# Streamgaging: measuring stream velocity and discharge

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

**8th Annual Water Monitoring and Education Summit**
**December 1-2, 2011**
**PHEAL**
**West Trenton, New Jersey**

**Jason Shvanda**

***Providing reliable, impartial, and timely data to assess the quantity and quality of New Jersey's water resources***

USGS
science for a changing world

# History of Streamgaging by USGS

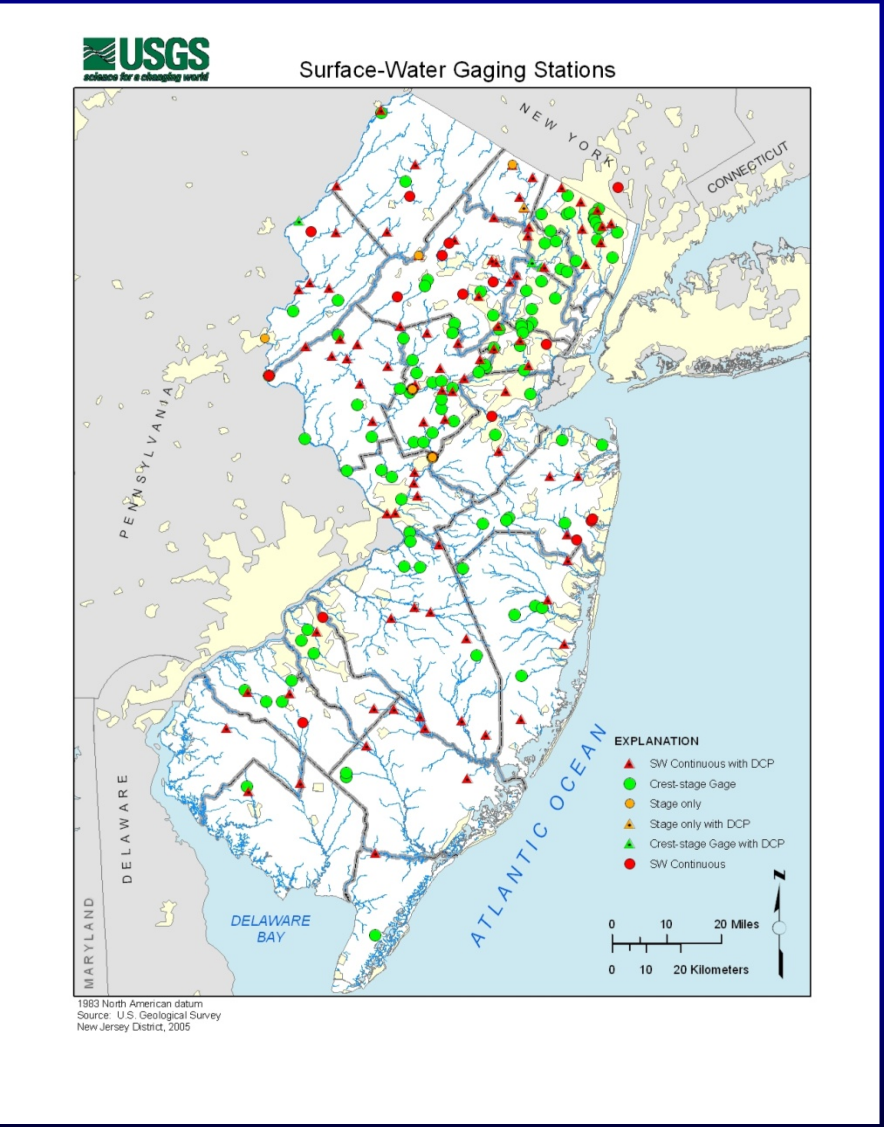
- Director John Wesley Powell establishes first gaging station in 1888
- First USGS gage in New Jersey, Delaware River at Lambertville in 1897
- Nationally the first USGS flood studies in Passaic River basin in 1902 & 1903
- NJ USGS office , cooperative streamgaging program with State & local agencies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

# Why does USGS measure streamflow?

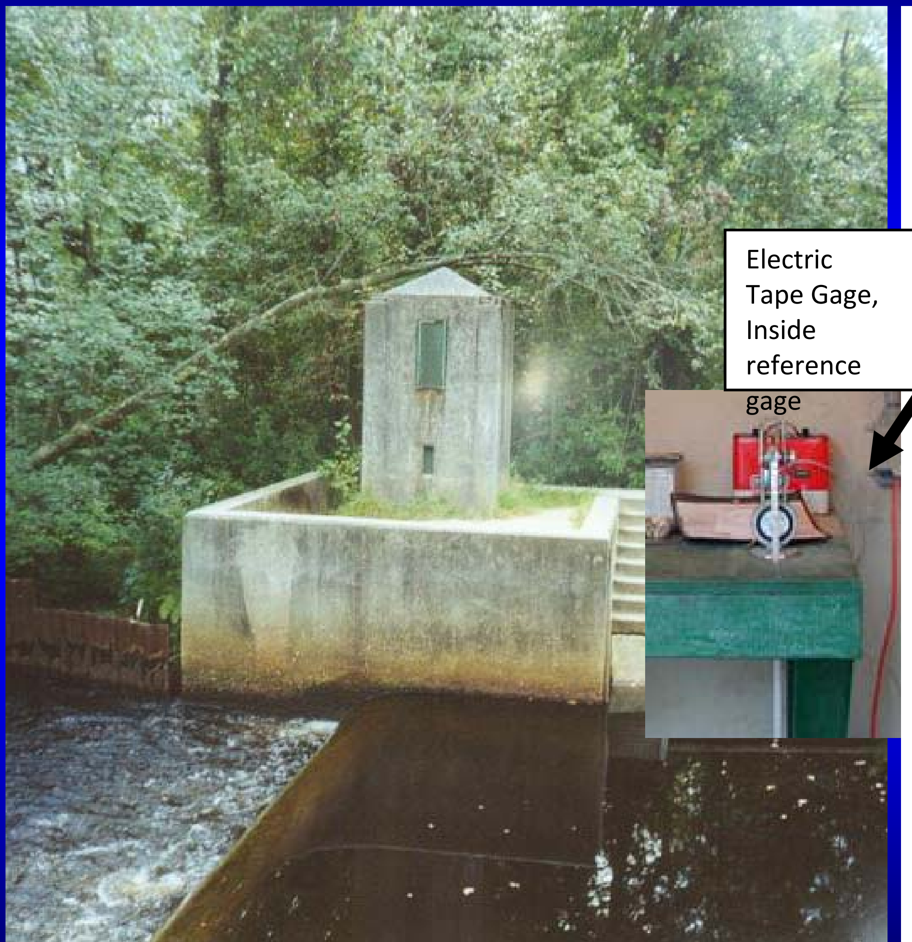
- To provide Nat'l Weather Service with data for flood forecasting and for flood warning
- To compute flood frequencies for designing bridges, dams, flood control structures & flood plain designation
- For issuing discharge permits to point sources & withdrawal permits to purveyors
- Water supply planning & 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

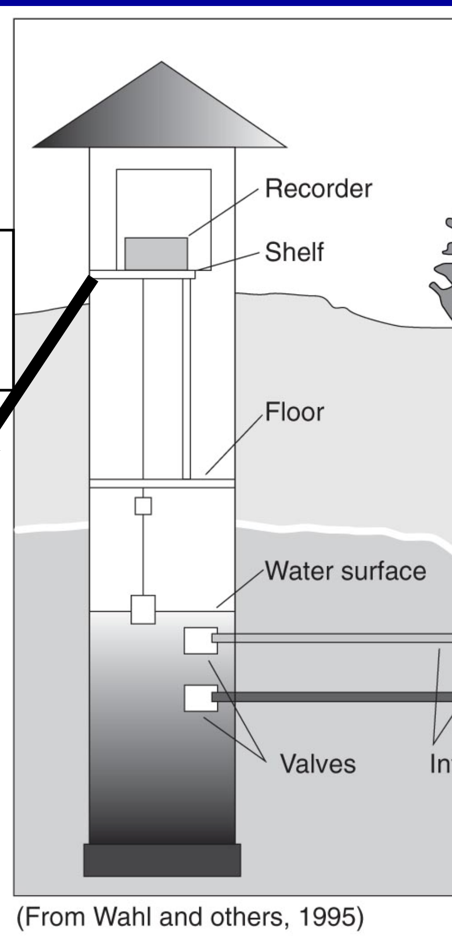
# Surface Water Networks in NJ

- 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

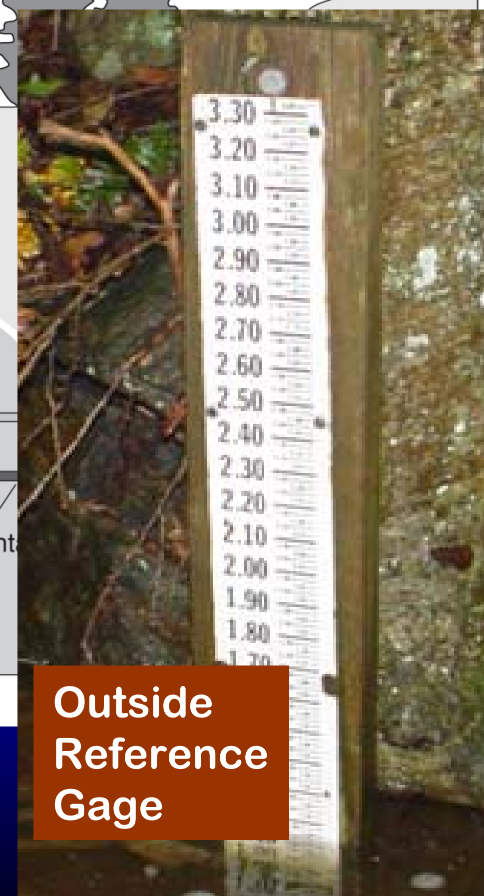


# Gaging Station Design

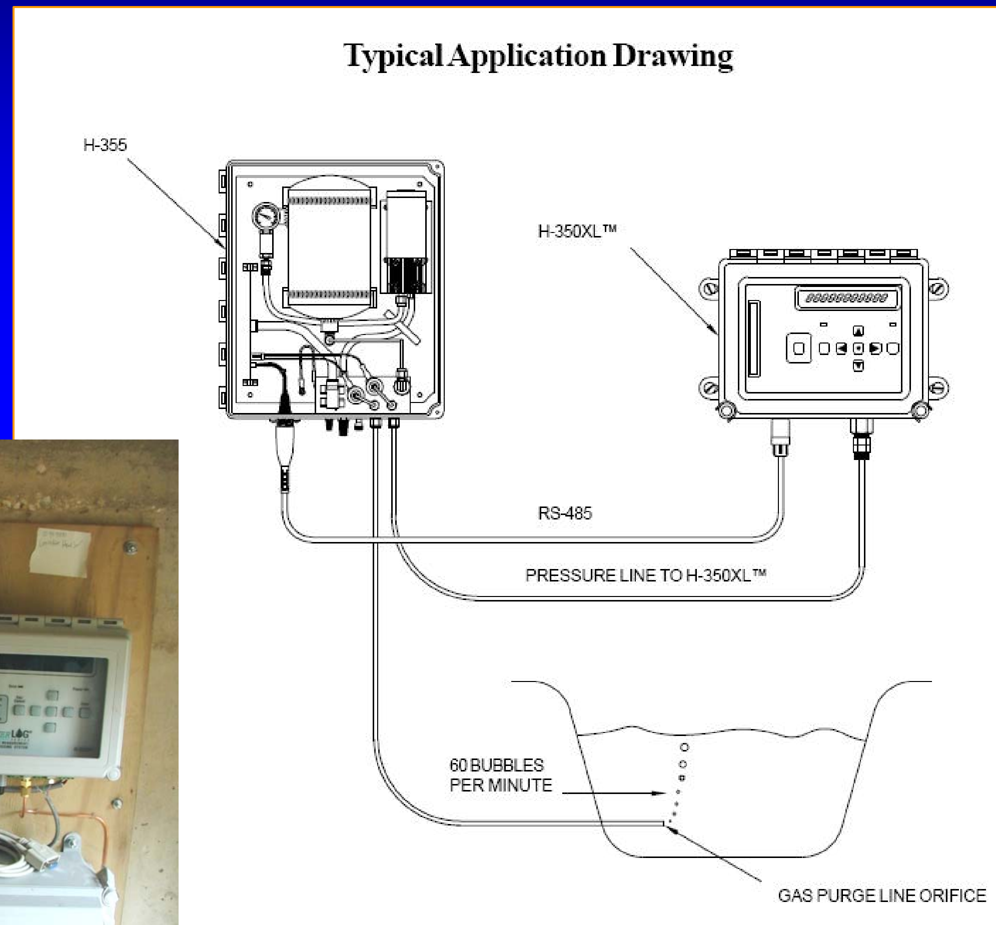


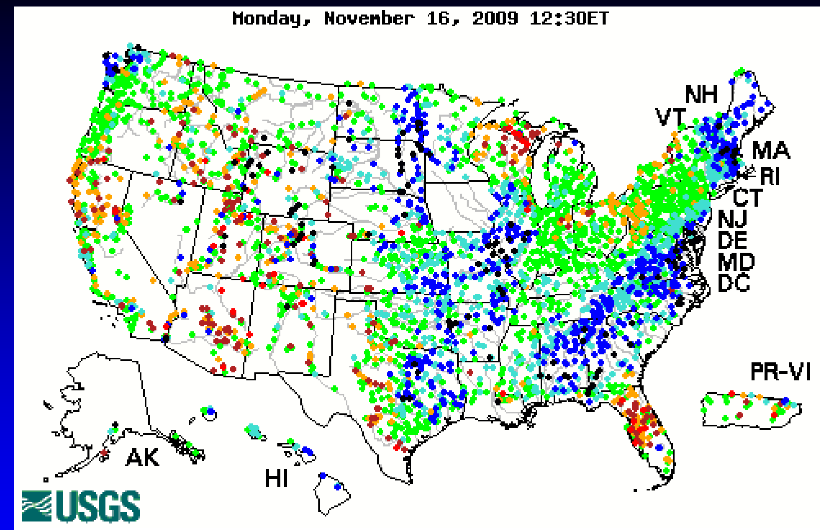

(From Wahl and others, 1995)



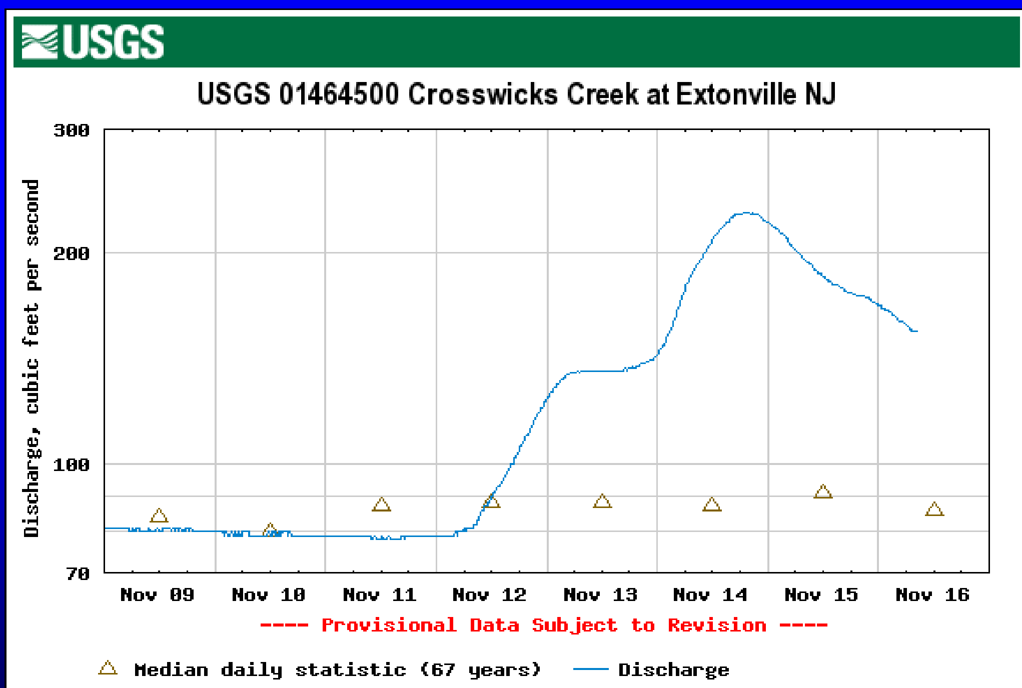
# New Gaging Station Design

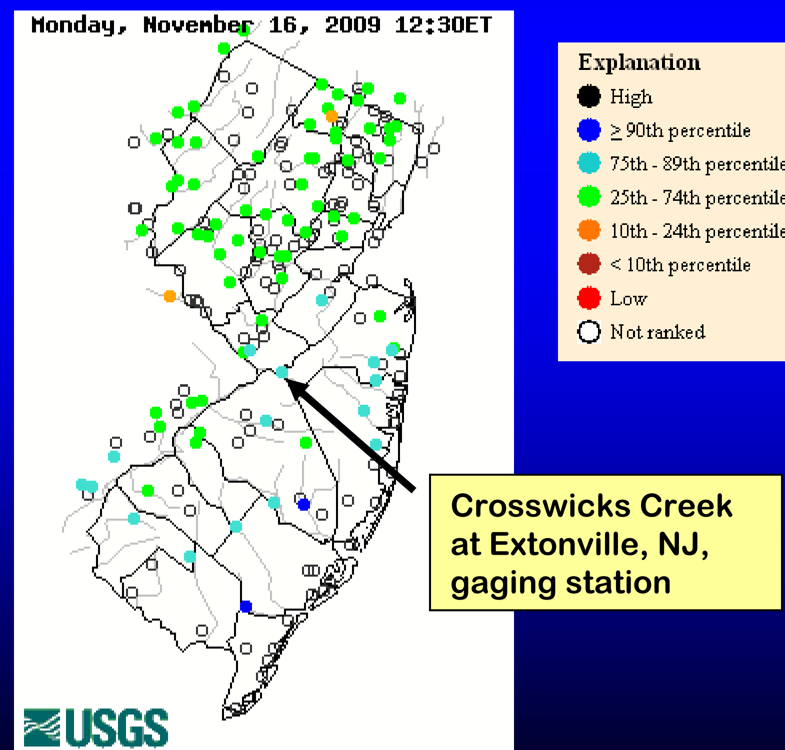



# Real-time Surface Water Data



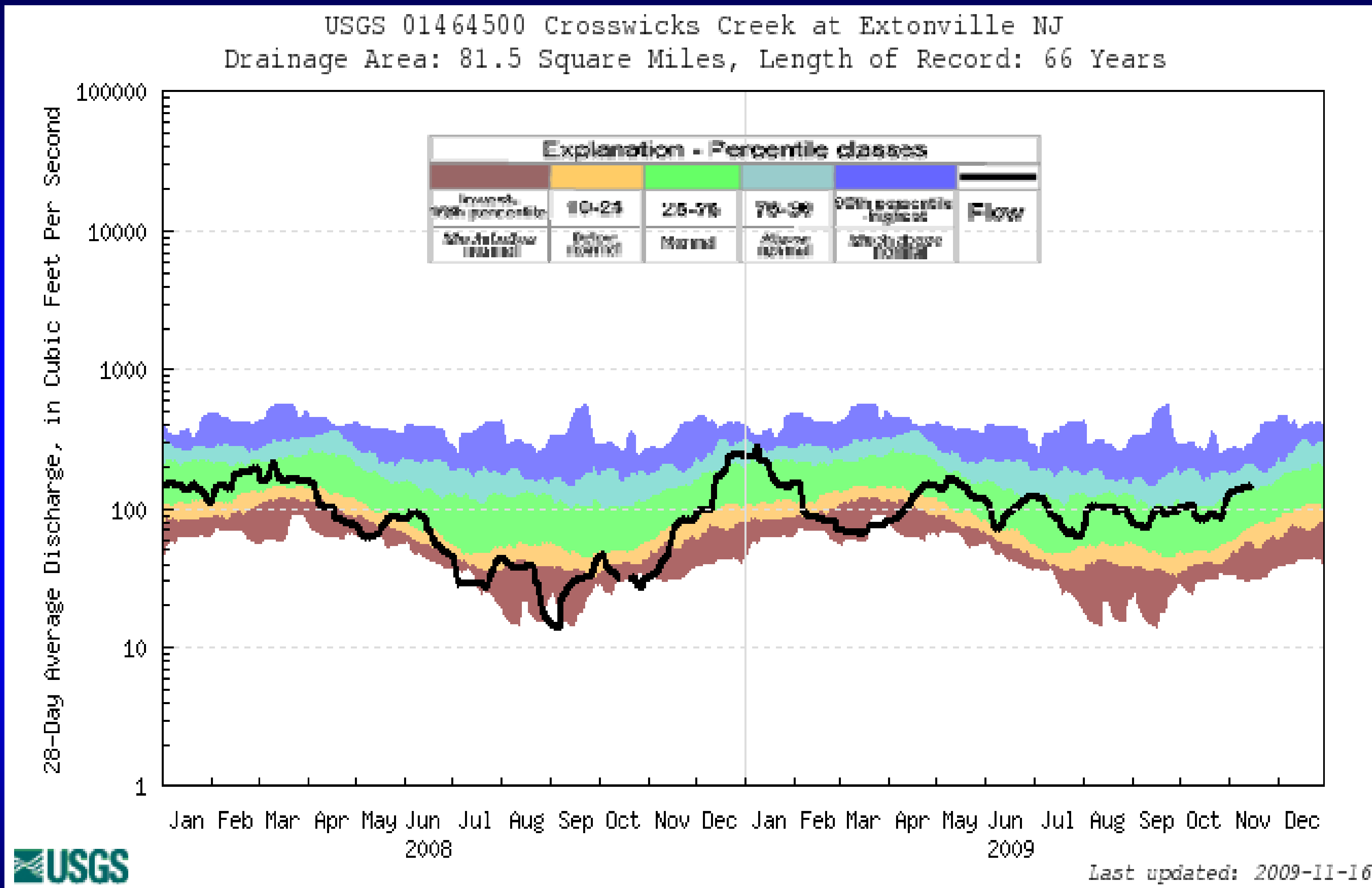

http://water.usgs.gov/water watch




http://nj.usgs.gov

# Real-time Comparison with Historical Data




**http://nj.usgs.gov/drought/duration.plots/**

# National Water Information System (NWIS WEB)

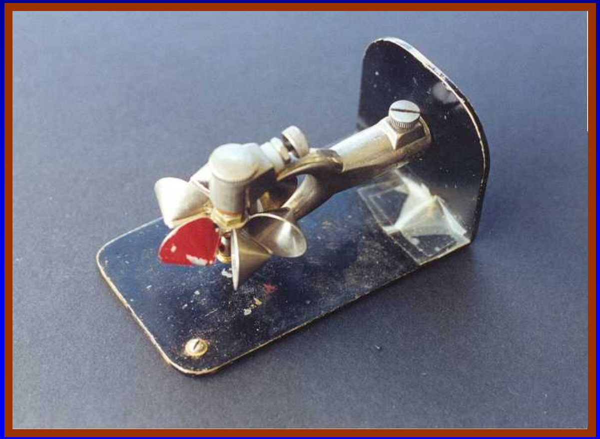
- Much of the hydrologic data collected by the USGS is available through the NWIS Web interface
- Surface water - Water flow and levels in streams, lakes, and springs ,
- Ground water - Water levels in wells
- Water quality data - Chemical and physical data for streams, lakes, springs, and wells
- http://waterdata.usgs.gov/nwis

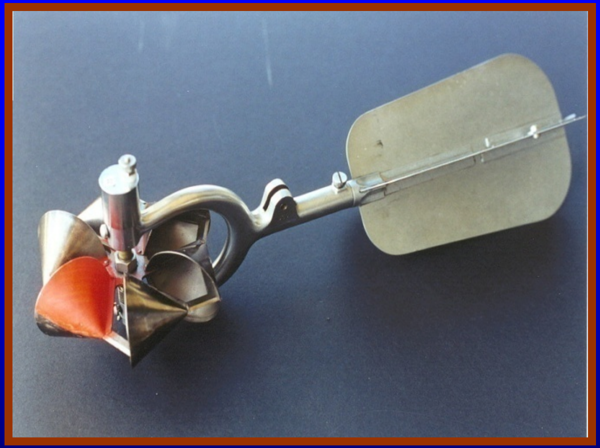
# Streamgaging
# Methods for measuring streamflow

- 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

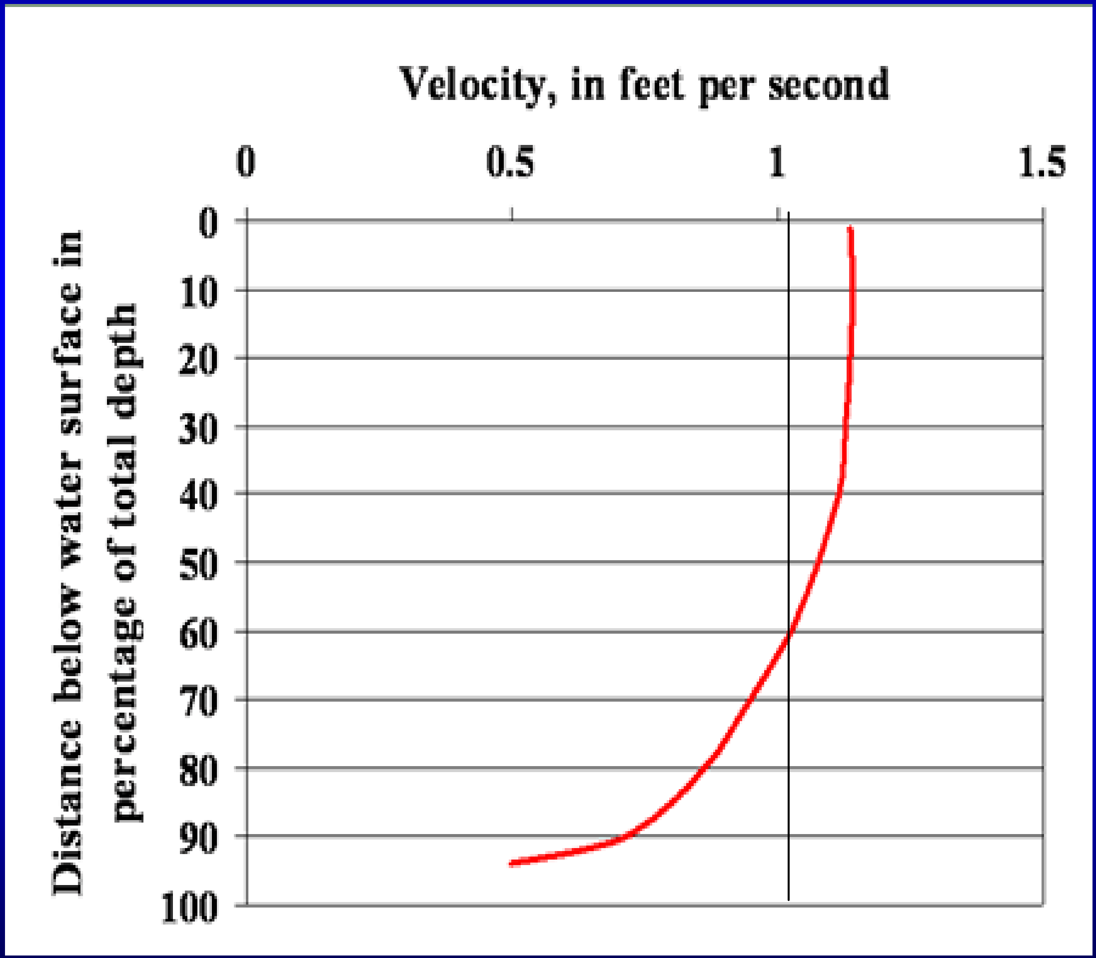




# Mechanical Velocity Meters

- Velocity is determined by placing meter in stream and counting number of revolutions in a measured amount of time, $\geq$ 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 x max. velocity < 10.

# Velocity Profile

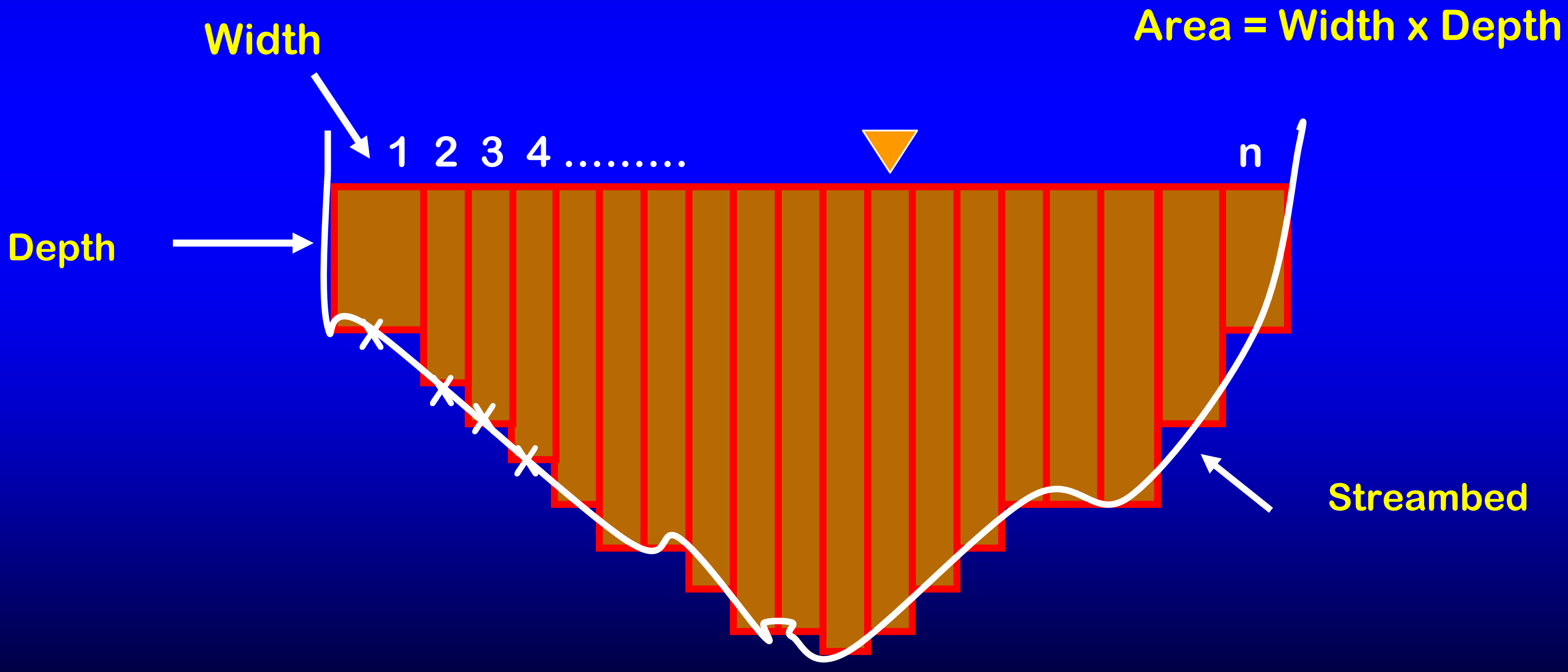



- Goal is to measure the average velocity in the vertical
  - Measured at 0.6 the depth when depths are <2.5'
  - Measured at 0.2 and 0.8 the depth when depths are > 2.5'
  - If abnormal flows Measure 0.2, 0.8 & 0.6
  - These velocities are averaged to represent average velocity in the vertical

# Velocity Area Method

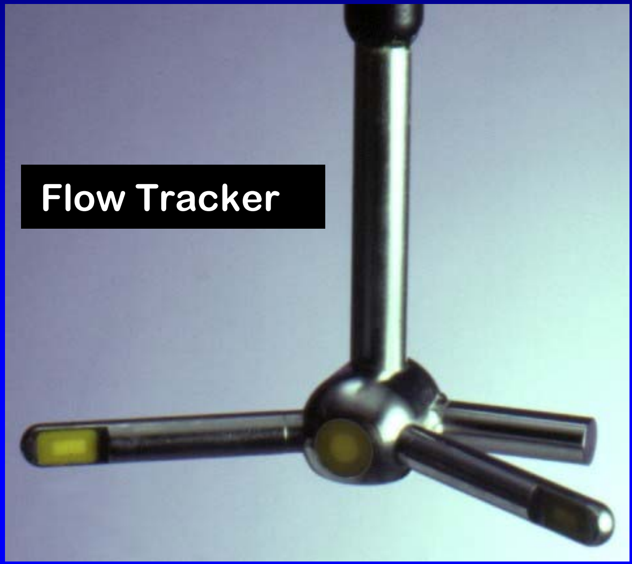
**Discharge = (Area of water in cross section) x (Water velocity)**

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

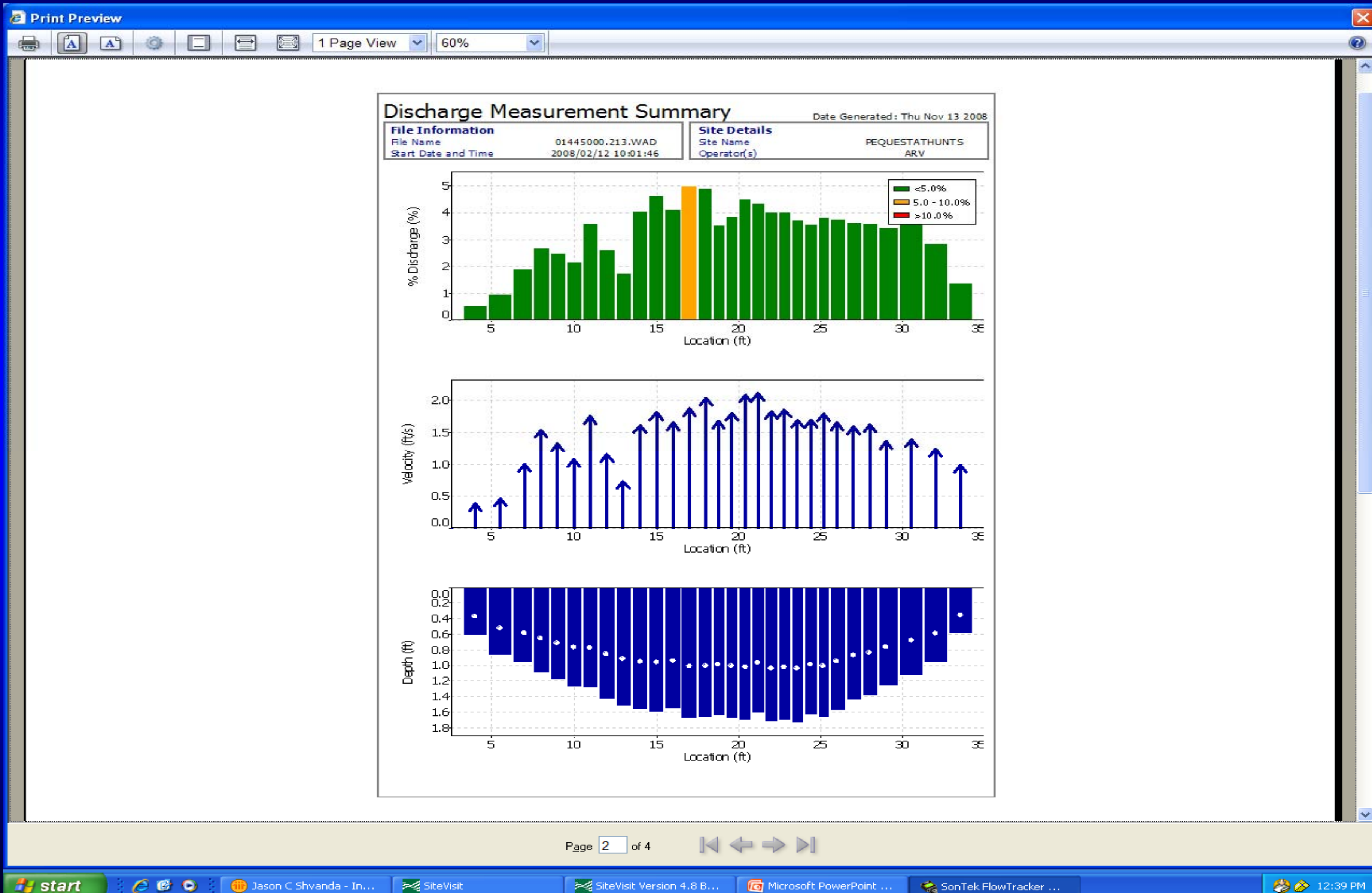


# Acoustic Doppler Velocimeter

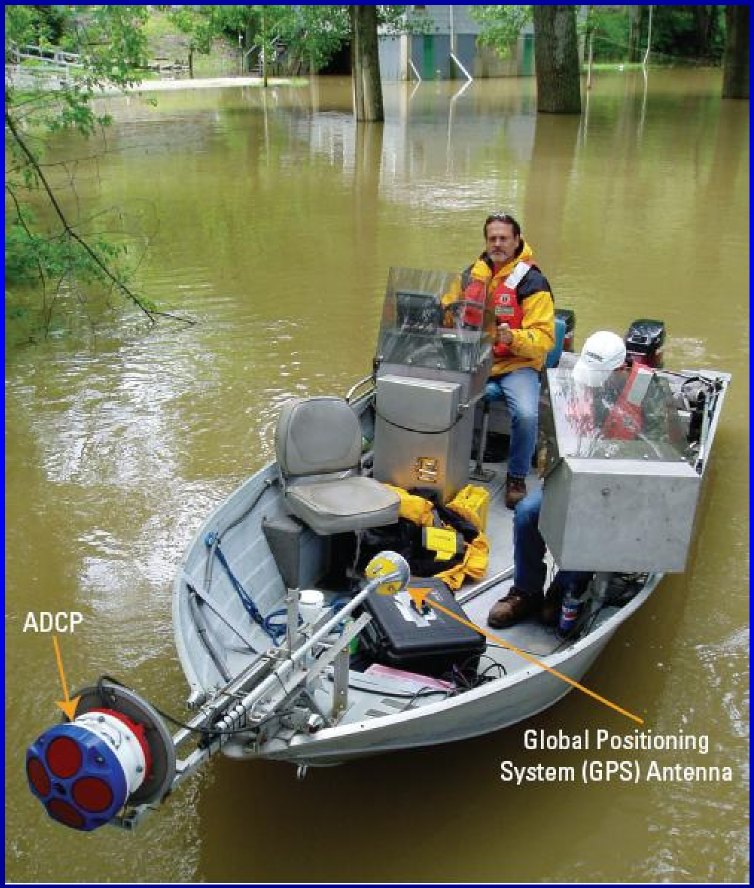
- Attaches to top setting wading rod (replaces mechanical meter)
- Velocities: 0.003 – 16 ft/sec
  - Resolution: 0.0003 ft/sec
  - Accuracy: ± 1%
  - Measured 4” from transmitter
- Depths: $\geq$ 1 inch
- Automatic discharge computation includes angles
- RS-232 interface




# Output From ADV Software



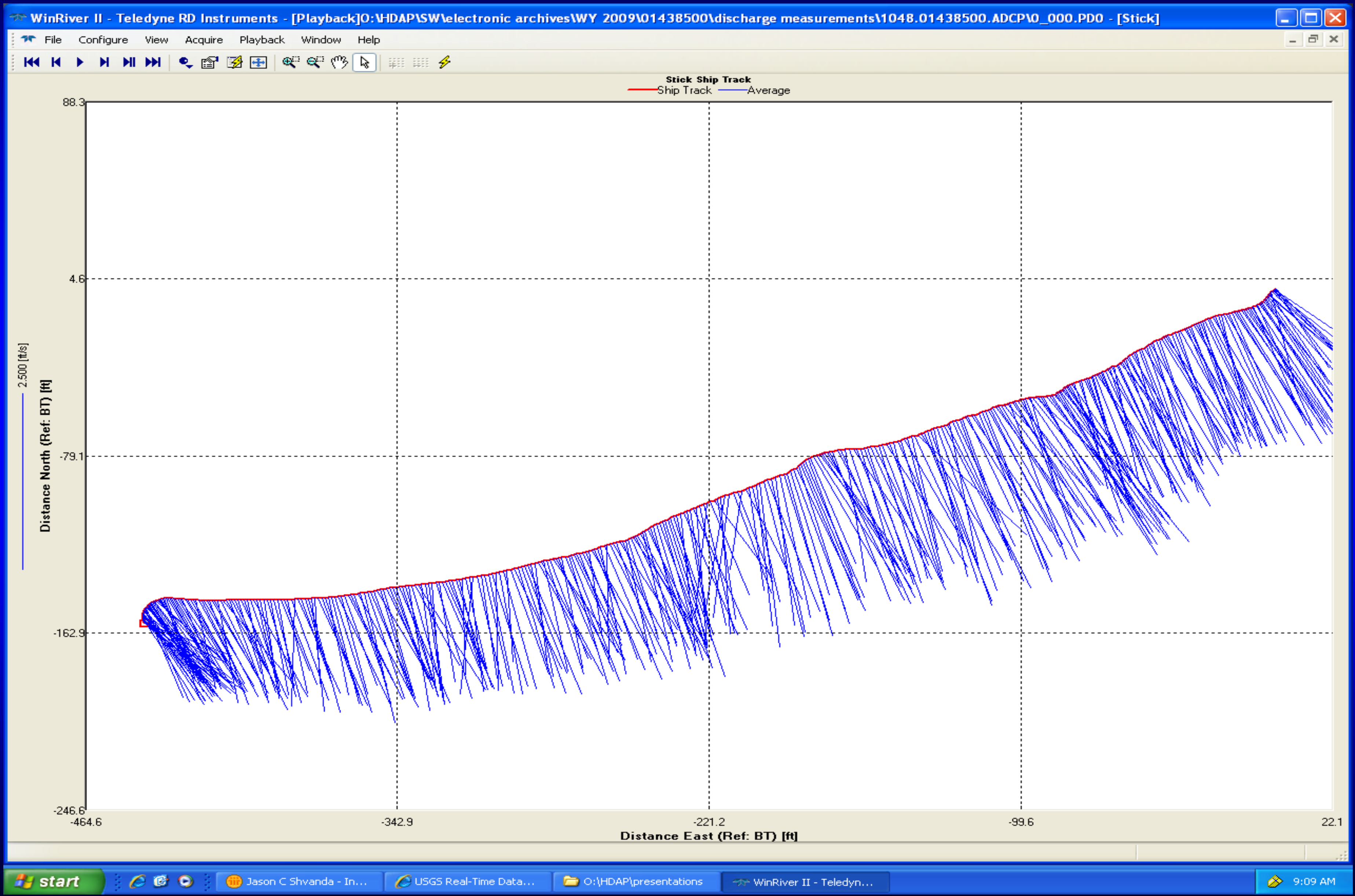
# Boat Mounted Acoustic Doppler Current Profilers





http://pubs.usgs.gov/of/2001/ofr0101/text.pdf

# Ship Track


WinRiver II - Teledyne RD Instruments - [Playback]O:\HDAP\SW\electronic archives\WY 2009\01438500\discharge measurements\1048.01438500.ADCP\0_000.PD0 - [Stick]
File Configure View Acquire Playback Window Help
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Ship Track
Average
88.3
4.6
-79.1
-162.9
-246.6
-464.6
-342.9
-221.2
-99.6
22.1
Distance East (Ref: BT) [ft]
Distance North (Ref: BT) [ft]
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Jason C Shvanda - In...
USGS Real-Time Data...
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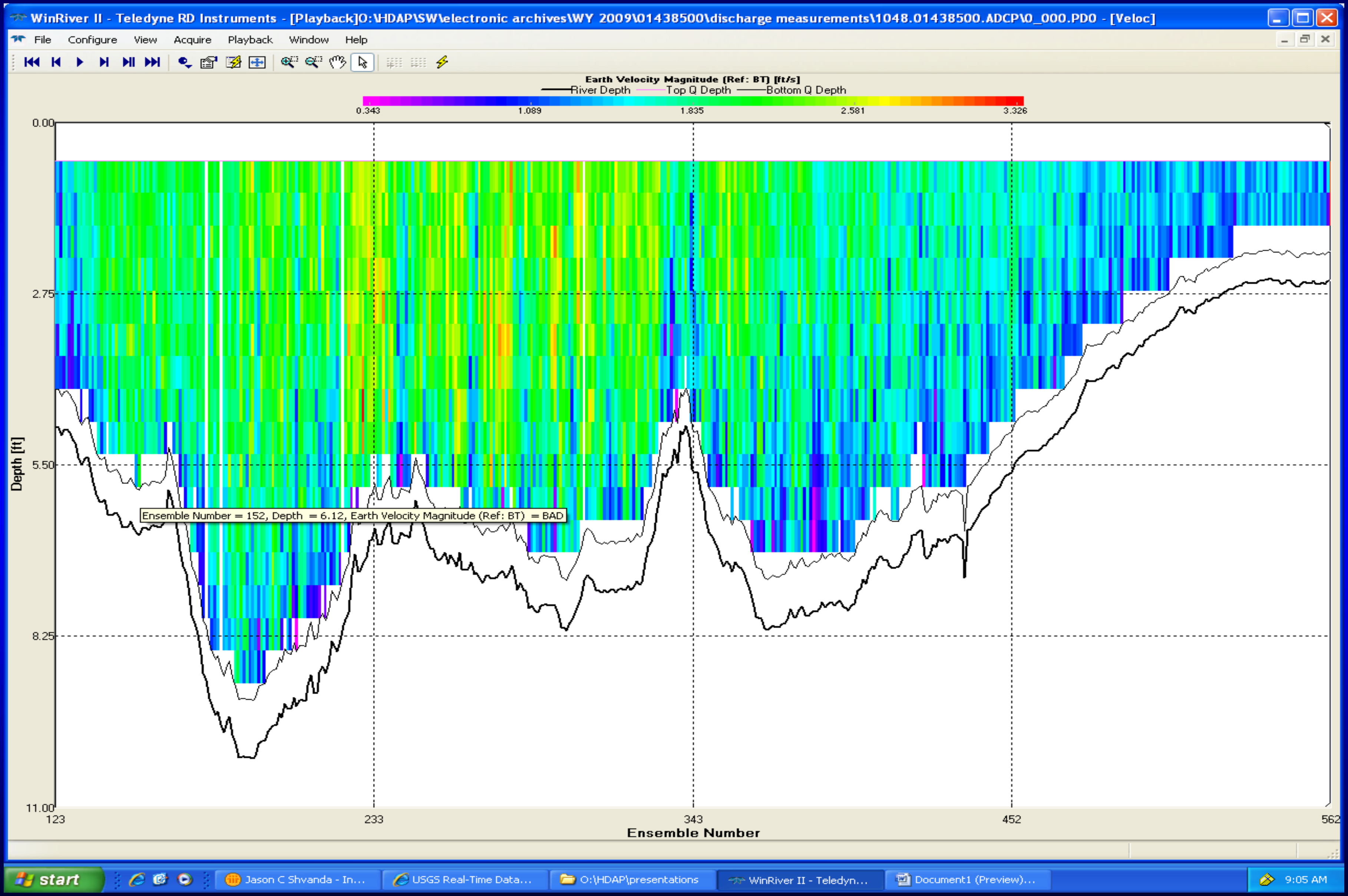
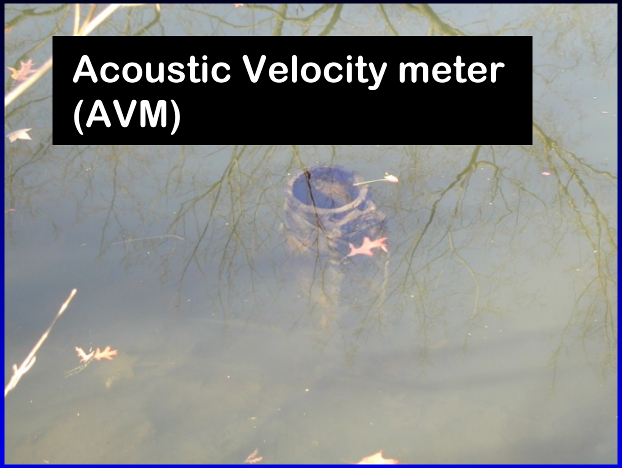
# Velocity Profile



# 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





# 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 then parshall flumes, at low-flow conditions
- Used when depths are too shallow and velocity 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 $\pm$ 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]

| Cross section | Flowtracker | Pygmy meter | Floatation Method | Culvert Computation | Percent Difference |
|---|---|---|---|---|---|
| Ideal cross section | 1.04 | 1.06 | 1.00 | - | 4 - 6% |
| Expansion reach (pool,very slow velocity) | 1.04 | * | - | - | - |
| Contracting reach (eddies) | 0.96 | 1.09 | - | - | 13% |
| Outlet of culvert(uneven, turbulent) | 0.80 | 0.92 | - | 1.3 | 62% |
| Percent difference between sections | 30% | 18.5% | | | |

# 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

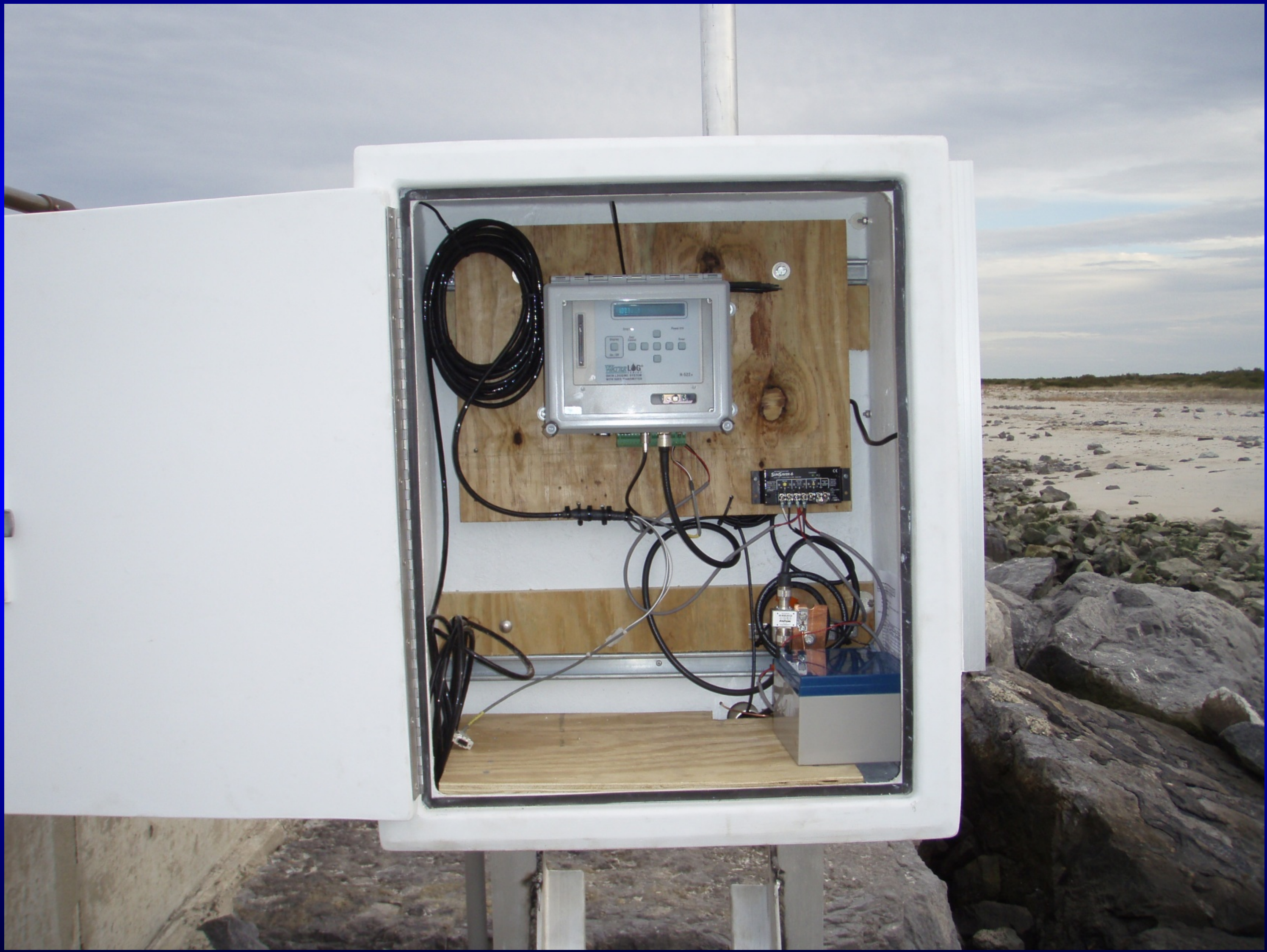



# Barnegat Bay Restoration Activity

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
    - http://pubs.usgs.gov/twri/
  - Water Supply Paper 2175 Measurement and computation of streamflow http://pubs.usgs.gov/wsp/wsp2175
  - Discharge measurements using a broadband Acoustic Doppler Current Profiler http://pubs.usgs.gov/of/2001/ofr0101/text.pdf
- **Water Resources Information for Students and Teachers http://water.usgs.gov/education.html**
- Equipment - Rickly Hydrological Company
  - www.rickly.com
  - Forestry Suppliers, Inc
  - 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
  - http://egsc.usgs.gov/isb/pubs/forms/educmat.pdf

# Resources Continued

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

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