Streamgaging: measuring stream velocity and discharge

U.S. Geological Survey
New Jersey Water Science Center
Hydrologic Data Assessment Program
West Trenton, New Jersey

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Providing reliable, impartial, and timely data to assess the quantity and quality of New Jersey’s water resources
History of Streamgaging by USGS

- Director John Wesley Powell establishes first gaging station in 1888
- First USGS gage in New Jersey, Delaware River at Lambertville in 1897
- Nationally the first USGS flood studies in Passaic River basin in 1902 & 1903
- NJ USGS office, cooperative streamgaging program with State & local agencies established in 1921
Why does USGS measure streamflow?

- To provide Nat’l Weather Service with data for flood forecasting and for flood warning
- To compute flood frequencies for designing bridges, dams, flood control structures & flood plain designation
- For issuing discharge permits to point sources & withdrawal permits to purveyors
- Water supply planning & drought management
- Compute loadings to develop water quality standards and TMDL’s
- Study trends
- Boaters, fishermen and other outdoor enthusiasts use data to plan activities
Surface Water Networks in NJ

- Gaging stations, continuous-record discharge
- Stage-only gages, continuous-record
  - tidal, non-tidal
- Crest-stage gages
  - tidal, non-tidal
- Partial-record sites
  - Instantaneous flow measurements
Gaging Station Design

Electric Tape Gage, Inside reference gage

Outside Reference Gage

(From Wahl and others, 1995)
New Gaging Station Design

Typical Application Drawing
Real-time Surface Water Data

http://nj.usgs.gov

http://water.usgs.gov/water watch

USGS 01464500 Crosswicks Creek at Extonville NJ

Explaination
- High
- ≥ 90th percentile
- 75th to 90th percentile
- 50th to 74th percentile
- 10th to 24th percentile
- < 10th percentile
- Low
- Not ranked

Crosswicks Creek at Extonville, NJ, gaging station

http://nj.usgs.gov
Real-time Comparison with Historical Data

USGS 01464500 Crosswicks Creek at Extonville NJ
Drainage Area: 81.5 Square Miles, Length of Record: 66 Years

http://nj.usgs.gov/drought/duration.plots/
National Water Information System (NWIS WEB)

- Much of the hydrologic data collected by the USGS is available through the NWIS Web interface
- Surface water - Water flow and levels in streams, lakes, and springs
- Ground water - Water levels in wells
- Water quality data - Chemical and physical data for streams, lakes, springs, and wells
- [http://waterdata.usgs.gov/nwis](http://waterdata.usgs.gov/nwis)
Streamgaging

Methods for measuring streamflow

- Mechanical Meters
- Acoustic Meters
- Volumetric
- Floatation
- Flumes and portable weir plates
- Dye Dilution
- Indirect methods – surveying high water marks
Mechanical Velocity Meters

- **Price Pygmy meter**
  - Depths 0.3 - 1.5 ft
  - Velocities 0.1 - 3 ft/sec

- **Price AA meter**
  - Depths > 0.5 ft
  - Velocities 0.2 - 8 ft/sec

- **Clean and spin test after every use**

Use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.
Mechanical Velocity Meters

- Velocity is determined by placing meter in stream and counting number of revolutions in a measured amount of time, ≥ 40 sec.
- Price AA and Pygmy are attached to top setting wading rod
- Price AA can be suspended from a bridge crane in non-wadable streams
- Safe wading: max depth × max. velocity < 10.
Goal is to measure the average velocity in the vertical:

- Measured at 0.6 the depth when depths are < 2.5’
- Measured at 0.2 and 0.8 the depth when depths are > 2.5’
- If abnormal flows, measure 0.2, 0.8 & 0.6
- These velocities are averaged to represent average velocity in the vertical
Velocity Area Method

Discharge = (Area of water in cross section) x (Water velocity)

Total Discharge = ((Area 1 x Velocity 1) + (Area 2 x Velocity 2) + ….. (Area n x Velocity n))

Area = Width x Depth
Acoustic Doppler Velocimeter

- Attaches to top setting wading rod (replaces mechanical meter)
- Velocities: 0.003 – 16 ft/sec
  - Resolution: 0.0003 ft/sec
  - Accuracy: ± 1%
  - Measured 4” from transmitter
- Depths: ≥ 1 inch
- Automatic discharge computation includes angles
- RS-232 interface
Output From ADV Software
Velocity Profile
Acoustic Meters
Permanently installed

- Continuous Data Collection
- Acoustic Velocity Meter
  - Delaware & Raritan Canal at Port Mercer
- Acoustic Doppler Current Meter
  - Whippany River at Pine Brook, NJ
  - Passaic River near Pine Brook, NJ

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Portable Flumes

- Constrict open channel flow for measurements of low flow on shallow, slow moving or steep gradient streams
- A defined relation between depth upstream and flow through constriction (set in level position)
- Parshall flumes have 1” to 9” throats, 3” up to 0.5 cfs
- Cutthroat flume, 8” up to 2.3 cfs
- Staff gages in approach & downstream end of throat, used to rate the flow
- An adjustment to reduce flow is used when submergence occurs
- 2-3% accuracy during free flow conditions - 3” flume
Portable Weir Plates

- Discharge from 90 degree portable weir plates is computed using the formula
  - \( Q = 2.49 \times H^{2.48} \)
  - \( H = \) height of water behind the notch

- Used to measure larger discharges than parshall flumes, at low-flow conditions
- Used when depths are too shallow and velocity is too low for a conventional velocity meter
Parshall Flume measurement of discharge
Volumetric

- Most accurate method for small flows
- Volume of water measured from outlet of a culvert, v-notch weir or narrow stream diverted thru a pipe ( avg 3 or 4 measurements)
- Equipment: calibrated bucket, stopwatch, scale
- Method 1 Time it takes to fill container to a known volume.
- Method 2 Volume = \( W_2 - W_1 / w \)
  - \( W_2 \) = weight of water and container
  - \( W_1 \) = weight of empty container
  - \( w \) = unit weight of water, 62.4 lb/ft\(^3\) or 1,000 kg/m\(^3\)
Volumetric Measurement of discharge
**Floatation**

- Method rarely used – emergencies
- Equipment: 1) A floating object: Bottle partially filled with water or orange or debris floating in stream 2) two taglines 3) four stakes, 4) stopwatch
- Two cross sections selected along a uniform constricted section of the channel
- Get width and depths at 4 or 5 locations along both cross sections. Mark water surface elevation with stakes on bank if too deep to wade
- Space cross sections to allow travel time of at least 20 seconds between taglines
Floatation cont...

- Drop floats upstream of upstream tagline. Usually at a few locations, near center, and ~ ¼ - 1/3 of width from each bank.
- Velocity = distance divide by time.
- A coefficient of 0.85 is commonly used to convert surface velocity to mean velocity in the vertical.
- Sub section Area = depth x width.
- Total Discharge = ((Area 1 x Velocity 1) + (Area 2 x Velocity 2) + ….. (Area n x Velocity n)).
- Measurement results could be ± 10% under ideal conditions and > 25% in a non-uniform reach w/ few floats.
Comparison of methods

Summary of discharge measurements at 01402000 Millstone River at Blackwells Mills, NJ on May 10, 2006 during field training exercise [* velocity too slow to measure]

<table>
<thead>
<tr>
<th>Cross section</th>
<th>Flowtracker</th>
<th>Pygmy meter</th>
<th>Floatation Method</th>
<th>Culvert Computation</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal cross section</td>
<td>1.04</td>
<td>1.06</td>
<td>1.00</td>
<td>-</td>
<td>4 - 6%</td>
</tr>
<tr>
<td>Expansion reach (pool, very slow velocity)</td>
<td>1.04</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Contracting reach (eddies)</td>
<td>0.96</td>
<td>1.09</td>
<td>-</td>
<td>-</td>
<td>13%</td>
</tr>
<tr>
<td>Outlet of culvert (uneven, turbulent)</td>
<td>0.80</td>
<td>0.92</td>
<td>-</td>
<td>1.3</td>
<td>62%</td>
</tr>
<tr>
<td>Percent difference between sections</td>
<td>30%</td>
<td>18.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparison of Velocity Measurements

- Culvert on Whale Pond Brook October 2006
- Floatation measured 20% higher than meters
- Pygmy meter: 0.87 ft/sec, 17 verticals
- Flow tracker: 0.83 ft/sec, 17 verticals
- Floatation: 1.02 ft/sec, 3 measurements
- A correction factor of 0.83 applied to the velocity from the floatation method would equal 0.85 ft/sec, the mean of the velocity measured from the meters, 2% higher than flowtracker and 2% lower than pygmy meter
Comparison of Flow measurements
November 2, 2006 Whale Pond Brook

- Floatation method measured 20% more flow than the acoustic meter method
- Flowtracker 8.1 cfs, 0.36 ft/sec, 22.3 ft$^2$ area
- Floatation method 9.8 cfs, 0.36 ft/sec, 27.2 ft$^2$ area
- A correction factor of 0.85 applied to the flow measured from the floatation method would equal 8.3 cfs, 2% higher than the flowtracker
Current Projects

Two projects the Hydrologic Data Assessment Program (HDAP) are currently undertaking are Bridge Scour and Barnegat Bay Restoration among others.
New Jersey Bridge Scour Monitoring Program

• General objectives of the project are twofold
  • Monitor and validate the effects of scour at NJDOT bridge structures
  • Obtain updated flow & velocity data at identified structures to determine the magnitude of local scour over a range of streamflows

• Monitoring program will accomplish several specific objectives
  • Document the rate of increase of scour at identified structures over a fixed period of time
  • Update and improve flow rate data used in calculating scour
  • Provide documentation of the empirical data collected

• This project is planned to continue for a minimum of three to five years from initial set-up for each identified structure.

• Out of the above, the USGS role is data collection and dissemination
  • We are not involved with data analysis
  • Data analysis contracted out by NJ DOT to a consulting firm
Scour Countermeasures Installation
Barnegat Bay Restoration Activity

The Barnegat Bay Restoration Activities will provide NJDEP and other interested parties with an improved quantitative understanding of critical physical, chemical, and biological conditions and processes that are relevant to the health of this important coastal resource. This understanding will be the foundation for other scientific analyses of Barnegat Bay’s hydrologic and biologic systems that may proceed contemporaneously or subsequent to this project.
Barnegat Light Gage Shelter
Barnegat Light Gage Shelter
Barnegat Light Sensor Mount
Mantoloking Bridge Gage Shelter
Mantoloking Bridge
Resources

- **Guidance – USGS reports**
  - Techniques in Water Resources investigations

- **Water Resources Information for Students and Teachers** [http://water.usgs.gov/education.html](http://water.usgs.gov/education.html)

- **Equipment - Rickly Hydrological Company**
  - [www.rickly.com](http://www.rickly.com)
  - Forestry Suppliers, Inc
  - [www.forestry-suppliers.com](http://www.forestry-suppliers.com)
Resources Continued

USGS Educational Websites

- http://education.usgs.gov/
- Water Science for Schools
  - http://ga.water.usgs.gov/edu/
  - Glossary of terms
    http://ga.water.usgs.gov/edu/dictionary.html
- List of educational materials from USGS
Resources Continued

- USGS Surface Water Training Website
  http://wwwrcamnl.wr.usgs.gov/sws/SWTraining/Index.htm

- New Jersey Water Science Center
  810 Bear Tavern Road Suite 206
  West Trenton, NJ 08628
  (609)771-3980
  http://nj.usgs.gov
  http://water.usgs.gov