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
Streamgages
Follow the flow

- Core Systems
- Energy and Minerals
- Ecosystems
- Climate and Landuse
- Environmental Health
- Natural Hazards
- Water
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
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 surface water and ground water
<table>
<thead>
<tr>
<th>Number of sites</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,841</td>
<td>Gage height</td>
</tr>
<tr>
<td>8,134</td>
<td>Discharge</td>
</tr>
<tr>
<td>3,339</td>
<td>Precipitation</td>
</tr>
<tr>
<td>2,048</td>
<td>Water temperature</td>
</tr>
<tr>
<td>1,832</td>
<td>Ground-water Level</td>
</tr>
<tr>
<td>1,087</td>
<td>Specific conductance</td>
</tr>
<tr>
<td>815</td>
<td>Lake/Res elevation</td>
</tr>
<tr>
<td>632</td>
<td>Dissolved oxygen</td>
</tr>
<tr>
<td>492</td>
<td>Stream velocity</td>
</tr>
<tr>
<td>466</td>
<td>Air temperature</td>
</tr>
<tr>
<td>523</td>
<td>pH</td>
</tr>
<tr>
<td>323</td>
<td>Turbidity</td>
</tr>
<tr>
<td>179</td>
<td>Wind speed</td>
</tr>
<tr>
<td>159</td>
<td>Salinity</td>
</tr>
<tr>
<td>144</td>
<td>Wind direction</td>
</tr>
<tr>
<td>119</td>
<td>Reservoir storage</td>
</tr>
<tr>
<td>60</td>
<td>Soil temperature</td>
</tr>
<tr>
<td>52</td>
<td>Air pressure</td>
</tr>
<tr>
<td>50</td>
<td>Relative humidity</td>
</tr>
<tr>
<td>39</td>
<td>Soil moisture</td>
</tr>
<tr>
<td>25</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td>19</td>
<td>Pressure, diss gases</td>
</tr>
<tr>
<td>15</td>
<td>Barometric pressure</td>
</tr>
<tr>
<td>14</td>
<td>Solar radiation</td>
</tr>
<tr>
<td>10</td>
<td>Sodium adsorption ratio</td>
</tr>
<tr>
<td>13</td>
<td>Tide elevation</td>
</tr>
<tr>
<td>7</td>
<td>Redox potential</td>
</tr>
<tr>
<td>5</td>
<td>NO2+NO3</td>
</tr>
<tr>
<td>5</td>
<td>Cyanobacteria</td>
</tr>
</tbody>
</table>
## USGS NWISWeb Database

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total monitoring sites</td>
<td>1.5 million</td>
</tr>
<tr>
<td>Real-time sites</td>
<td>11,000</td>
</tr>
<tr>
<td>Real-time ground water</td>
<td>958</td>
</tr>
<tr>
<td>Daily values</td>
<td>286 million</td>
</tr>
<tr>
<td>Ground-water levels</td>
<td>8.0 million</td>
</tr>
<tr>
<td>Water quality samples</td>
<td>4.5 million</td>
</tr>
<tr>
<td>Water quality analyses</td>
<td>69.4 million</td>
</tr>
<tr>
<td>Peak discharges (floods)</td>
<td>750,000</td>
</tr>
</tbody>
</table>

August 1, 2007
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%

2013
Shared Funding is Most Common
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
Gages Often Support Multiple Uses

Number of Data Use Categories For all 7,955 Streamgages

Percent of Streamgages

Number of Data Uses per Streamgage
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/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
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.
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.
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
Backbone Network (total)

Adds

Total Network

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
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
Hydraulic 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

Beetee Creek nr Swannanoa, NC
The Streamgaging Process

Streamgage

Flow Measurements

Stage

Rating

Flow

Time

Flow / Stage

Shift

USGS
Inside a Gage
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.
HydroAcoustic Moving Boat Flow Measurements

![Boat Flow Measurements Diagram]

- Distance
- Velocity
- Backscatter
Remember
\[ Q = V \times A \]!!

Modeled Disturbance
The Bartlett Skew Rating
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
Measurement Methods Vary

\[ Q = \frac{1}{n} \left( \frac{A}{P} \right)^{2/3} \left( \frac{S}{2} \right)^{1/2} \cdot A \]
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

Discharge Measurements at Gaging Stations
Chapter 9 of Book 3, Section A

Levels at Gaging Stations
Chapter 11 of
Section A, Surface-Water Techniques
Book 3, Applied Use of Hydraulics

Computing Discharge Using the Index Velocity Method
Techniques and Methods 3-A23
The Future
Non-Contact Radar Derived Discharge?
Index Radar Gage on Rio Grande at Embudo, NM
Terrestrial LIDAR Scanning
Water Surface Measurements

Big Thompson River, CO
Post-flood
PIV results

St. Vrain Creek, CO
Oblique side view

Best for video camera images with objects on surface
TLS + video concept

1. Video x,y,z origin, declination, and orientation determined from TLS scan.

2. TLS determines WSE plane.

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

Indirect surface velocity measurements during floods (in 5 minutes)

TLS scan seen from scanner origin, looking towards video camera.

St. Vrain Creek, CO
‘Dense Motion’ Velocimetry

South Platte River, CO
(Near nadir)

Best for Inferred images

(video)
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, NE$\Delta T$) are on the order of 20 mK

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 of 12 distinct configurations, labeled AROSS-IR and AROSS-V, configuration consists of a dual camera system. Images and a large format (LF) 4000 by 2660

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.

Delivering the Data - WaterWatch

**Current Streamflow**
Wednesday, August 15, 2012 16:31ET

**Drought**
Tuesday, August 14, 2012

**Flood**
Wednesday, August 15, 2012 16:31ET

**Past Flow/Runoff**
Tuesday, August 14, 2012
USGS WaterAlert and WaterNow

Wireless or E-mail
Customized WaterAlert

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

--- Flood Stage ---

--- Road elevation ---

--- Provisional Data Subject to Revision ---

Graph courtesy of the U.S. Geological Survey
Streamgaging/Forecasting Data Interoperability

Rainfall Data

USGS streamflow data

USGS Obs.

NWS Pred.

Rainfall-Runoff Model

USGS Rating
Flood-Inundation Mapping

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

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

Map showing states with different implementation statuses:
- Fully Implemented
- Delineation and basin characteristics only
- Undergoing Implementation
- Not participating

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

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

Explanation:
- User-selected site
- Streamgaging station
- Water storage
Questions??