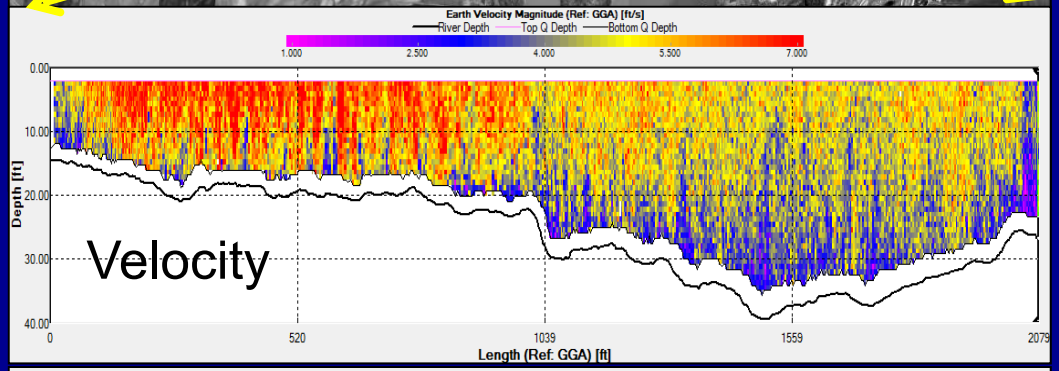
-52 flood measurements
-10 days
-Staff of 11+
-Average time -- 96 min.

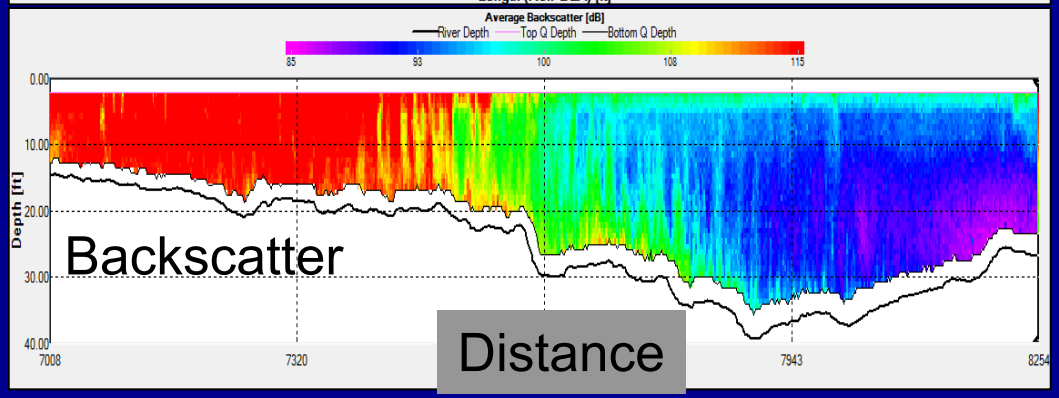
With Acoustics (2012)

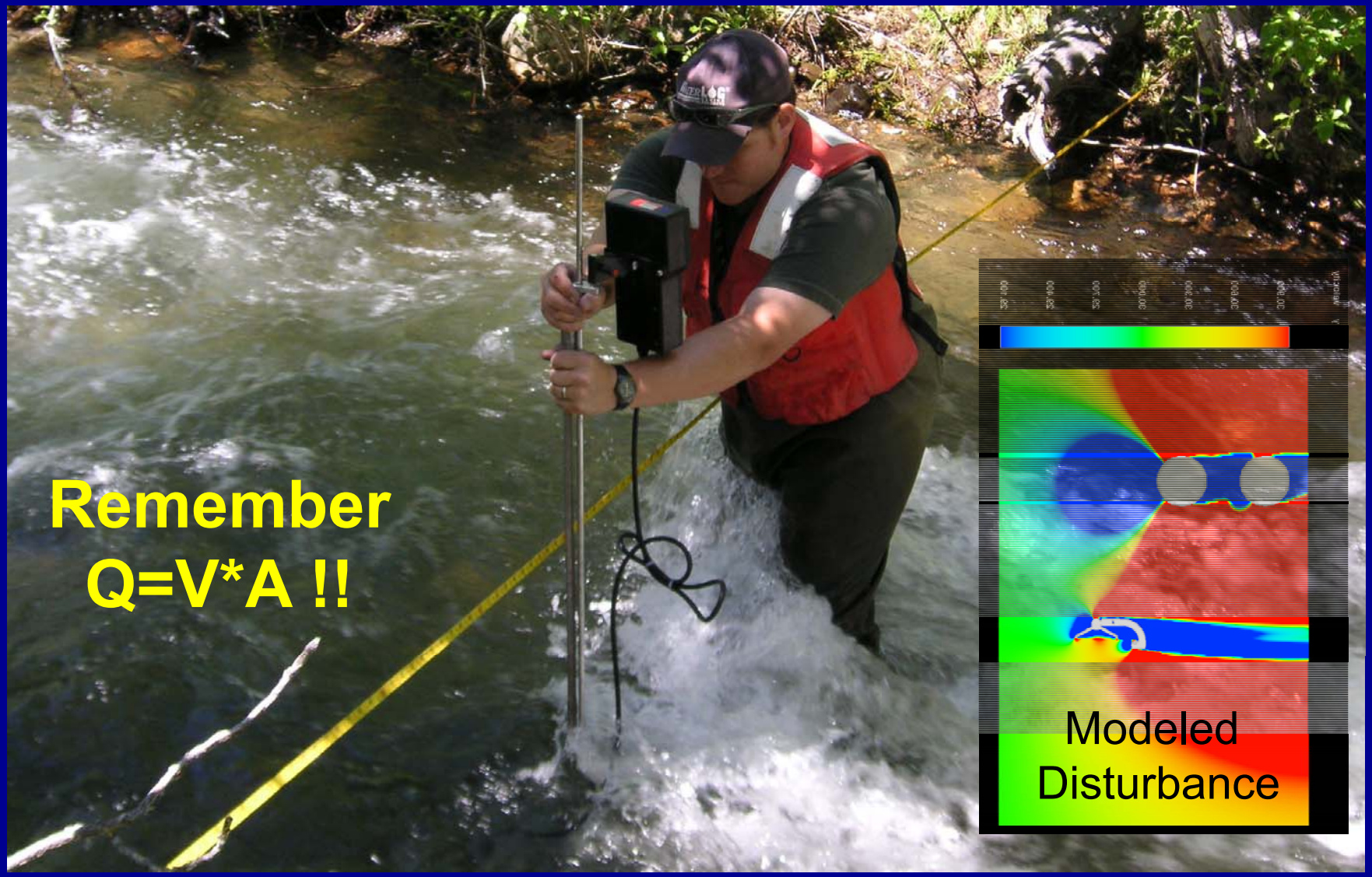
-62 flood measurements
-10 days
-Staff of 6
-Average time -- 18 min.

USGS

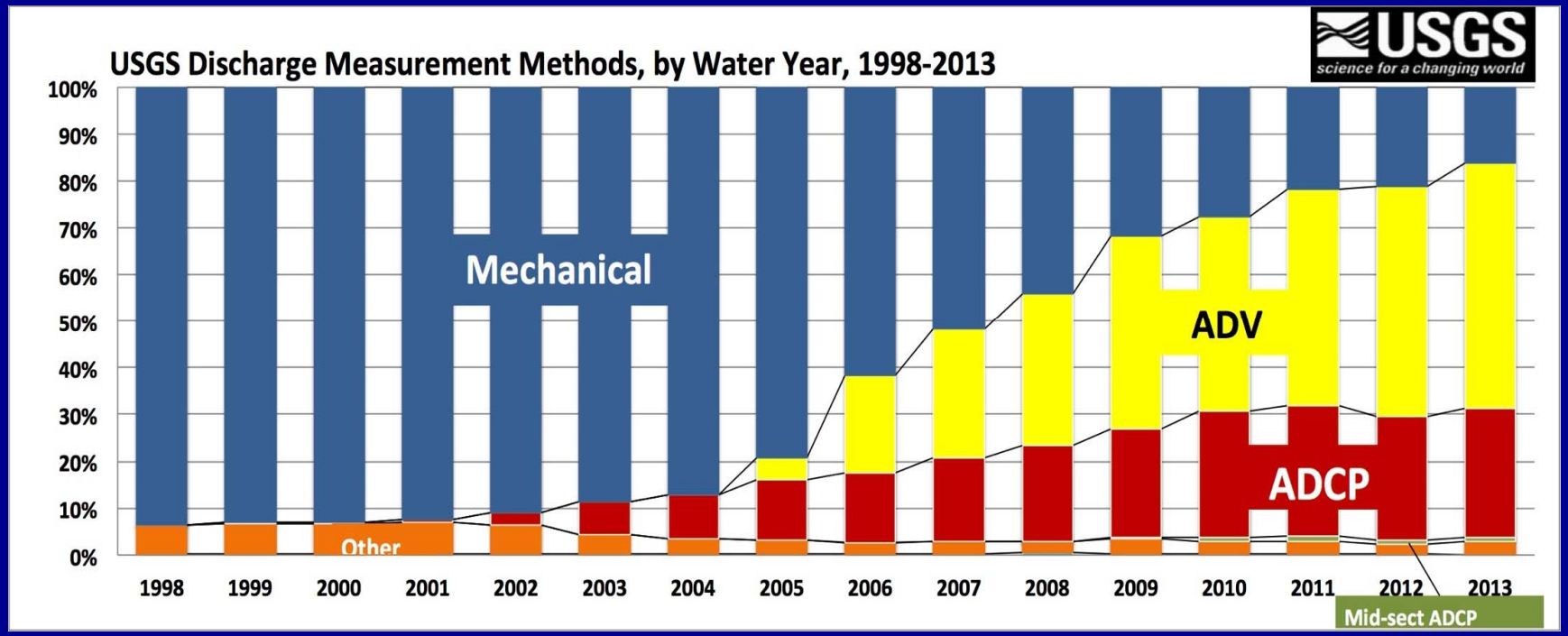
HydroAcoustic Moving Boat Flow Measurements

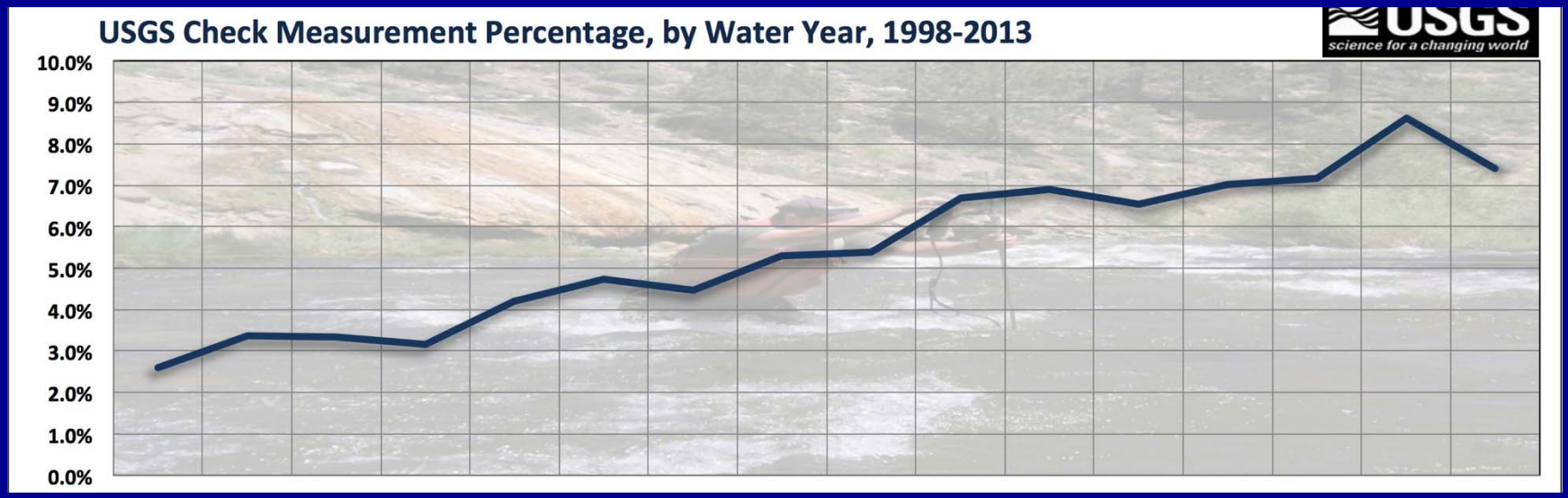


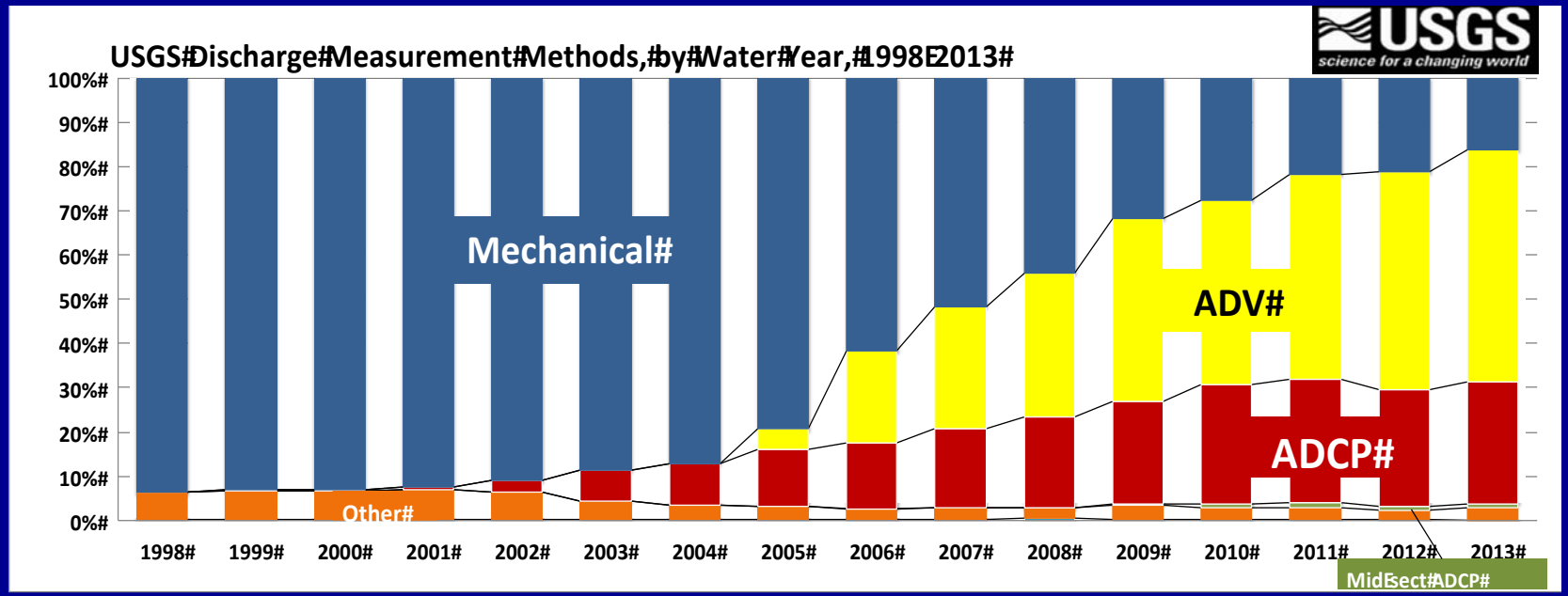


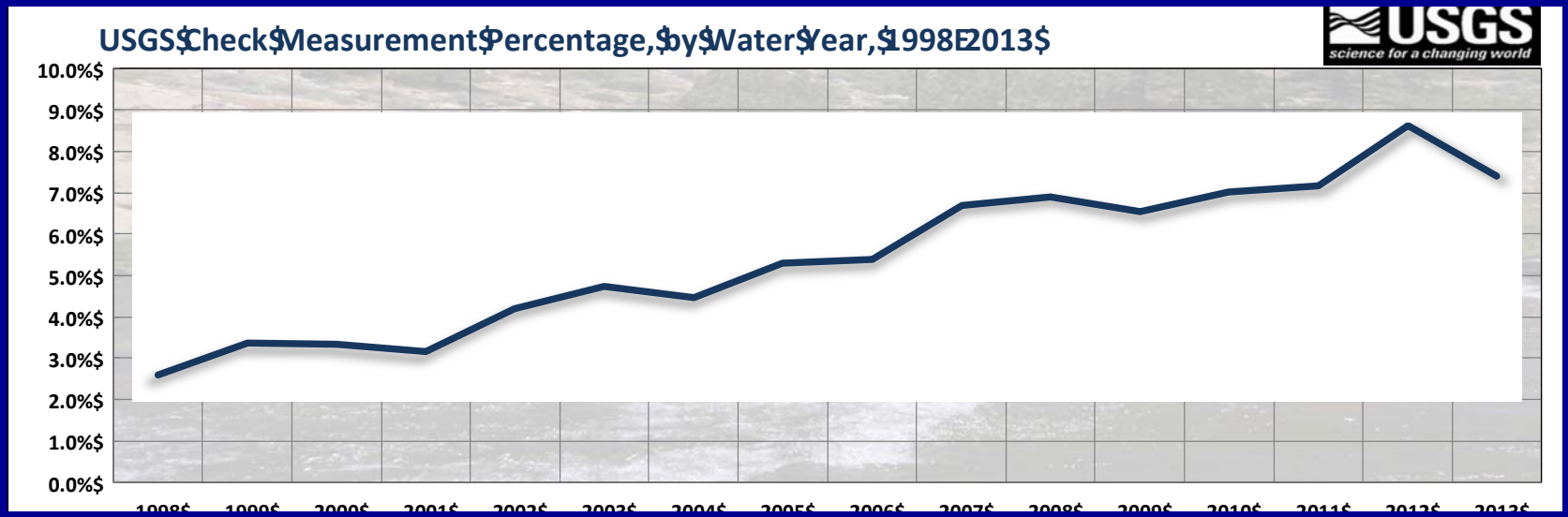


USGS

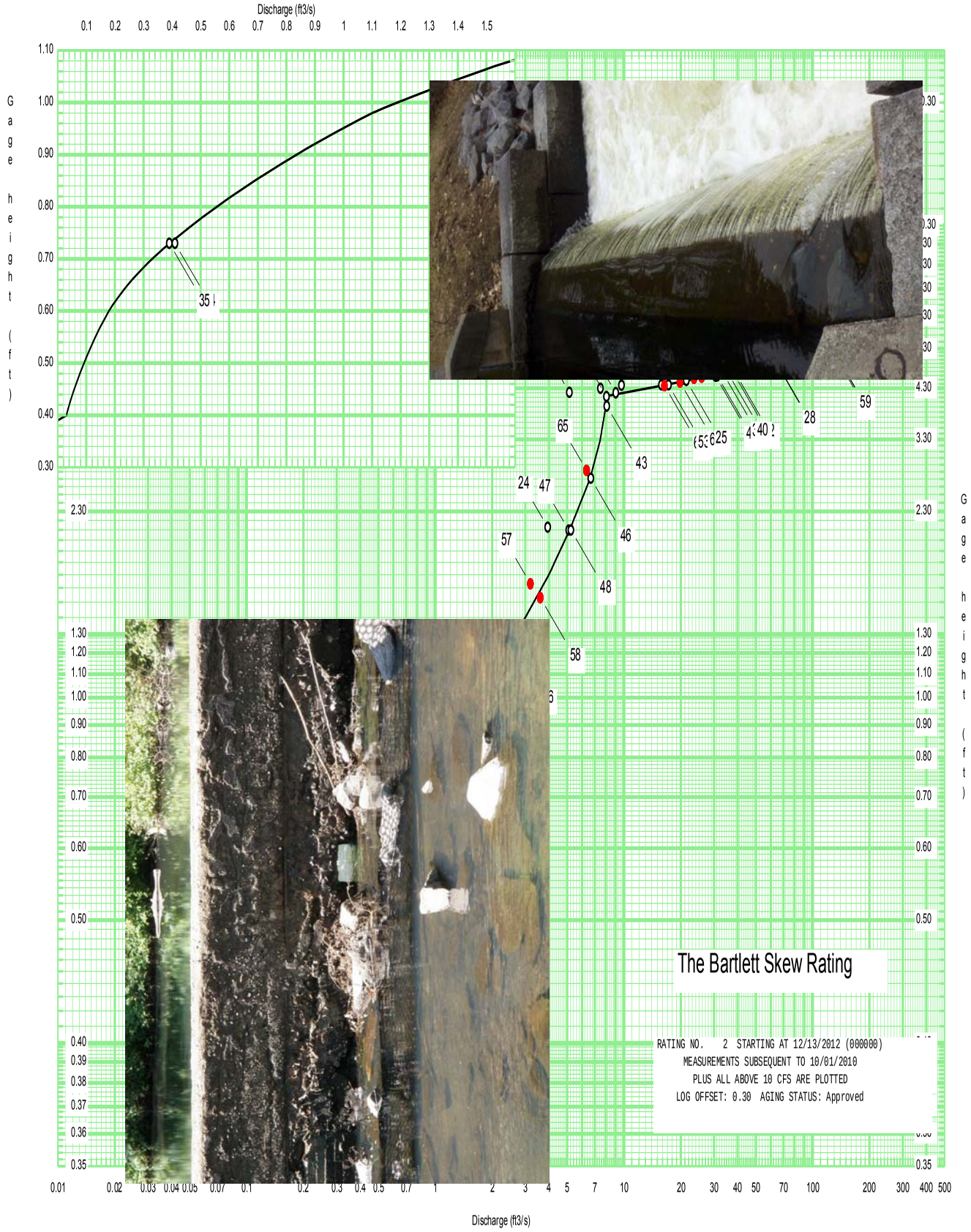

USGS Discharge Measurement Methods, by Water Year, 1998-2013
USGS
science for a changing world
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Mechanical
ADV
ADCP
Other
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Mid-sect ADCP


USGS Check Measurement Percentage, by Water Year, 1998-2013
USGS
science for a changing world
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%


USGS Discharge Measurement Methods, by Water Year, 1998-2013
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Mechanical
ADV
ADCP
Other
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Mid-Sect ADCP


USGS Check Measurement Percentage, by Water Year, 1998-2013
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%

COCHITUATE BK BL LAKE COCHITUATE AT FRAMINGHAM, MA USGS 01098500



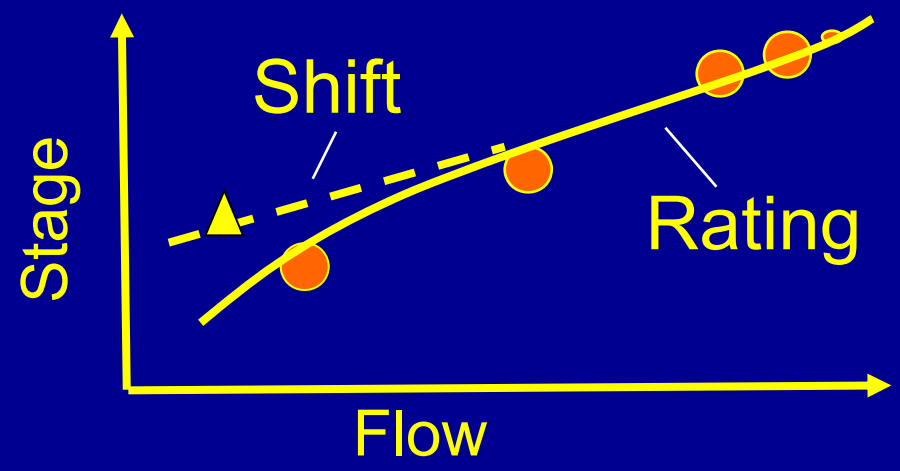
Records Processing

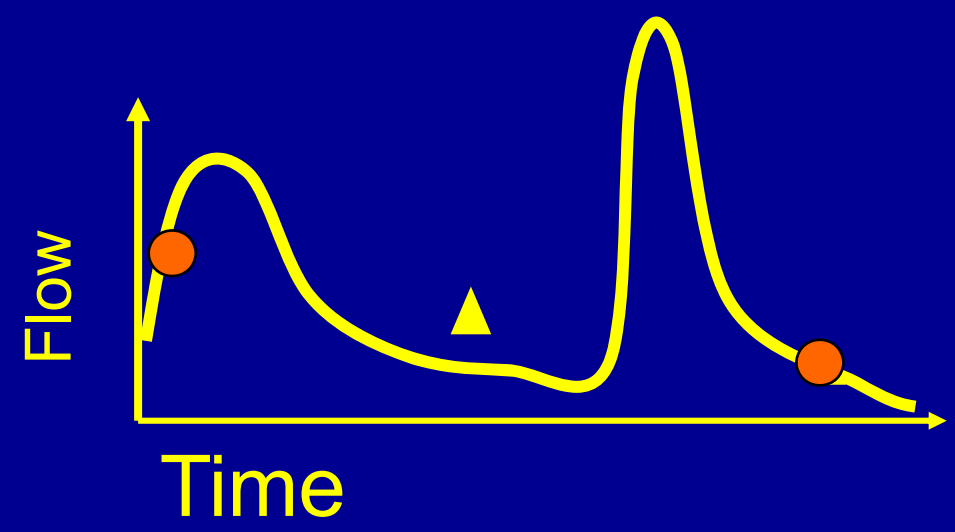
Examine stage records
- -Retrieve missing data
- -Apply corrections

Update Rating
- -Plot flow meas on rating
- -Plot shift curve
- -Develop shift diagram
- -Examine stage hydrograph for date/time
- Manually enter shifts

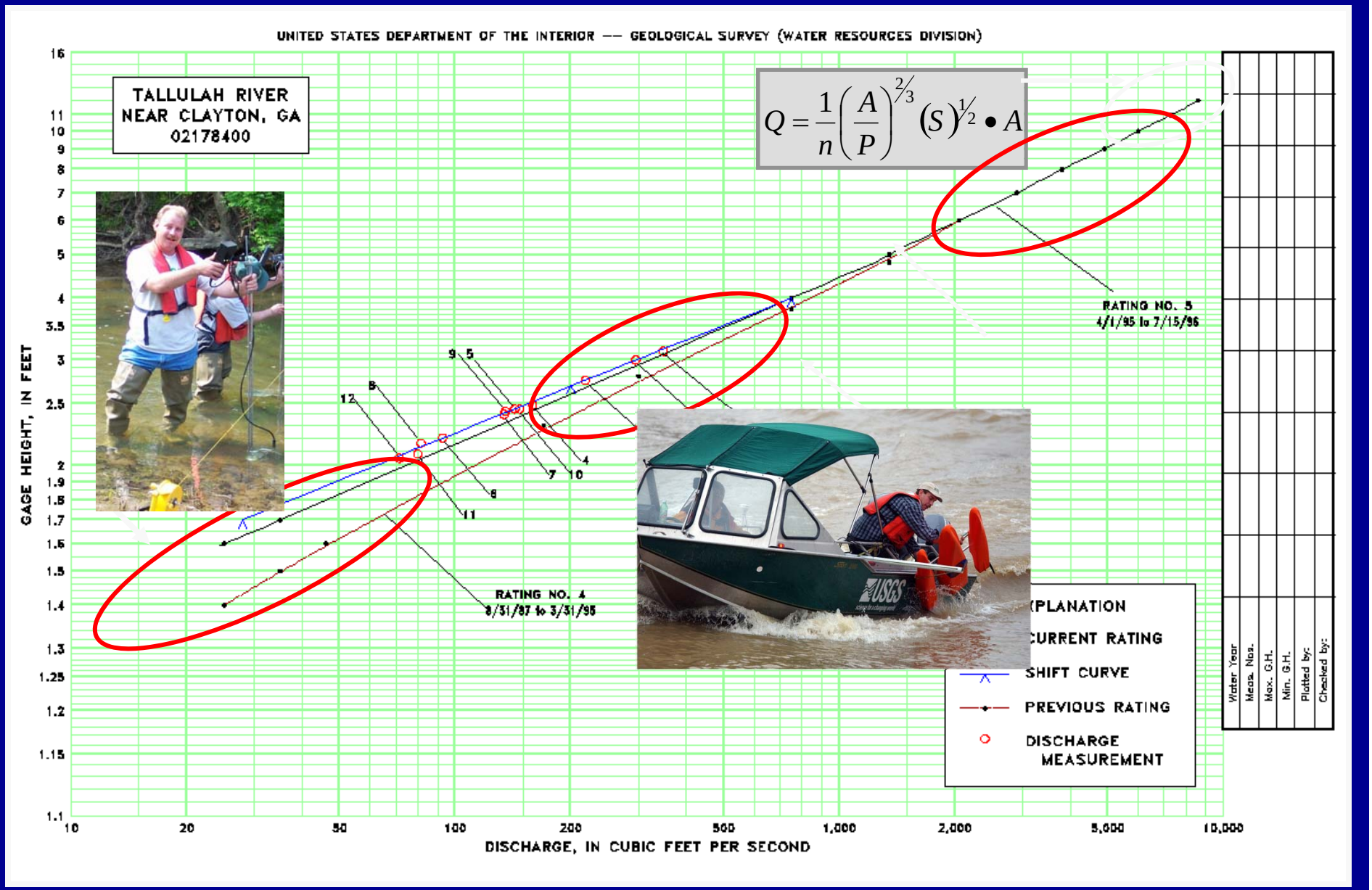
Run computations

Check/Review/Archive
- -Develop shift diagram
- -Check against nearby gages
- -Write station analysis
- -Approve records





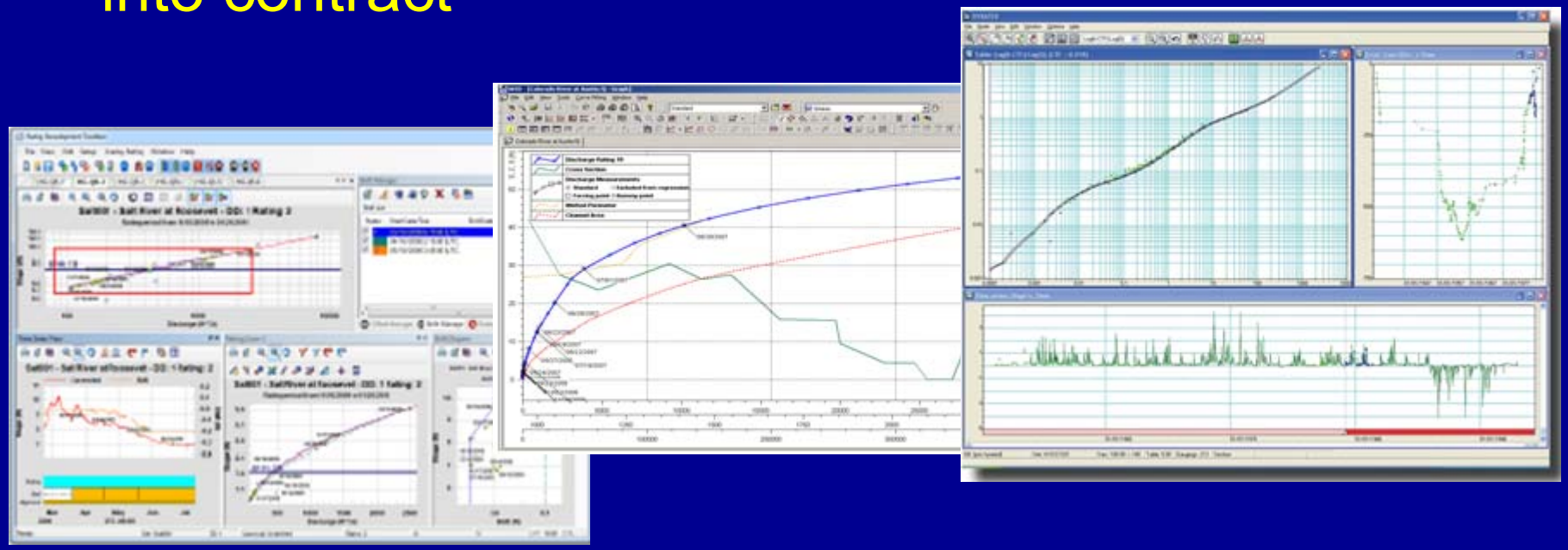
USGS


UNITED STATES DEPARTMENT OF THE INTERIOR -- GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)
TALLULAH RIVER
NEAR CLAYTON, GA
02178400
$Q = \frac{1}{n}\left(\frac{A}{P}\right)^{2/3}(S)^{1/2} \bullet A$
GAGE HEIGHT, IN FEET
DISCHARGE, IN CUBIC FEET PER SECOND
RATING NO. 5
4/1/95 to 7/15/96
RATING NO. 4
8/31/87 to 3/31/95
EXPLANATION
CURRENT RATING
SHIFT CURVE
PREVIOUS RATING
DISCHARGE MEASUREMENT
Water Year
Meas. Nos.
Max. G.H.
Min. G.H.
Plotted by:
Checked by:

Replacing ADAPS with Commercial Software

Aquarius

- Smallest of 3 major commercial systems used worldwide
- Off the shelf product
- Extensive expansion and tailoring capabilities built into contract

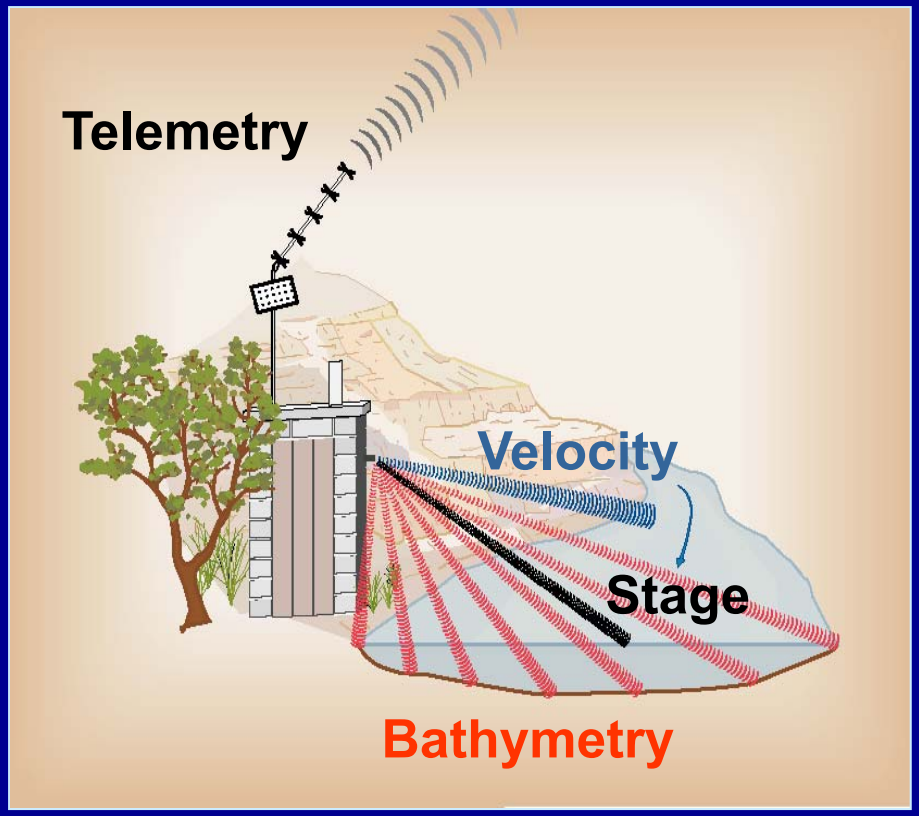


Published Standards of Practice

USGS

The Future

Non-Contact Radar Derived Discharge?

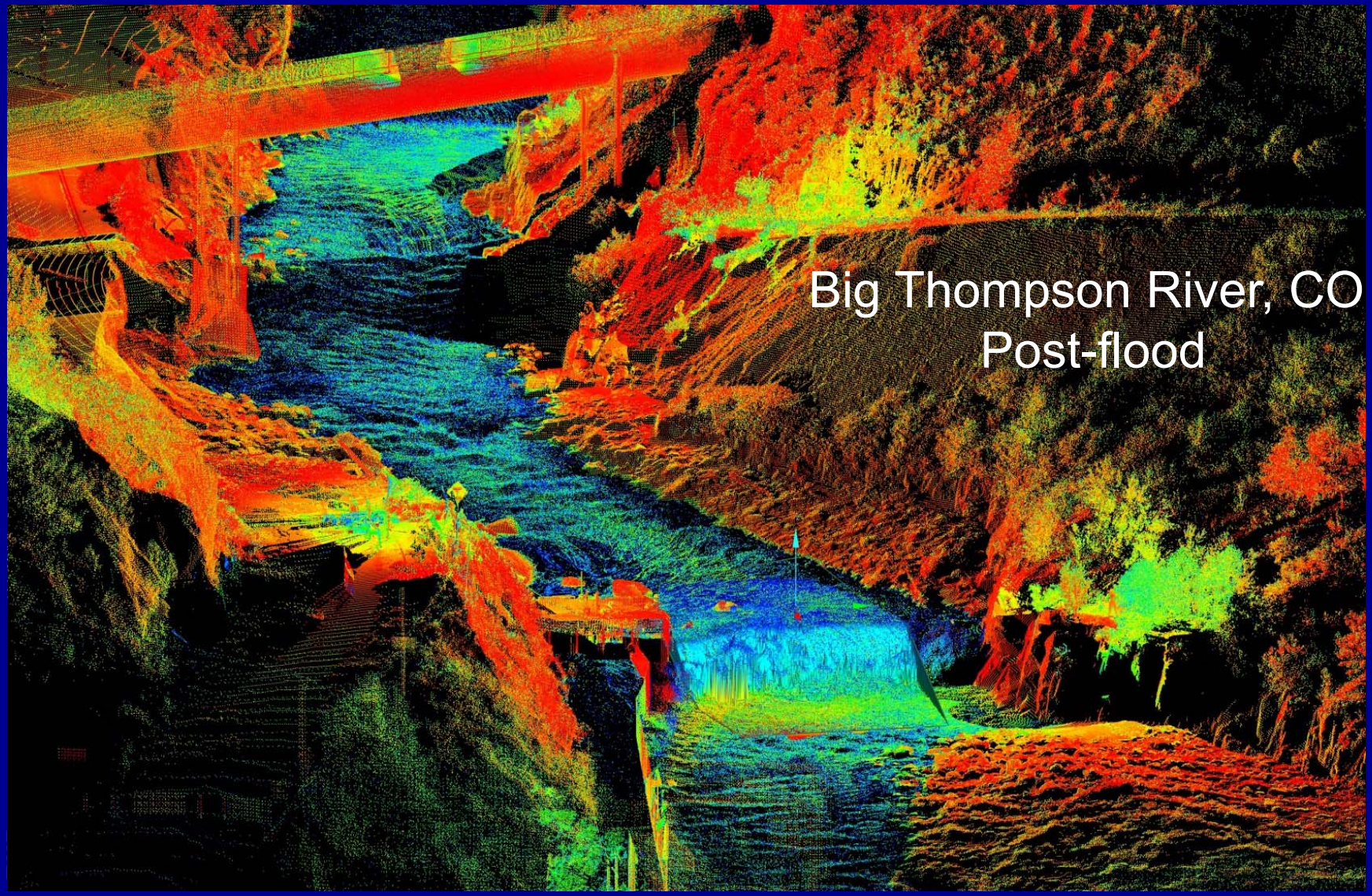


USGS

Index Radar Gage on Rio Grande at Embudo, NM

USGS

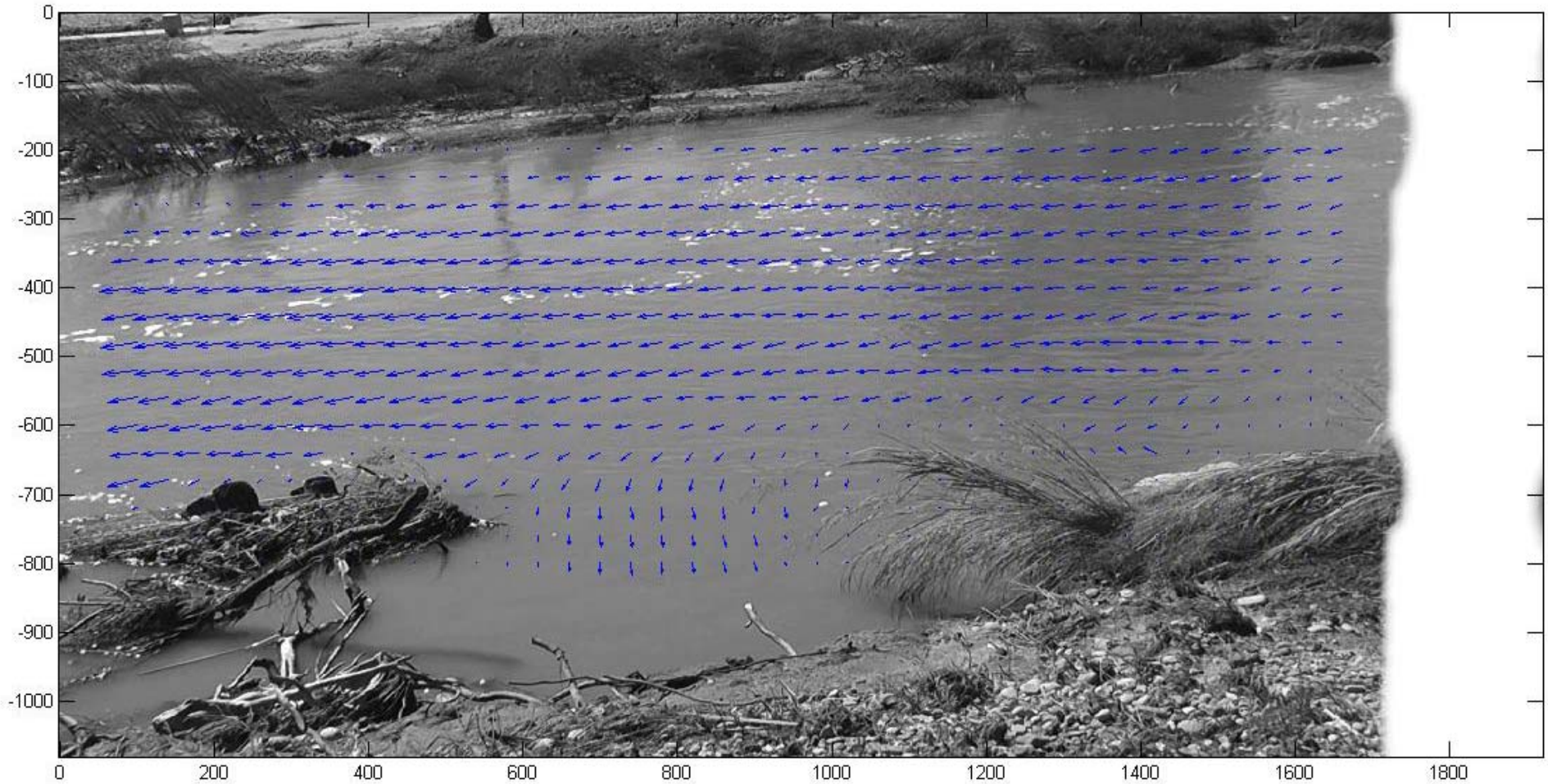
Terrestrial LIDAR Scanning
Water Surface Measurements



(video)

St. Vrain Creek, CO
Oblique side view

PIV results



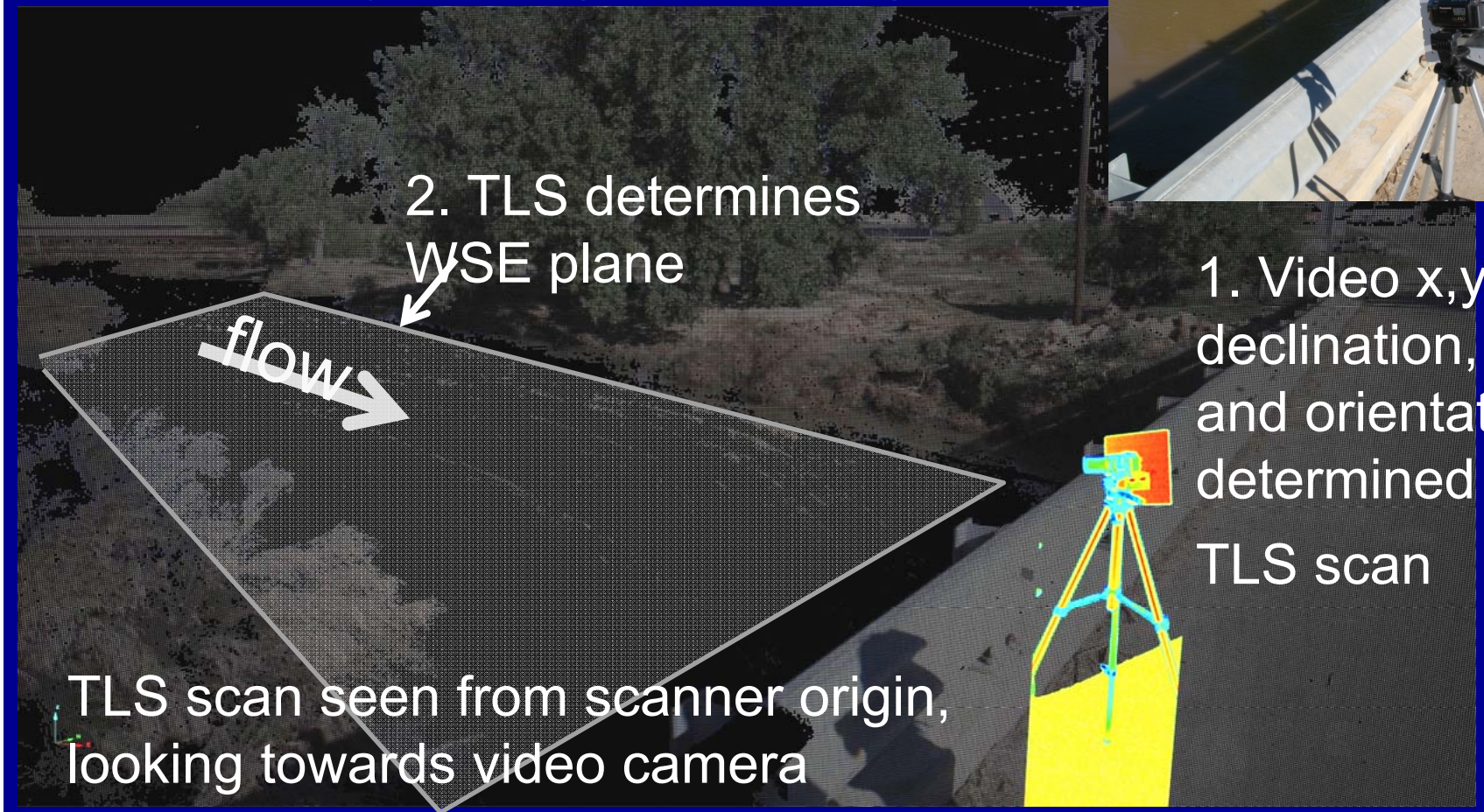
Best for video camera images with objects on surface

St. Vrain Creek, CO
Oblique side view

TLS + video concept

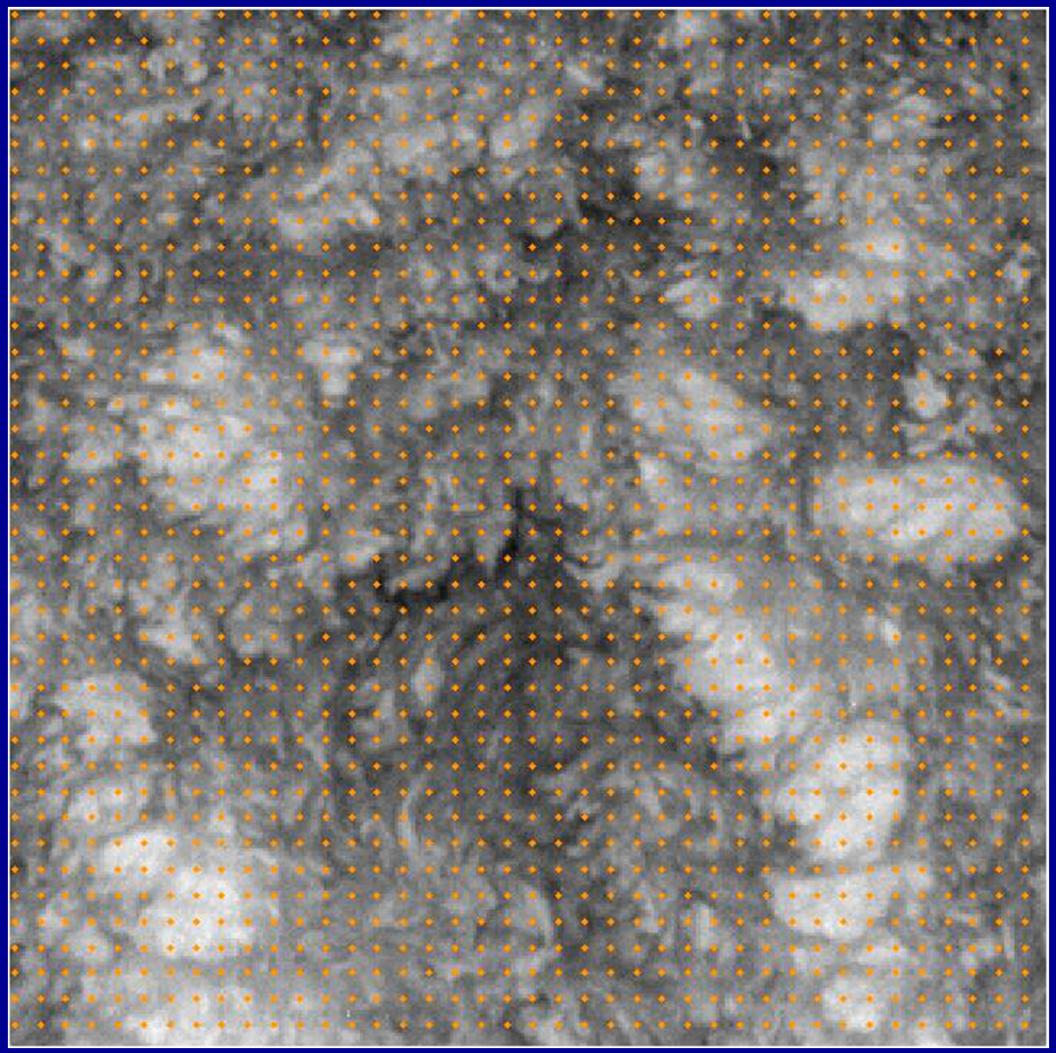
3. Transform of video into x,y,z coordinates for PIV / velocity

Indirect surface velocity measurements during floods (in 5 minutes)



St. Vrain Creek, CO

‘Dense Motion’ Velocimetry



Best for Inferred images

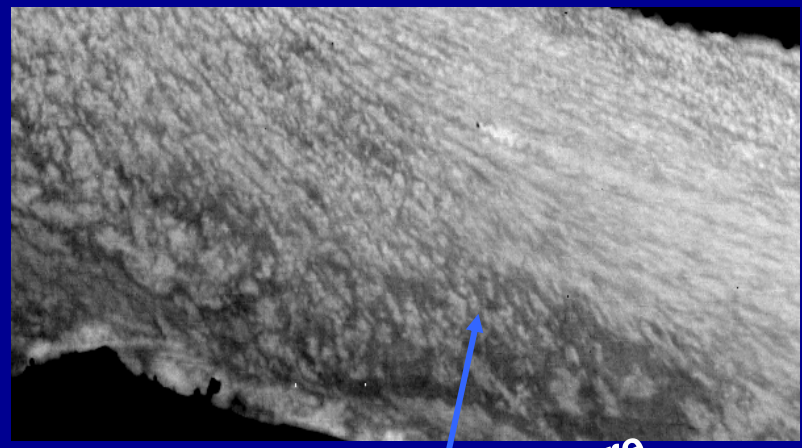
(video)

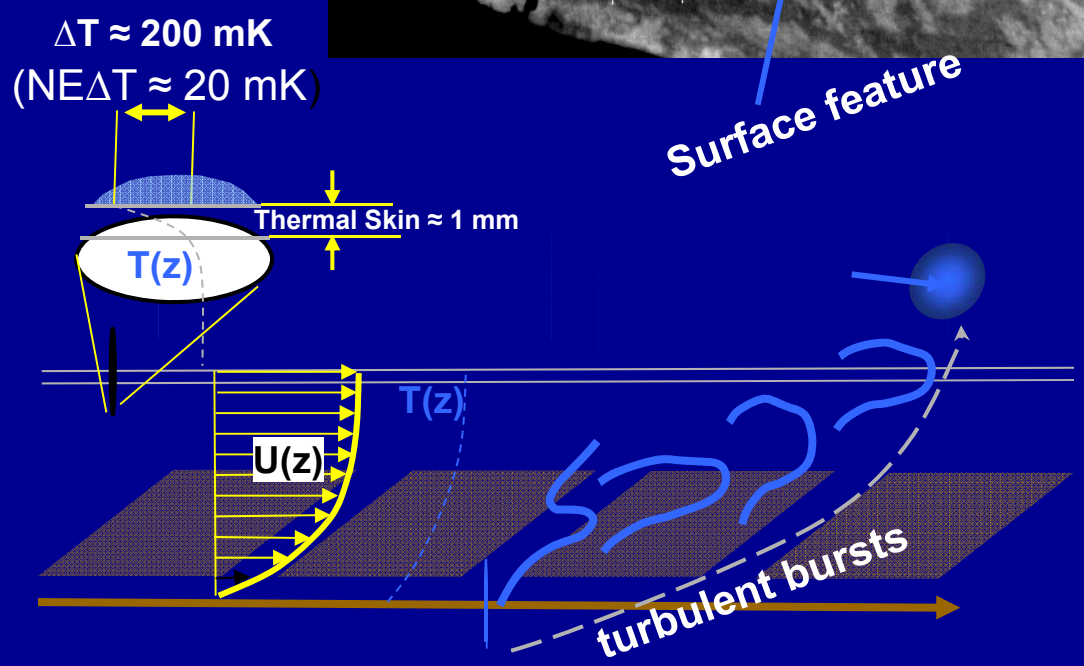
South Platte River, CO
(Near nadir)

IR Imagery allows for day-night capability and higher resolution than EO

- Turbulence in river generates a surface expression that is advected along with the mean flow of the river (Taylor's hypothesis)
- IR Surface feature is tracked using a cross-correlation algorithm to measure current
- Requires heat flux at the thermal skin on the order of $\Delta T \sim 200$ mK
- Typical MWIR camera sensitivities (noise equivalent delta temperature, NEΔT) are on the order of 20 mK

IR Imagery on Connecticut River





See Garbe et al (2004), Zappa and Jessup (2005), Veron and Melville (2010), Chickadel et al (2011),…

Emerging Technologies

detectable signal whenever there is a surface heat flux, as is typically the case in streams and rivers (Webb & Zhang 1999), as well as extending the capability to night-time collections. This paper presents a summary of our efforts to exploit the IR signal for airborne current retrievals by modifying the original AROSS camera system (Dugan et al 2001a) to include a sensitive mid-wave IR camera.

IMAGING SYSTEM

Our current retrieval approach uses time series imagery from visible band and MWIR cameras mounted on a Twin Otter aircraft, a system called the Airborne Remote Optical Spotlight System (AROSS). The spotlight terminology indicates a capability to continuously point the cameras to a spot on the water, thereby obtaining a temporal sequence of image data. Image sequences
configurations, labeled AROSS-IR and AR
configuration consists of a dual camera system
imager and a large format (LF) 4000 by 26

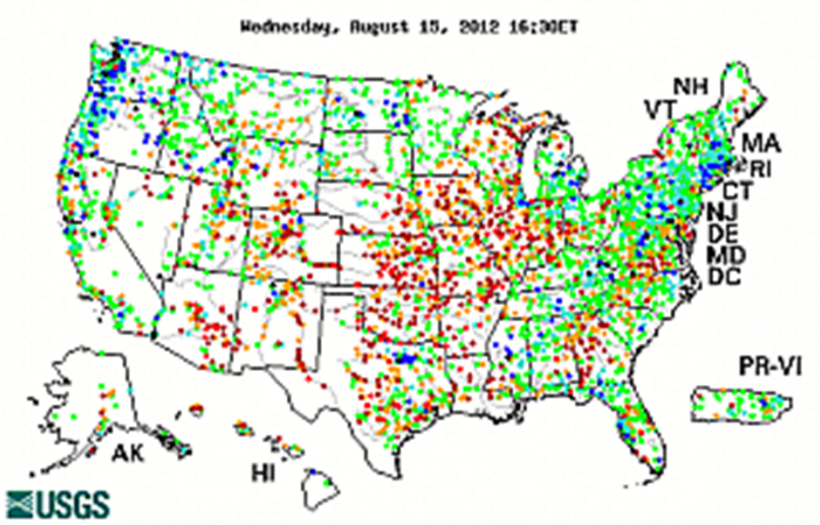
Figure 4. Potomac River Currents. Current extractions are from 16x16m grid cells. A mosaic of 10 orbits is shown and the river is ~250-300 m wide.

either moored or towed by a small boat. An example of such a comparison on the Connecticut River is shown in Figure 3. The majority (68%) of individual current speed differences were within 10 cm/s. The RMS differences were 10.3 cm s^{-1} and 10° for speed and direction respectively with no significant bias. There were occasions during daylight hours when the emissive IR signature was not strong enough for current retrievals. However, we were consistently able to retrieve currents at nighttime except for a few very shallow (<2m) and slow moving locations.

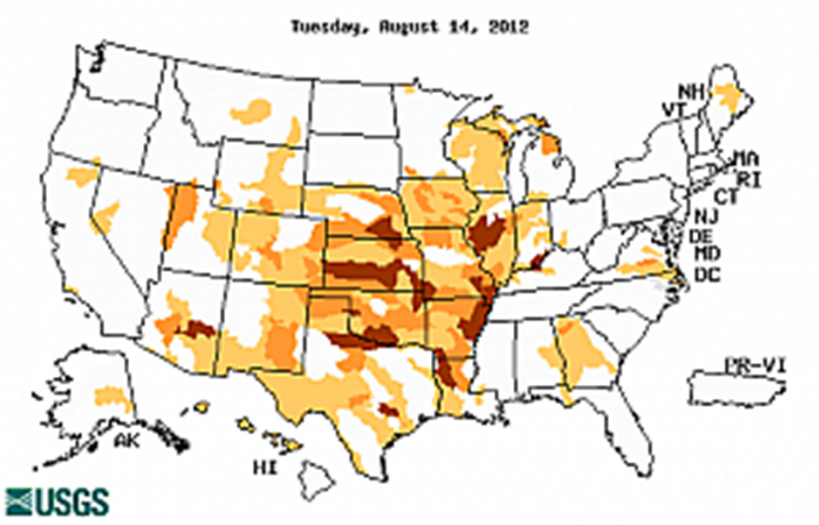
Source: Steven Anderson, Cindy Piotrowski, John Duganr, Robert DiMarcor and Seth Zuckerma, 2011, “Airborne Passive Remote Sensing of Surface Currents in Rivers and Estuaries”

Delivering the Data -WaterWatch

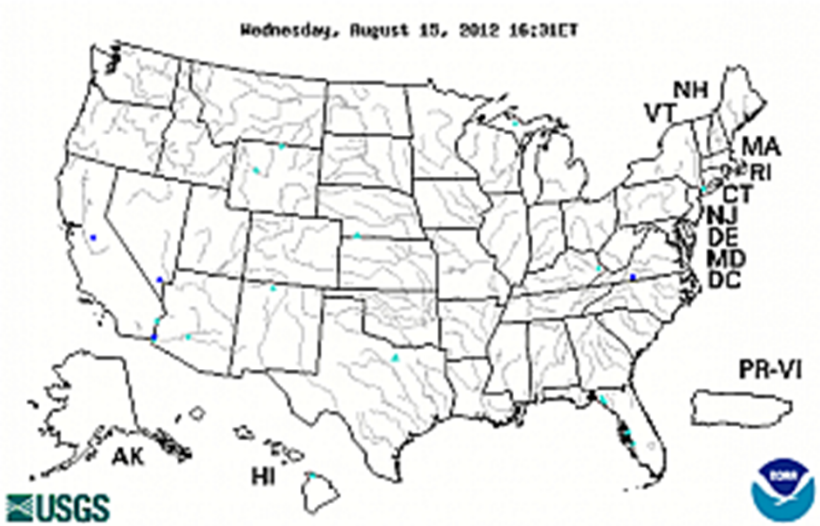
Current Streamflow



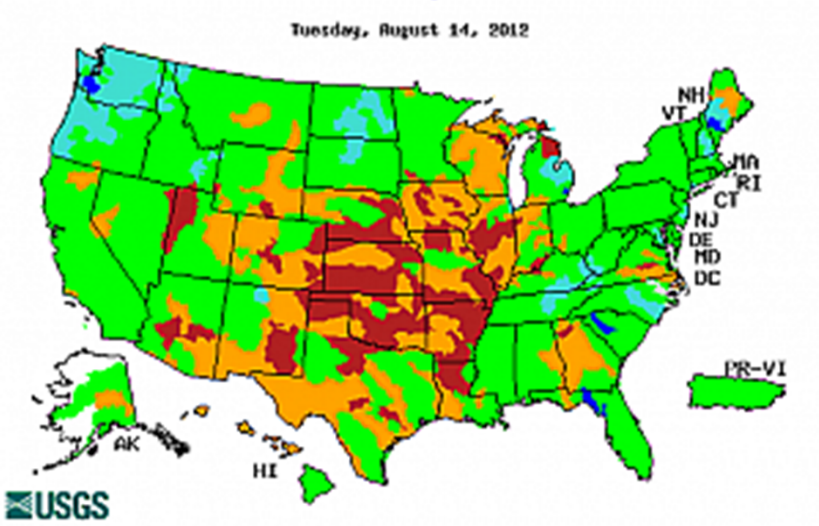
Drought



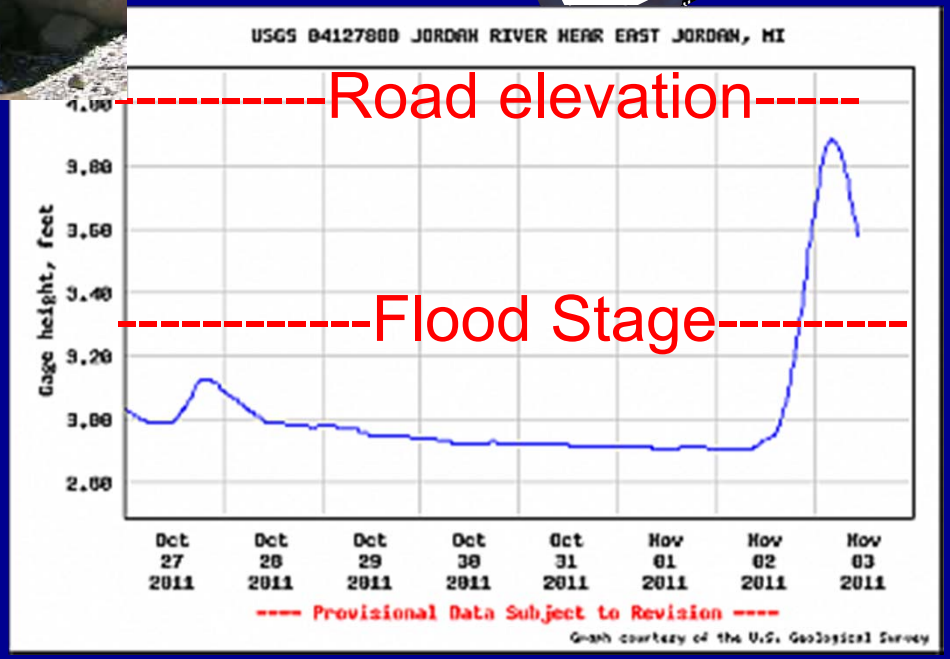
Flood



Past Flow/Runoff



USGS WaterAlert and WaterNow

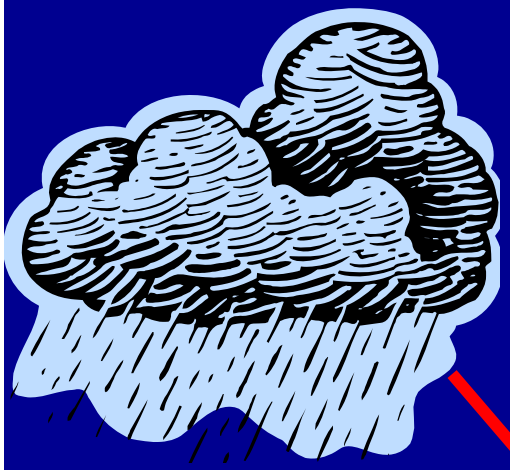


Wireless or E-mail
Customized WaterAlert

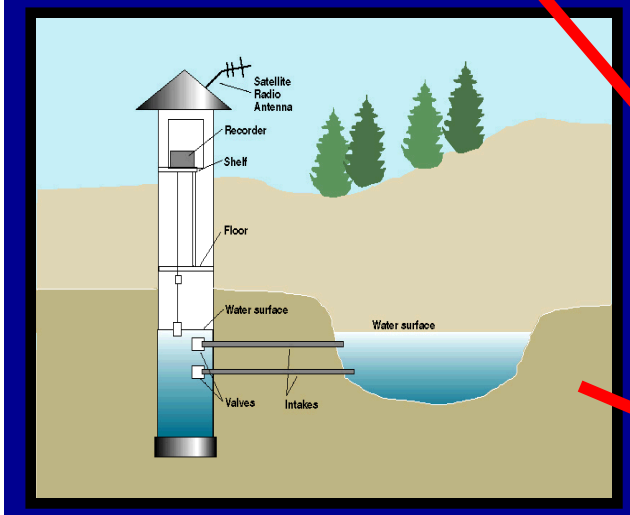
http://water.usgs.gov/WaterAlert/

USGS

Streamgaging/Forecasting Data Interoperability

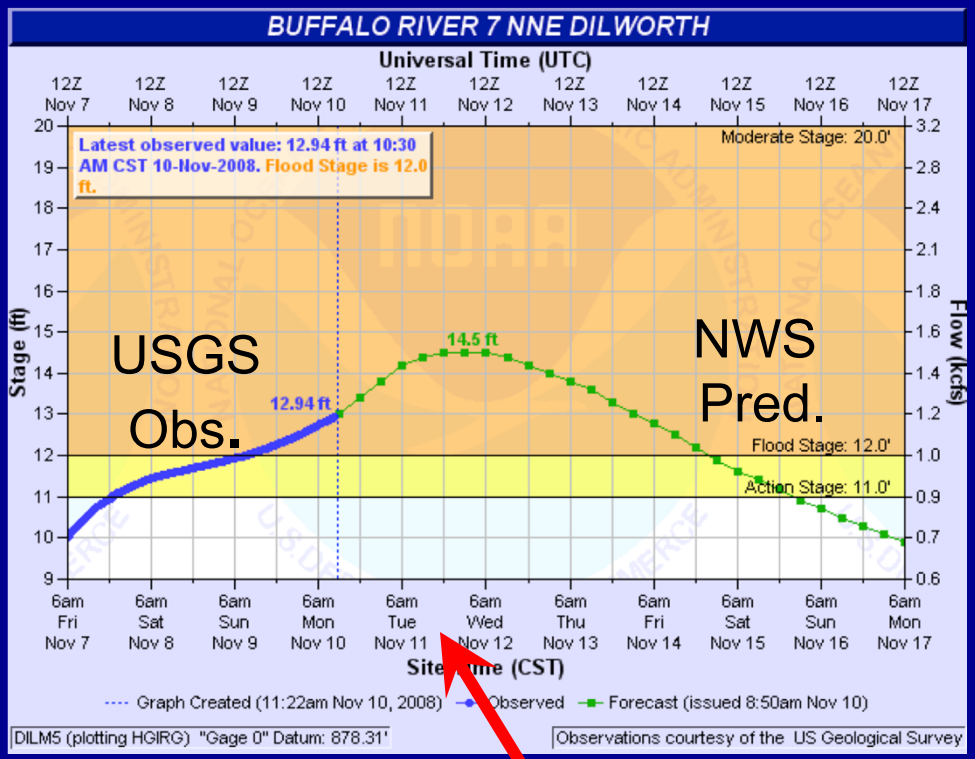


Rainfall Data



USGS streamflow data

River Stage

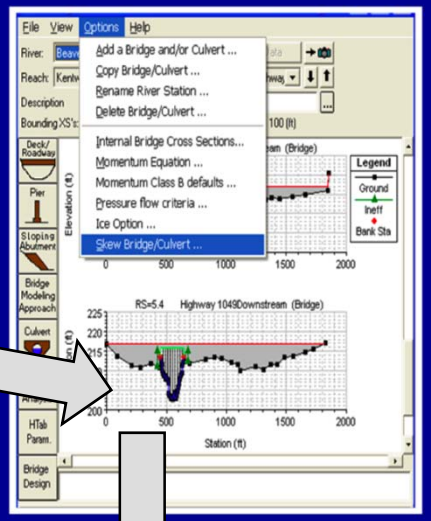


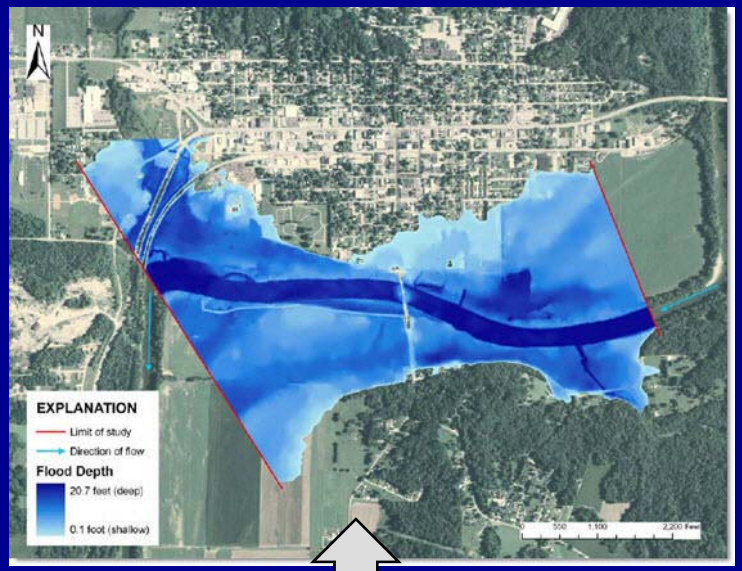
Rainfall-Runoff Model

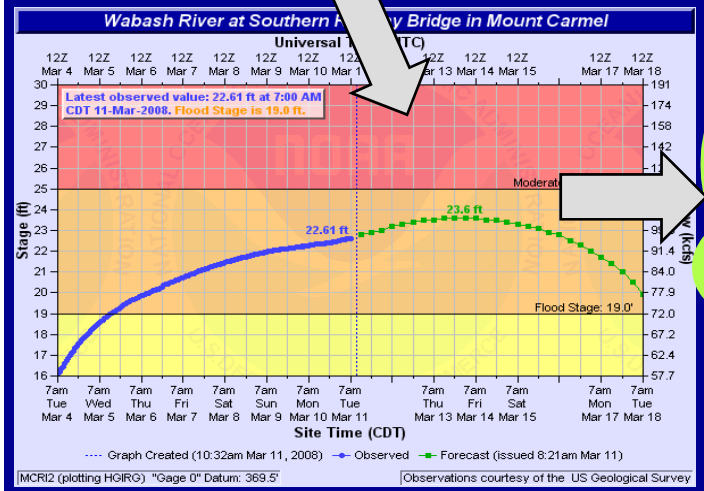
USGS Rating

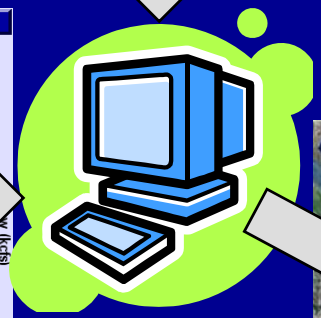
USGS

Flood-Inundation Mapping

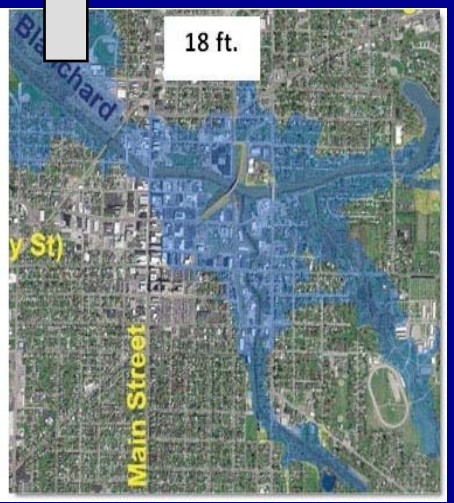






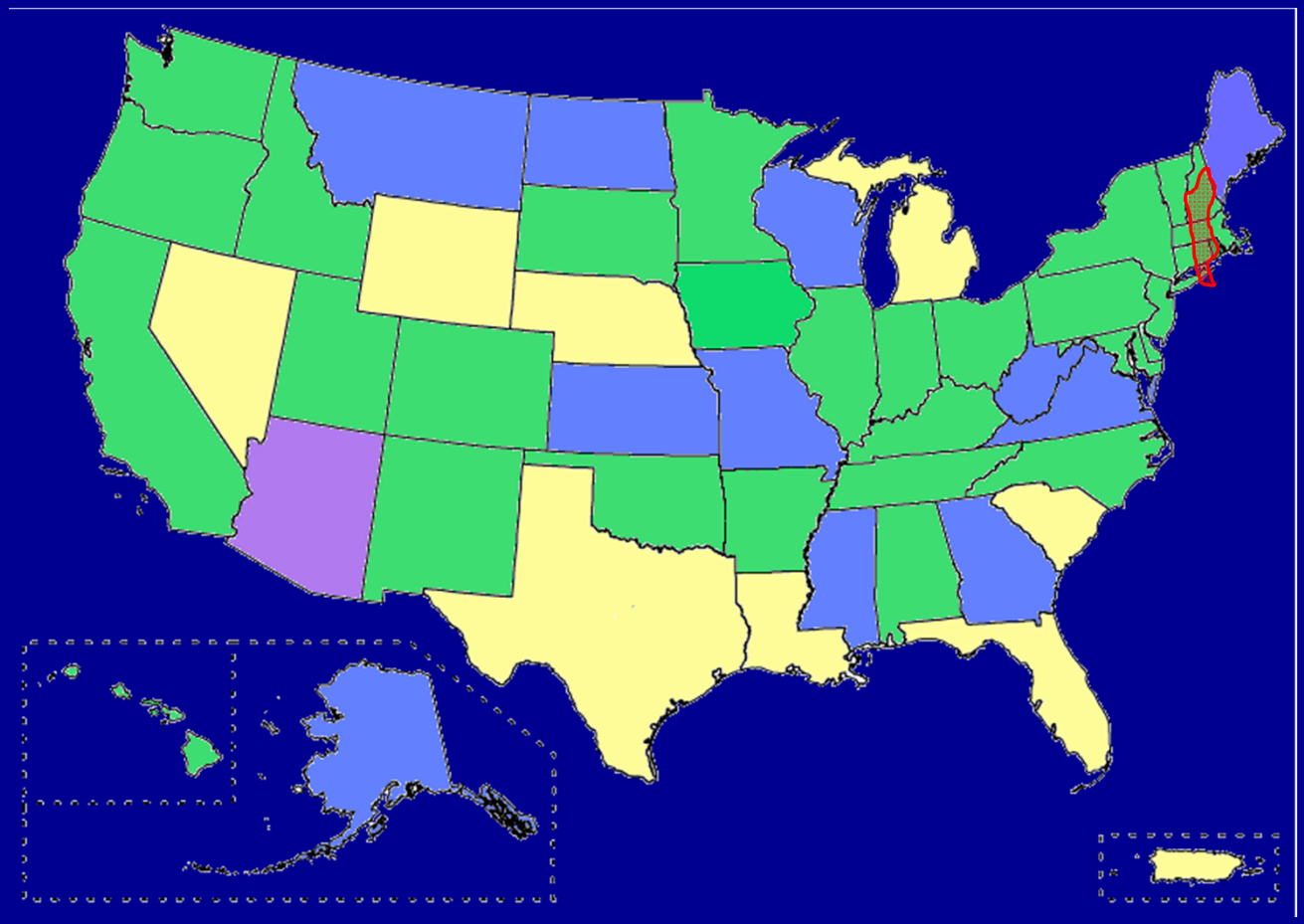


GIS



http://water.usgs.gov/osw/flood_inundation/

Regionalization –StreamStats, A Web-Based GIS Flow Estimation Tool



- 5400 equations
- Provides inputs
- Solves equations
- 30 states fully implemented

Fully Implemented

Delineation and basin characteristics only

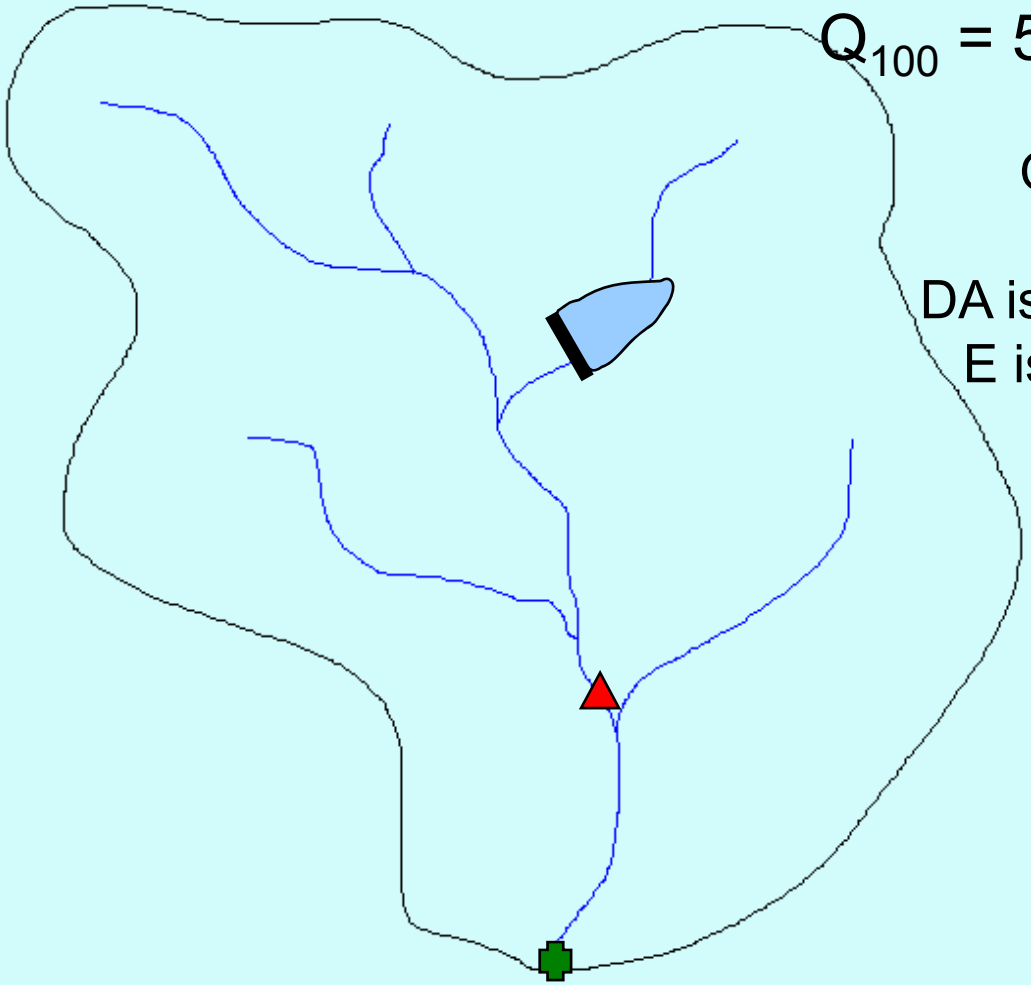
Undergoing Implementation

Not participating

USGS

http://water.usgs.gov/osw/streamstats/

Regionalization –Regression Equations for Estimating Flood Flows for Selected Probabilities of Annual Exceedences



$$Q_{100} = 5.39DA^{0.874}(E/1000)^{-1.13}S^{1.18}$$

where

Q_{100} is the 100-year flood, in feet^3/second

DA is Drainage Area, in square miles

E is mean basin elevation, in feet

S is storage in percent

<u>Explanation</u>

User-selected site

Streamgaging station

Water storage

Questions??