Stream Discharge Monitoring Overview

Outline of Topics

Introduction & Basics Concepts

Field Monitoring

Data Processing

Summary & Additional Resources

What is stream discharge?

Stream discharge ("Q")

Volume of water passing a specific point in a certain amount of time

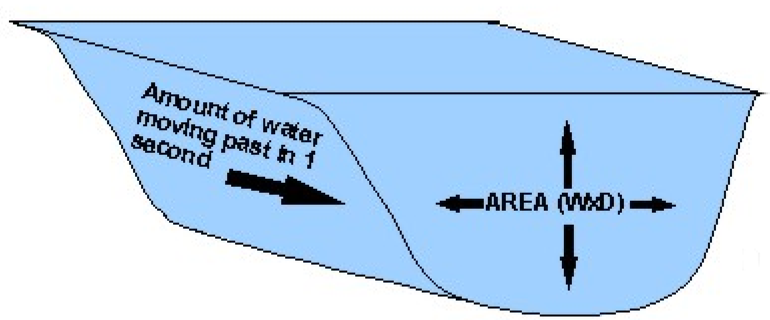


Image from: http://itc.gsw.edu/faculty/bcarter/physgeol/river/stream8.htm

Commonly expressed in cubic feet per second "cfs" or cubic meters per second

Velocity Distribution in a Channel

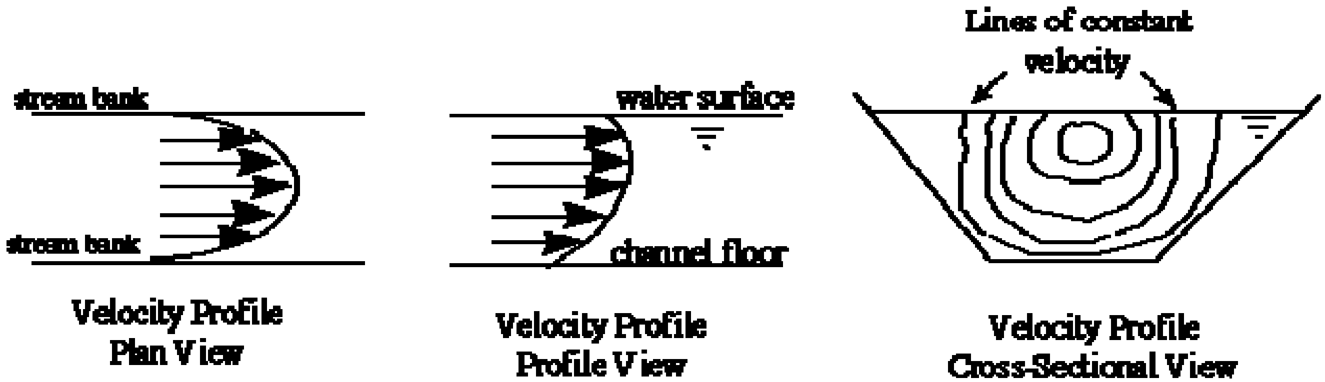


Image from: http://www.wvu.edu/~agexten/pubnwsltr/TRIM/5762.htm

$$Q = V \times A$$

Discharge = velocity x area

MARYLAND DEPARTMENT OF NATURAL RESOURCES

Why monitor stream discharge?

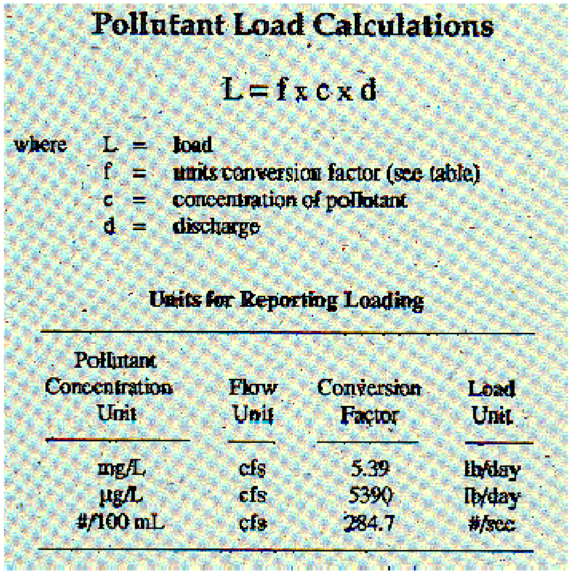
For Trust Fund projects,

to evaluate effectiveness of stream restoration

in reducing nutrient and sediment loads

Discharge used with concentrations

to estimate loads



Pollutant Load Calculations

$$L = f \times c \times d$$

where L = load
f = units conversion factor (see table)
c = concentration of pollutant
d = discharge

Units for Reporting Loading

Pollutant Concentration Unit	Flow Unit	Conversion Factor	Load Unit
mg/L	cfs	5.39	lb/day
µg/L	cfs	5390	lb/day
#/100 mL	cfs	284.7	#/sec

Image from http://www.ecy.wa.gov/

Discharge Monitoring Challenge
for Trust Fund Projects

Difficult to measure flow in very small streams;

so quantifying nutrient and sediment loads is difficult

When should stream discharge be monitored?

Timing / Duration

BEFORE (early enough to establish pre-restoration baseline),

DURING (if feasible, to monitor restoration implementation)

AFTER (long enough to reach stabilization/ to assess performance)

Frequency

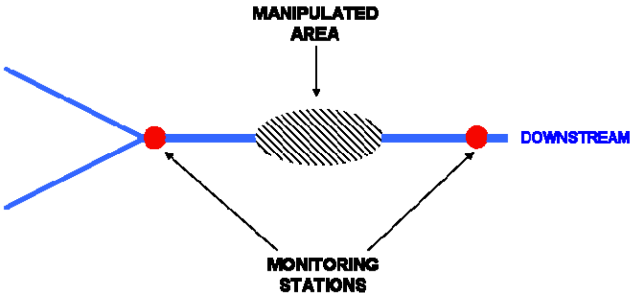
Often enough to capture seasonal variations as well as storm and non-storm flows

Where should stream discharge be monitored?

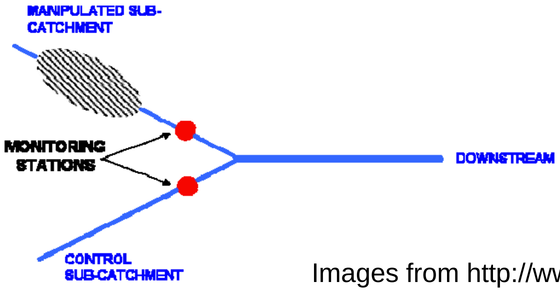
Locating stations for streamflow measurement

Factors related to restoration assessment:

- Upstream of restoration ("Control")
- Downstream of restoration ("Impact")
- Coordinated with water quality sampling



Reference site – nearby comparable reach, not restored



Images from http://www.avondtc.org.uk/

Where should stream discharge be monitored?

Factors related to streamflow measurement

Accessible site – safe and easy to reach; landowner permissions

Section with good physical characteristics, such as:

- Uniform flow – straight channel segment;
  free of eddies, turbulence, slack water
- Uniform stream bed - (no boulders, logs etc.)
- Streambanks fairly high and stable (to contain max flow);
  relatively free of brush
- Free of tidal or side tributary effects

How is stream discharge monitored?

Direct methods

Team measures discharge in field

Indirect methods

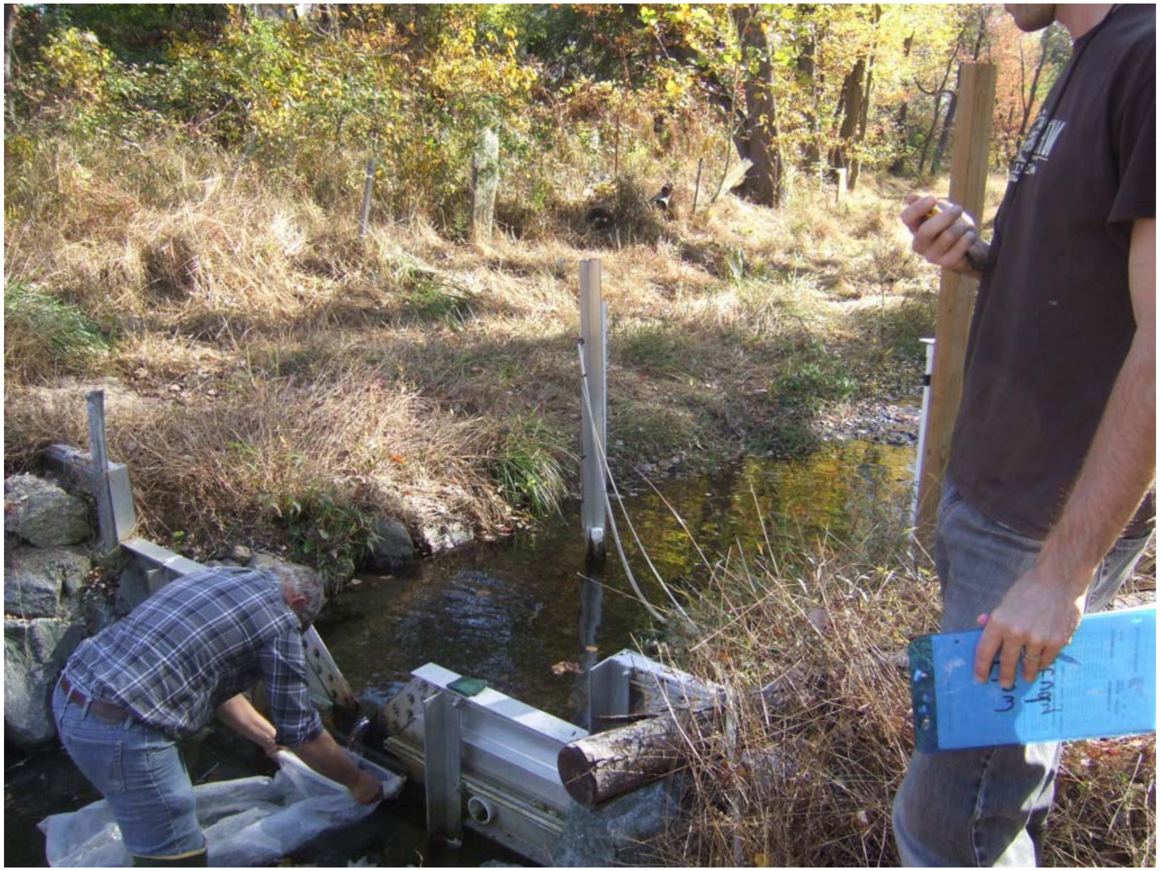
Relate stream water level to discharge

Use water level measurements
to estimate discharge

Direct Methods include:

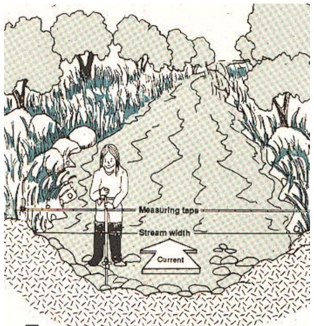
Volumetric –

volume (or weight converted to volume) and time

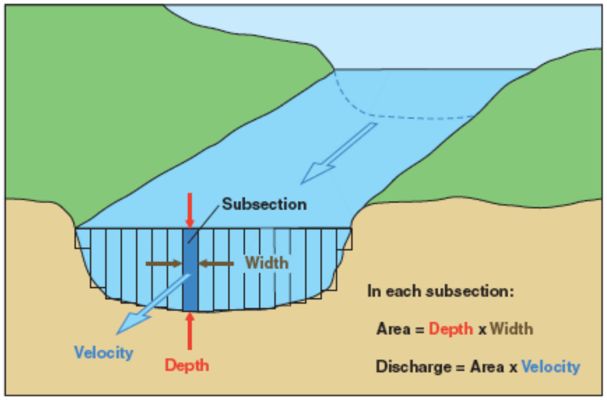


Direct Methods include:

Velocity (e.g., flowmeter) and cross section area



From www.ecy.wa.gov



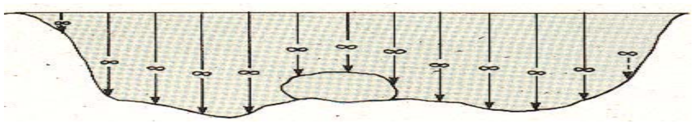
https://water.usgs.gov/edu/streamflow2.html

Number of subsections varies with the width

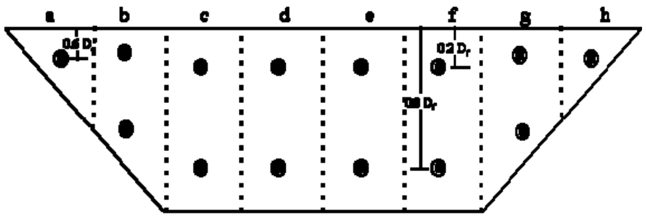
Sensor depth differs with stream depths:

≤ 2.5 ft one point at 60% depth

> 2.5 ft two point average at 20% & 80% depth



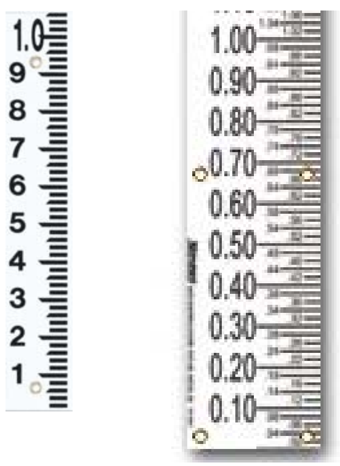
Modified from www.ecy.wa.gov



From www.wvu.edu

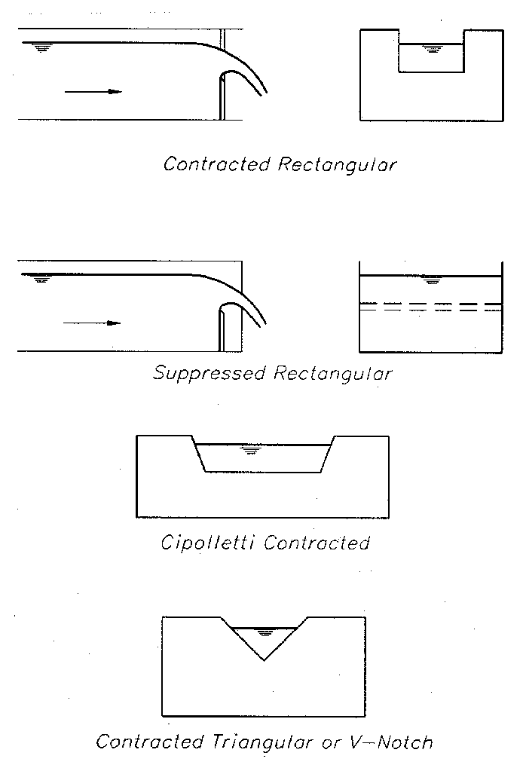
Indirect Methods include:

Staff gages



Pressure transducers

Weirs



From www.inmtn.com

Stream Monitoring Station

example of station set up

staff gage

use of weir or constriction

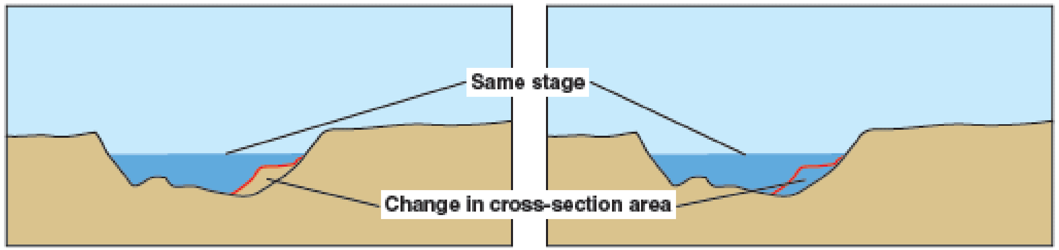
pressure transducer (inside pvc pipe)

How is stream discharge monitored?

Survey stations initially and periodically

- Various measuring points
- Channel sections

Example: same stage but different discharge

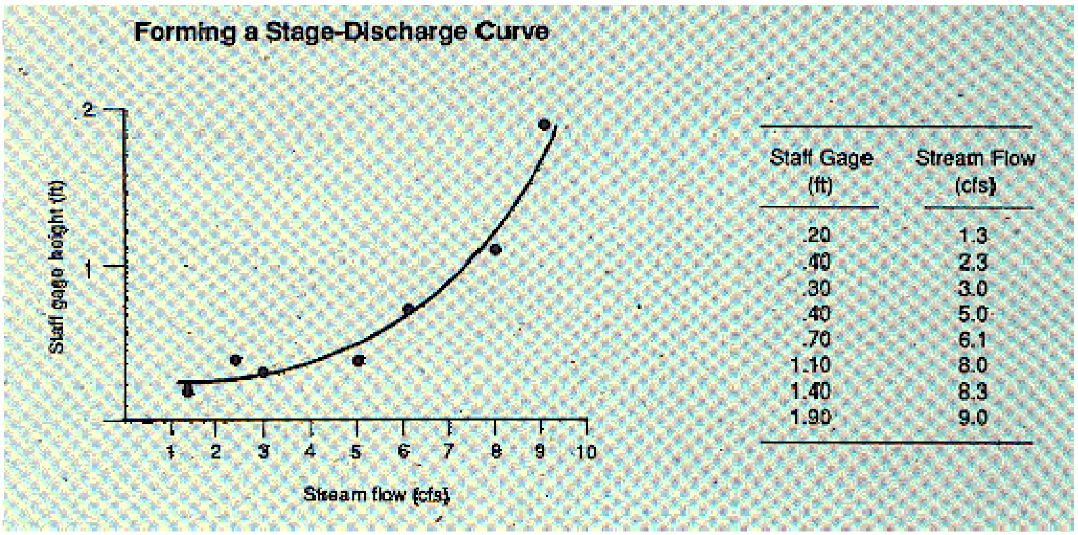


https://water.usgs.gov/edu/streamflow3.html

How is stream discharge monitored?

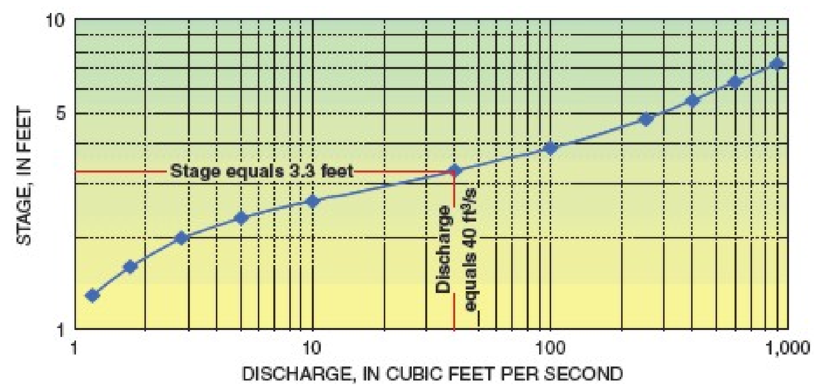
Relate water level (stage) to discharge

Examples



Staff Gage (ft)	Stream Flow (cfs)
.20	1.3
.40	2.3
.30	3.0
.40	5.0
.70	6.1
1.10	8.0
1.40	8.3
1.90	9.0

Image from
http://www.ecy.wa.gov/programs/wq/plants/management/joysmanual/5stage.html



https://water.usgs.gov/edu/streamflow3.html

Stream Discharge Monitoring Field Measurements

- Routine site visits- Twice monthly
- Storm event site visits

- Responsibilities

  -Discharge measurements

  -Datalogger data download

  -Record staff and crest gage height

“Bag Method”

- Discharge = cu ft. /sec
- 1 lb H2O = 0.016 cu ft.
- Limitations-
  -Must have weir
  -Baseflow only

"Bag Method"

Trust Fund Discharge/Download Data Sheet

Site: RHT0002 Date: 04 15 15 (m m d d y y) Scientist: THH Signoff: LJF

Flowmeter Ser. # / Cal. Date: ___ / ___

Initial Zero Reading: __.___ ft/s Zeroed? (yes, no, n/a) ___

Solinst Water Sensor # 1052907 Baro. Sensor # 1053136

Location of flow measurement at V notch

Crest Gage, if present Height: 6 3/8 in. Time: 0758 (EST, military)

Comments (weir condition, debris, ice, etc): notch clear

Staff Gage Height

Flow Measurement Gage Height Pre: 0.26 ft Post: 0.26 ft

Time (EST, military) 0743 0753

Sensor Removal/Re-deployment Gage Height Pre: 0.26 ft Post: 0.26 ft

Time (EST, military) 0754 0803

Download Filenames

Barometer File (.csv): RHT0006-baro_2015_04_15.csv

Water Sensor File (.csv): RHT0002_2015_04_15_compensated.csv

Time offset on sensor versus computer: No

Synchronized time to computer (restart on 5 min. interval): Yes

Discharge Measurement

Flowmeter Method: L or R indicates LEW or REW, Facing downstream starting at LEW

Location (ft)	Depth (ft)	Velocity (ft/s)	L/R	Location (ft)	Depth (ft)	Velocity (ft/s)	L/R

Bucket Method (3 trials):

Time (sec)

6.50 6.94 6.87

Weight (lbs.) / Volume (liters) **circle one**

37.31 40.57 39.38

Float Method: Distance used: __.___ ft

Depths (ft) @ Long. Loc. — Lateral Location: 1/3, Mid, 2/3

Upstream

Middle

Downstream

Time (sec) 5 trials:

37.31 lb / 6.50 sec = 5.74 lb/sec

40.57 lb / 6.94 sec = 5.85 lb/sec

39.38 lb / 6.87 sec = 5.73 lb/sec

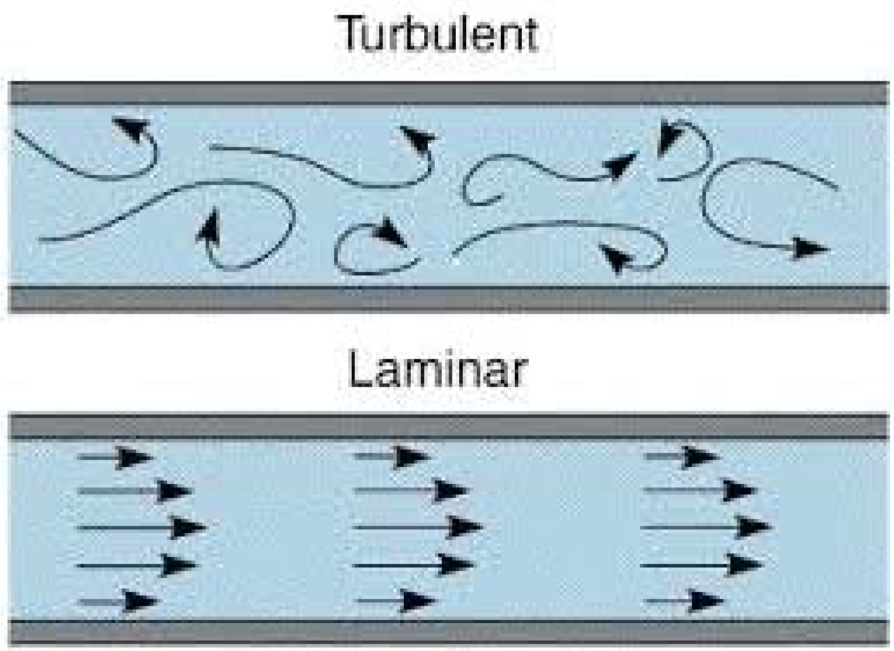
Average = 5.77 lb/sec

1 lb H2O = 0.016 cu ft.

5.77 lb/sec x 0.016 = 0.09 cu ft./sec

“Midsection Method”

“Midsection Method”

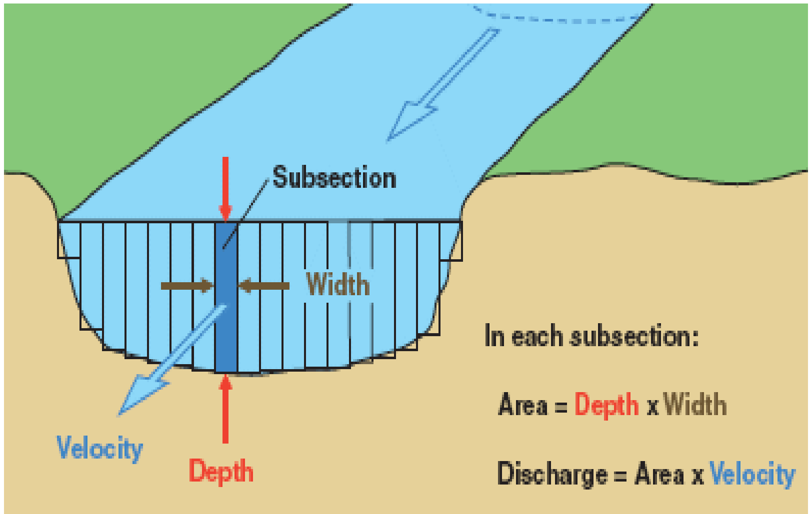


www.b17queenofthesky.com

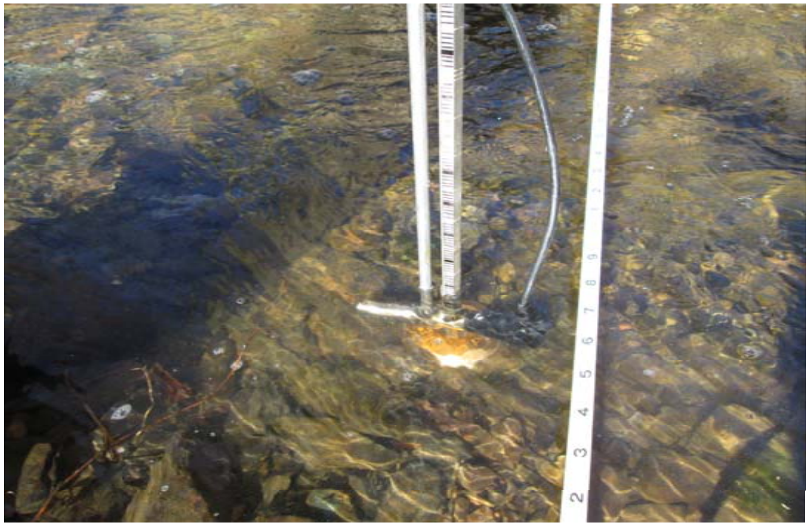
MARYLAND DEPARTMENT OF NATURAL RESOURCES

“Midsection Method”

- Storm event/ high flow
- Wier not present
- Discharge = velocity x cross sectional area
- Total Discharge = Sum of 25 cross-sectional discharge measurements
- Limitations
  - -High Flow- sum of 10
  - -Low Flow- cant submerge sensor



https://water.usgs.gov/edu/streamflow2.html



"Midsection Method"

Discharge Measurement

Flowmeter Method: L or R indicates LEW or REW, Facing downstream starting at LEW

Location (ft)	Depth (ft)	Velocity (ft/s)	L/R	Location (ft)	Depth (ft)	Velocity (ft/s)	L/R
2.60	0.00	0.00	L	5.10	0.48	0.38	
2.70	0.20	-0.16		5.30	0.46	0.33	
2.90	0.25	-0.15		5.50	0.50	0.32	
3.10	0.31	-0.13		5.70	0.47	0.41	
3.30	0.34	-0.08		5.90	0.44	0.43	
3.50	0.36	0.10		6.10	0.41	0.43	
3.70	0.37	0.28		6.30	0.40	0.38	
3.90	0.31	0.36		6.50	0.27	0.40	
4.10	0.34	0.43		6.70	0.19	0.29	
4.30	0.34	0.52		6.90	0.18	0.24	
4.50	0.32	0.59		7.10	0.20	0.11	
4.70	0.39	0.54		7.90	0.00	0.00	R
4.90	0.42	0.51		.	.	.	

- Total Discharge = Sum of 25 cross-sectional discharge measurements

Stream Discharge Monitoring

- Measure discharge in stretches of good laminar flow
- Staff gage
  -nearby in stable pool
- Staff gage level is recorded each time discharge is measured
- Develop relationship between staff gage height and discharge = Stage Discharge Curve

Stream Discharge Monitoring

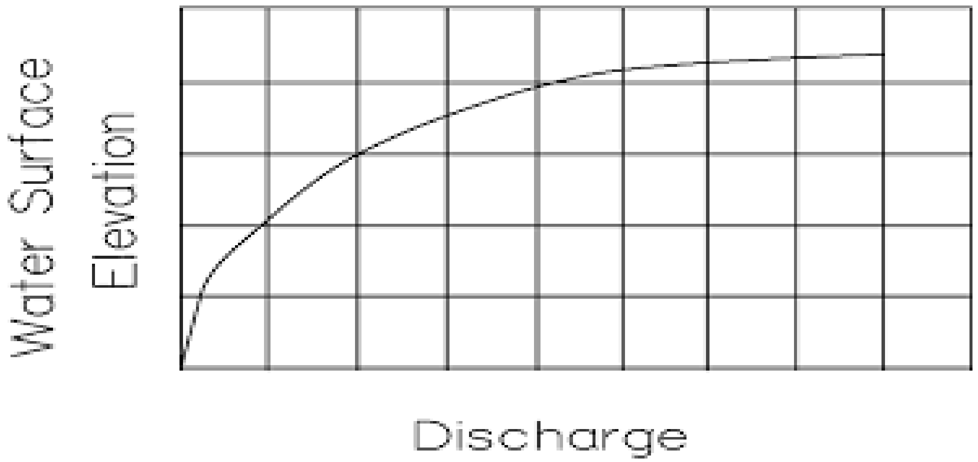


Image from: onlinemanuals.txdot.gov

- Stage discharge curve allows future discharge prediction from simple staff gage reading

- Site visit twice monthly plus rain events

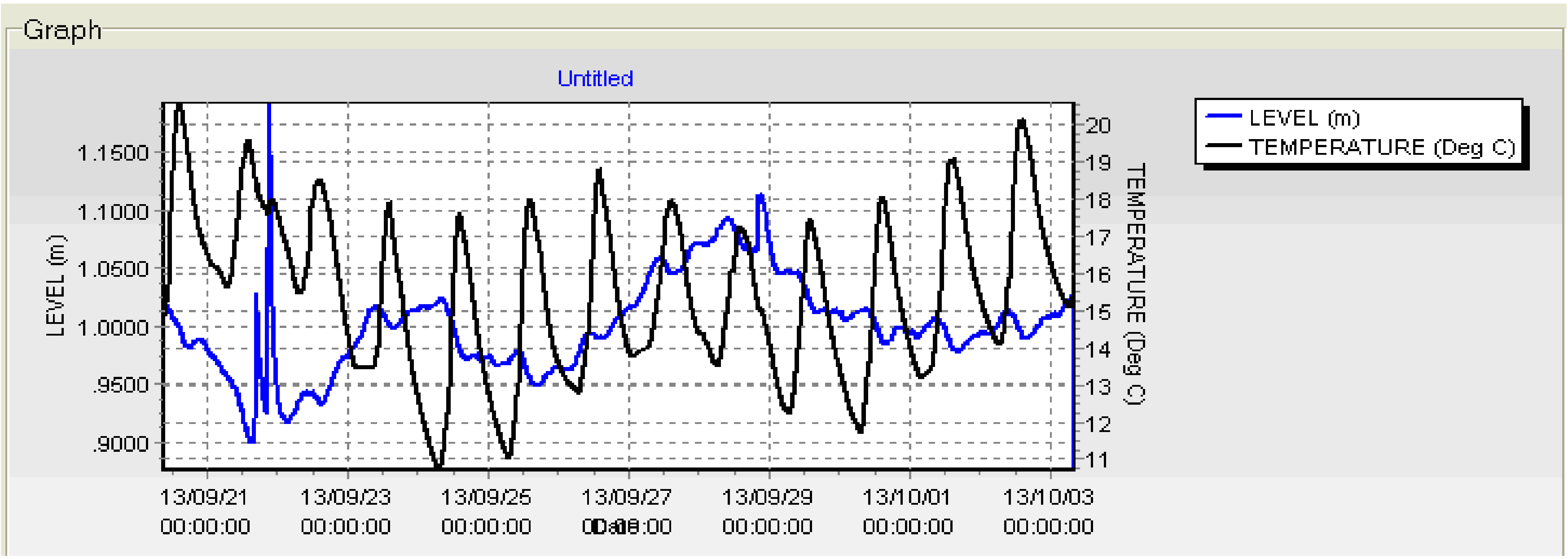
- How can we monitor discharge 24/7?

Stream Discharge Monitoring

MARYLAND DEPARTMENT OF NATURAL RESOURCES

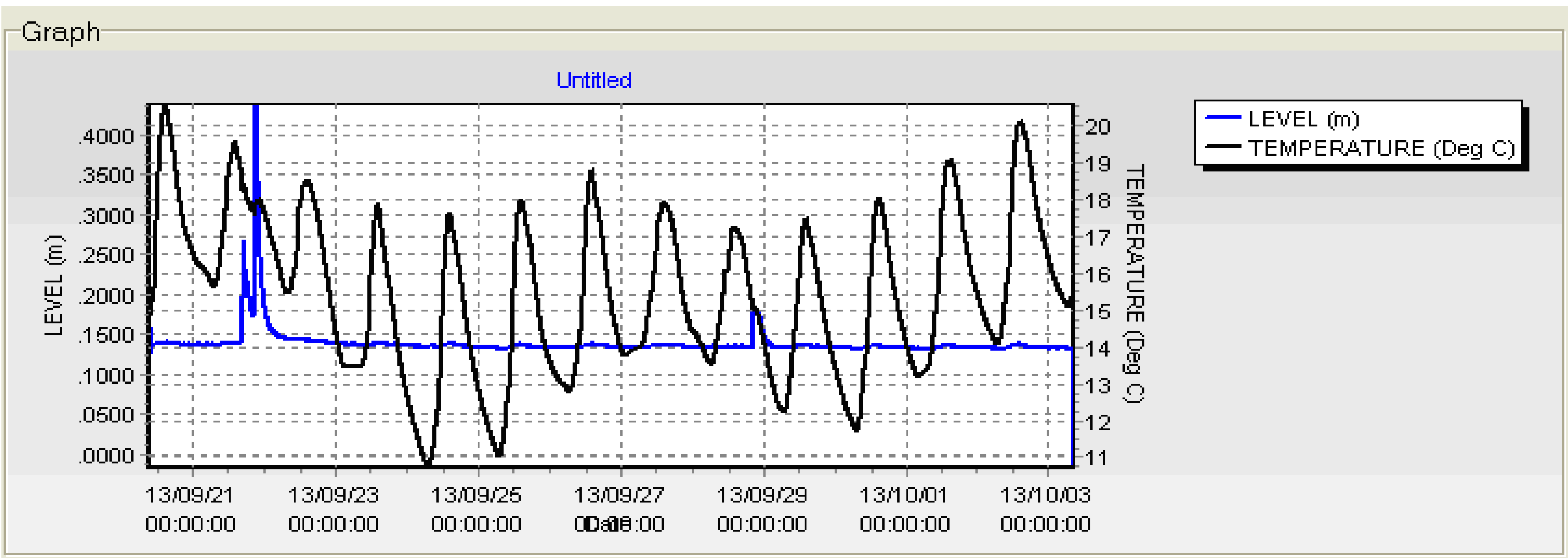
Stream Discharge Monitoring

- Solinst Levelloggers
  - -Pressure logged at 5 minute intervals
  - -Pressures automatically converted to water levels
  - -Loggers exposed to total pressure- water pressure plus atmospheric pressure



Stream Discharge Monitoring

- Barologgers in nearby floodplain log barometric pressure at 5 minute intervals
- Solinst software compensate Levellogger dataset using Barologger dataset
- Compensated dataset displays water levels at 5 minute intervals



MARYLAND DEPARTMENT OF NATURAL RESOURCES

Stream Discharge Monitoring

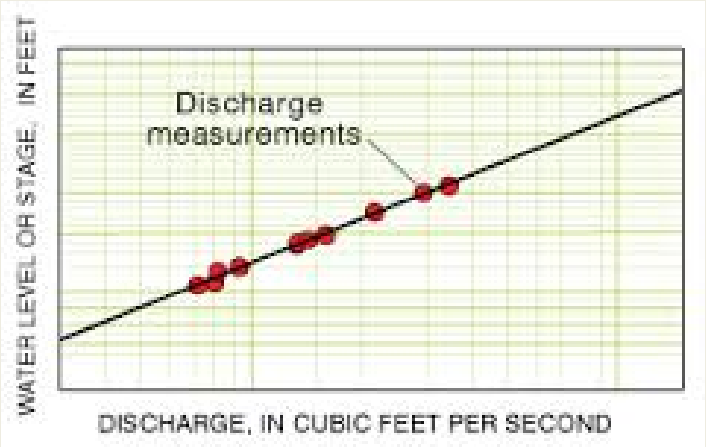
- Continuously monitored water levels
- Combined with a previously generated flow rating curve
- Discharge predictions at 5 minute intervals year round

Field Discharge Monitoring

Field Discharge Monitoring

Field Discharge Monitoring

Calculating discharge from field measurements



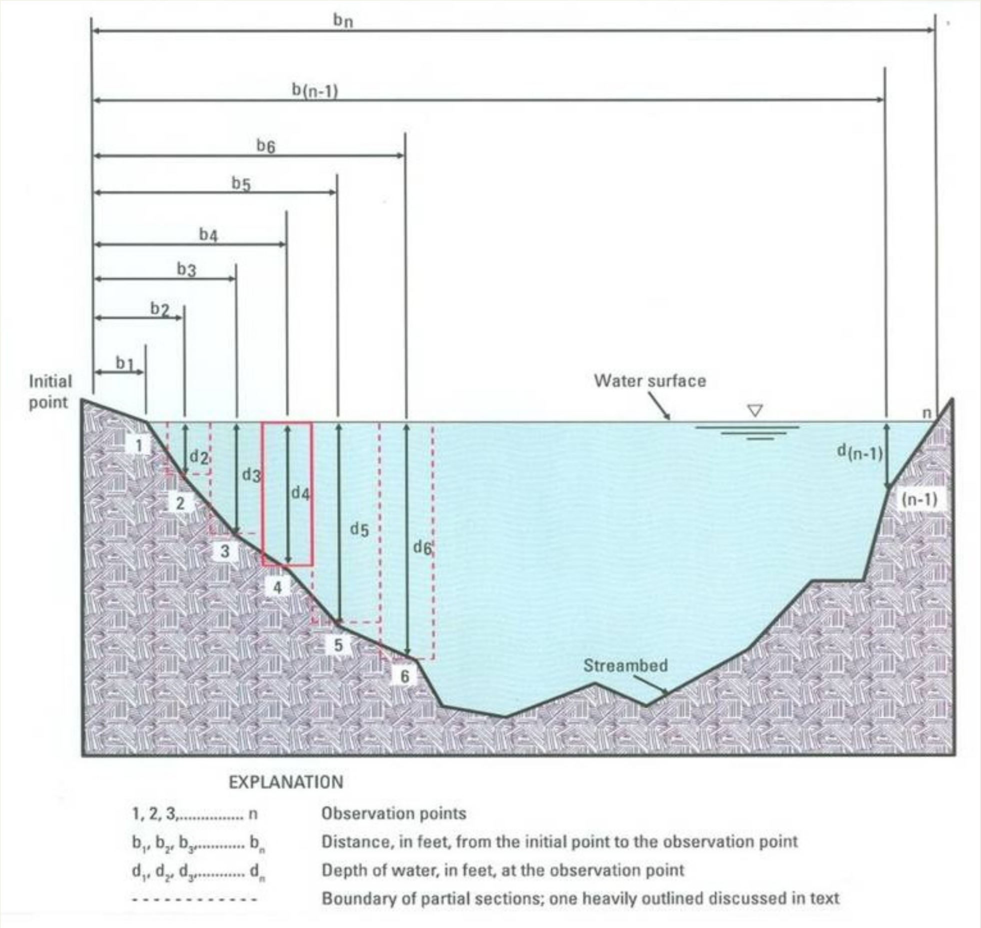
Bill Romano

MD Department of Natural Resources

Trust Fund Training Meeting

13 May 2015

Midsection method



From: Discharge Measurements at Gaging Stations, Chapter 8 of Book 3, Section A, by D. Phil Turnipseed and Vernon B. Sauer. *http://pubs.usgs.gov/tm/tm3-a8/*

Discharge through a stream section

- The mean velocity in each vertical, v_1, v_2, v_3,…, v_n, represents the mean velocity in that partial rectangular area (feet per second)
- The cross-section area for each segment extends laterally from half the distance from the preceding vertical to half the distance to the next one, and from the water surface to the bottom, d_1, d_2, d_3,…, d_n (feet squared)

Partial section discharge equation

$$q_i = v_i \left[\frac{b(i+1) - b(i-1)}{2}\right] d_i$$

where q_i discharge through partial section i,

v_i mean velocity at location i,

b_i distance from initial point to location i,

$b_{(i-1)}$ distance from initial point to preceding location,

$b_{(i+1)}$ distance from initial point to next location, and

d_i depth of water at location i

From: Discharge measurements at gaging stations

For example

- Discharge at partial section 4 would be
- $q_4 = v_4 \left[\frac{b_5 - b_3}{2}\right] d_4$
- Discharge at cross section ends would be
- $q_n = vn \left[\frac{b_n - b\,(n-1)}{2}\right] d_n$
- Total discharge is the sum of the partial section discharges

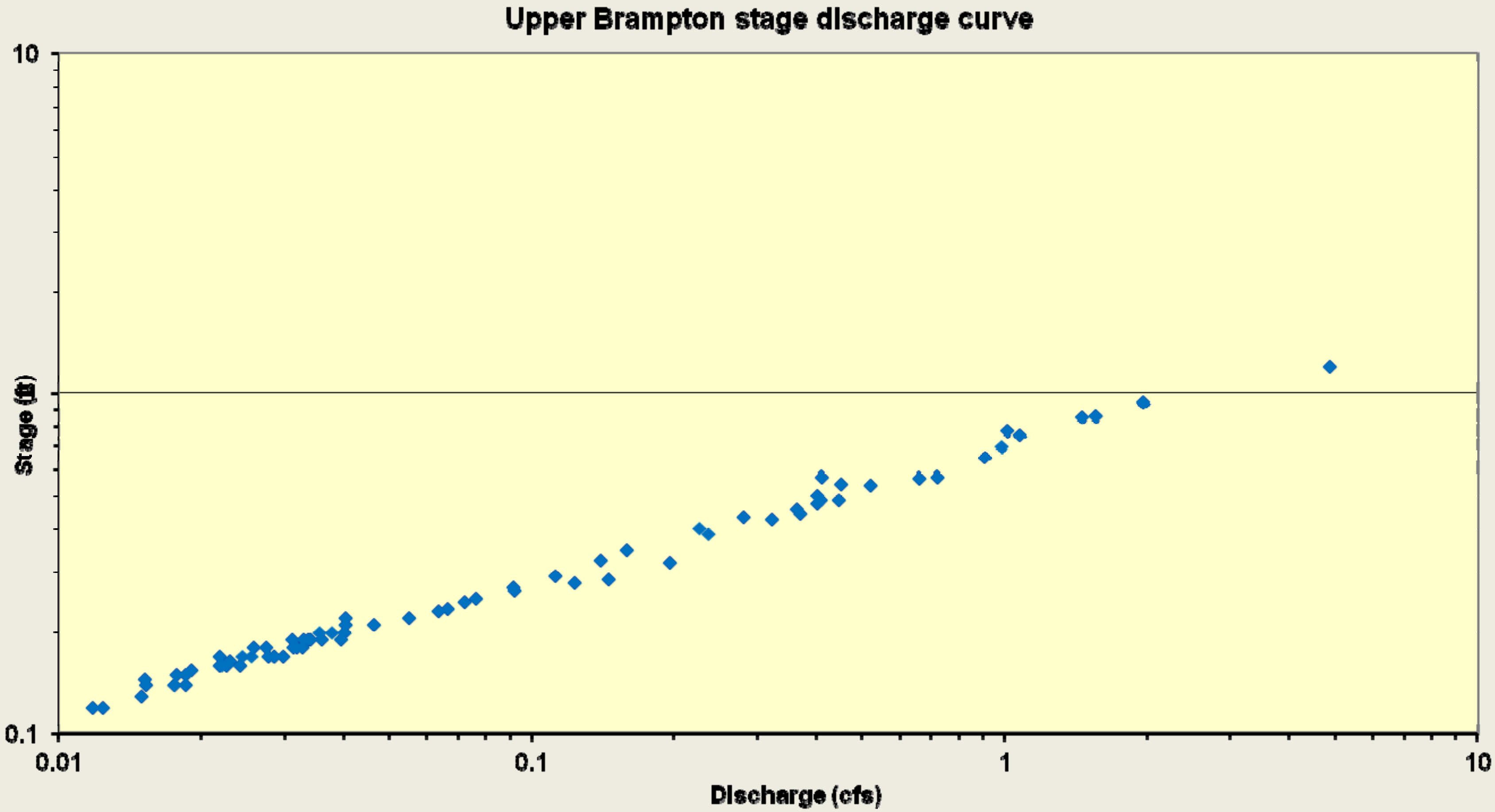
MARYLAND DEPARTMENT OF NATURAL RESOURCES

Field data

Distance (ft)	Depth (ft)	Velocity (fps)	Width (ft)	Q (cfs)
2.1	0	0	0.05	0
2.2	0.65	0.02	0.2	0.0026
2.5	0.65	0.02	0.3	0.0039
2.8	0.65	0.06	0.3	0.0117
3.1	0.6	0.13	0.3	0.0234
3.4	0.6	0.18	0.3	0.0324
3.7	0.62	0.23	0.3	0.0428
4	0.63	0.28	0.3	0.0529
4.3	0.55	0.26	0.3	0.0429
4.6	0.41	0.09	0.2	0.0074
4.7	0.39	0.07	0.15	0.0041
4.9	0.39	0.03	0.15	0.0018
5	0	0	0.05	0
Average	0.4723	0.1054	Sum	0.2259

MARYLAND DEPARTMENT OF NATURAL RESOURCES

Weir data

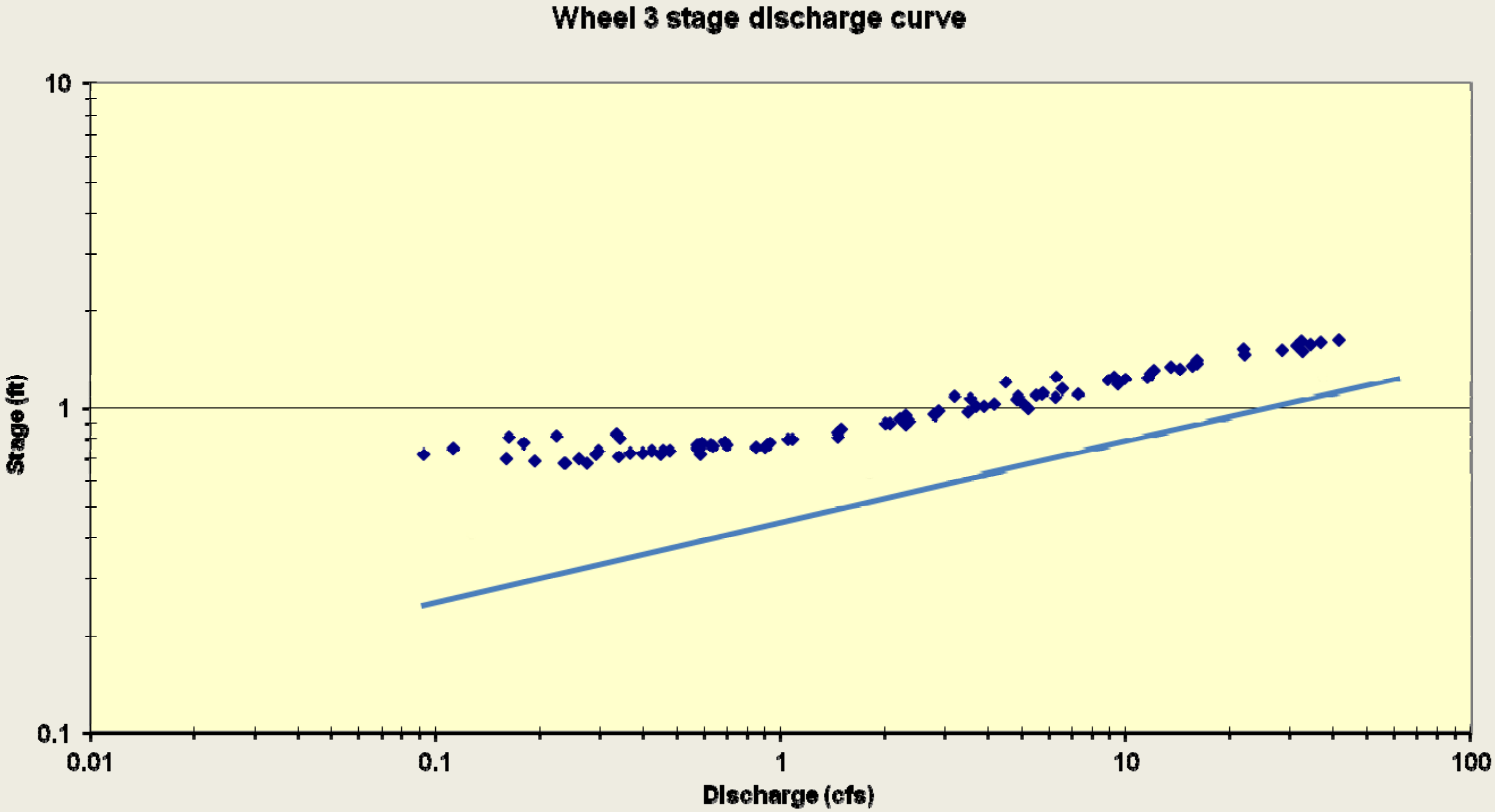

Upper Brampton stage discharge curve
10
1
0.1
Stage (ft)
0.01
0.1
1
10
Discharge (cfs)

Going from level logger to flow

- We use the measured staff plate readings and discharge data to develop a stage-discharge curve (rating) for each site
- The axes are reversed to develop an equation that predicts flow
- The weir data in the previous slide were best modeled using a log-log transformation
- You may have to account for back transformation bias when the dependent variable is log transformed

Natural control features can present challenges

Rating for a natural control

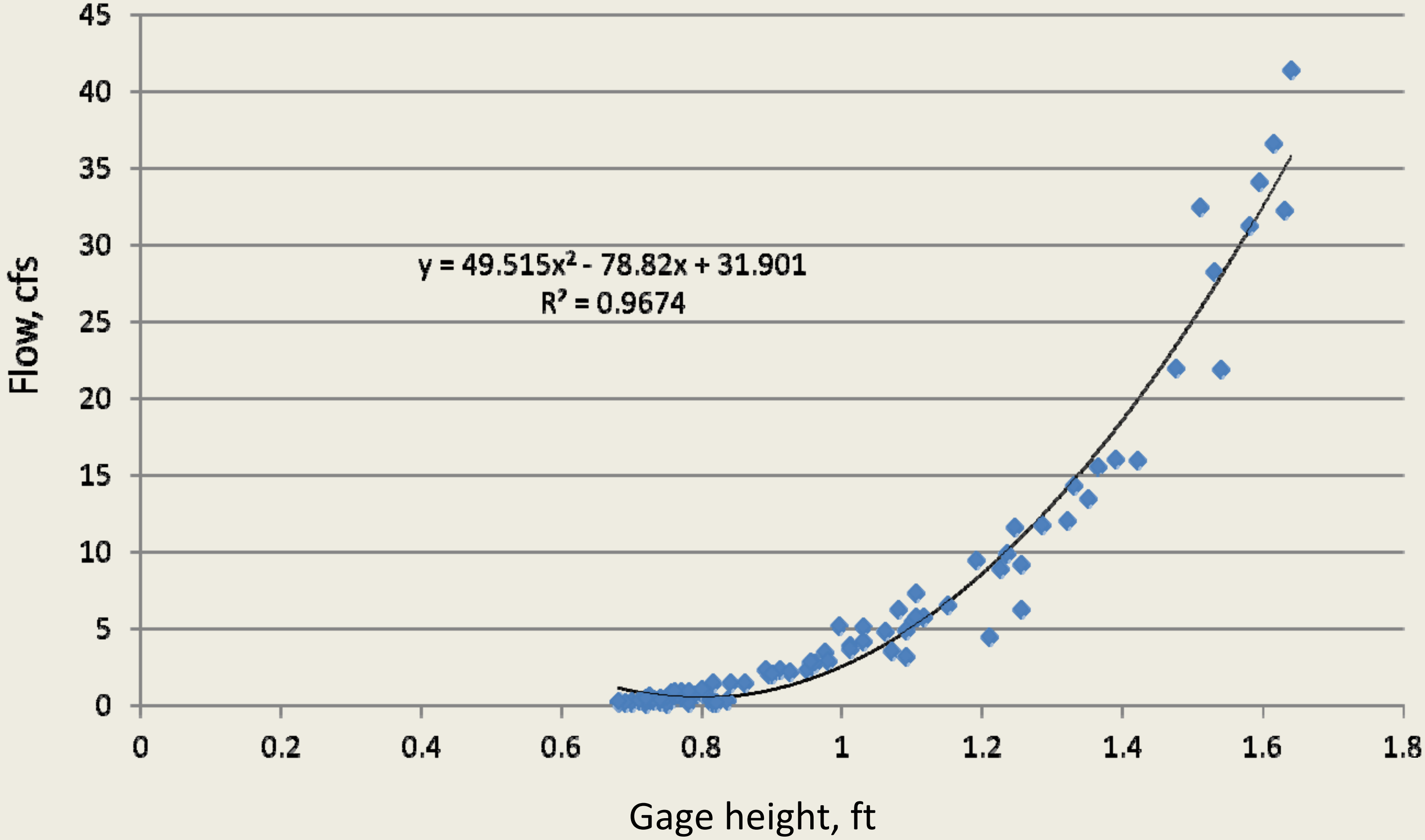


MARYLAND DEPARTMENT OF NATURAL RESOURCES

Scale offsets

- If a log-log transformation does not produce a straight line, you may need to apply a logarithmic (scale) offset to the y-axis of the stage data curve
- A good place to start is the gage height at zero flow
- Additional methods are described in 04-Scales&Offsets_new.ppt (http://ca.water.usgs.gov/FERC/presentations/04-Scales&Offsets_new.ppt), or Discharge ratings at gaging stations by E. J. Kennedy

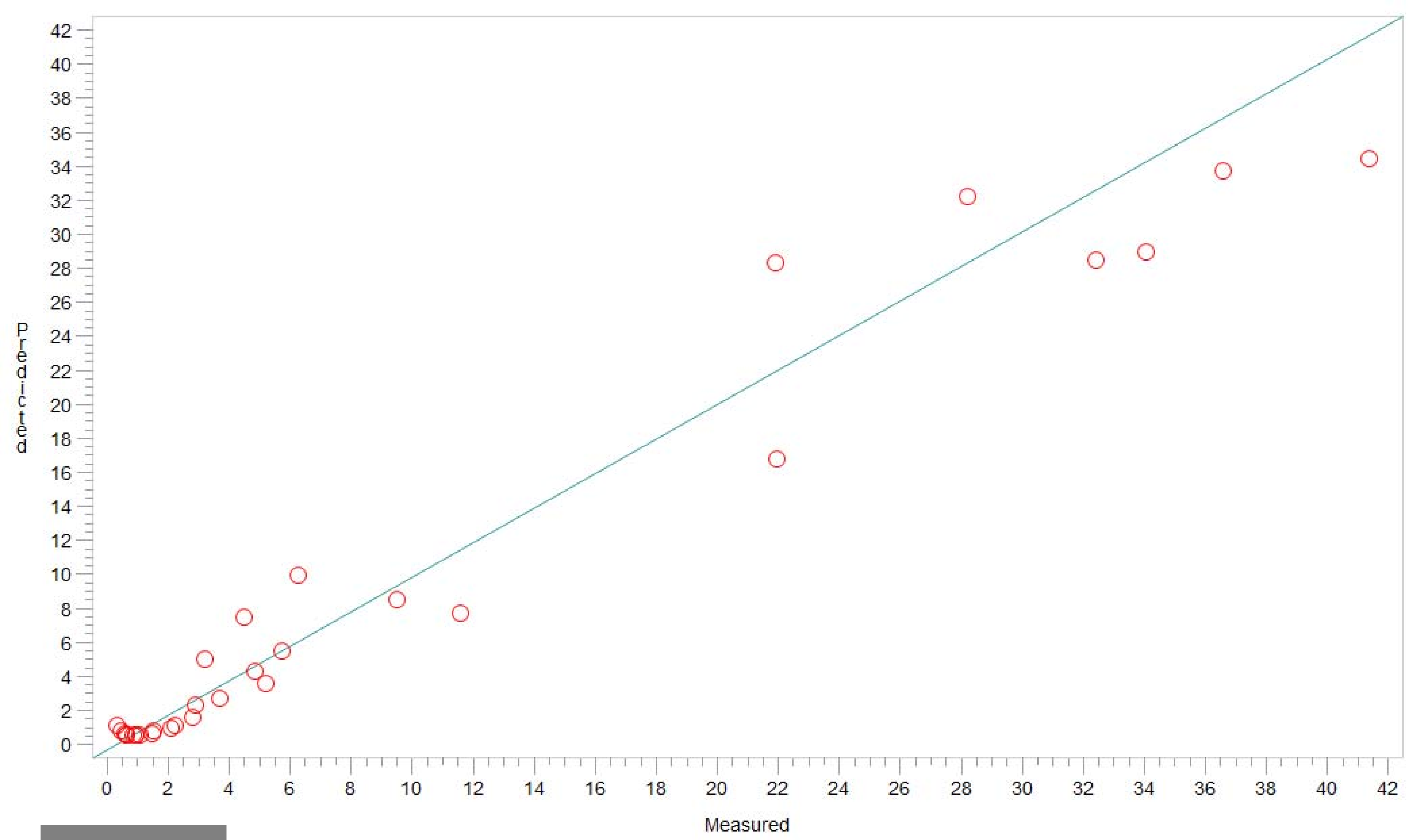
Flow data for Wheel 3 were best described by a quadratic model



Evaluating hydrologic models

- $E = 1 - [\sum(O_i - Pi)^2]/[\sum(O_i - Obar)^2]$
- The Nash-Sutcliffe model efficiency coefficient can range from -∞ to 1
- E = 1 means model predicts observed perfectly
- E = 0 means model is only as accurate as the mean of observed data
- E < 0 indicates the observed mean is a better predictor than the model

Predicted versus measured flow for Wheel Creek 3



E=0.9503

Summary & Considerations

Plan ahead

Monitor Before-After Control-Impact (BACI)

Standardize procedures & follow protocols

Install weirs if possible

Monitor a reference site if possible

Decontaminate boots and equipment (e.g., virkon)

Take photographs

Some Resources

Trust Fund monitoring protocols
http://www.dnr.state.md.us/streams/2010TrustFund.asp

Stream discharge monitoring protocol
http://www.dnr.state.md.us/streams/pdfs/TFStreamDischarge.pdf

Discharge Measurements at Gaging Stations
by D. Phil Turnipseed and Vernon B. Sauer
http://pubs.usgs.gov/tm/tm3-a8/pdf/tm3-a8.pdf

Discharge Ratings at Gaging Stations,
U.S. Geological Survey, Techniques for Water-Resources Investigations,
Book 3, Chapter A10, by E.J. Kennedy
http://pubs.usgs.gov/twri/twri3-a10/

Stream Channel Reference Sites: An Illustrated Guide to Field Technique
by Cheryl C. Harrelson C. L. Rawlins John P. Potyondy
http://www.stream.fs.fed.us/publications/PDFs/RM245E.PDF

Stream Discharge Monitoring
Questions?