Flow Monitoring Basics

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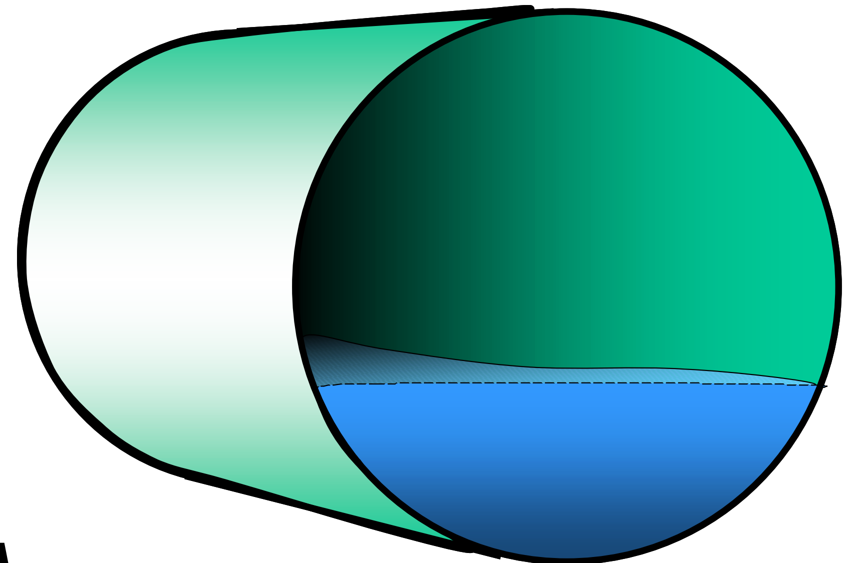
Flow Monitoring Basics

Where’s your Champion?

Having a Champion is a Critical Success Factor.

Pipe Flow



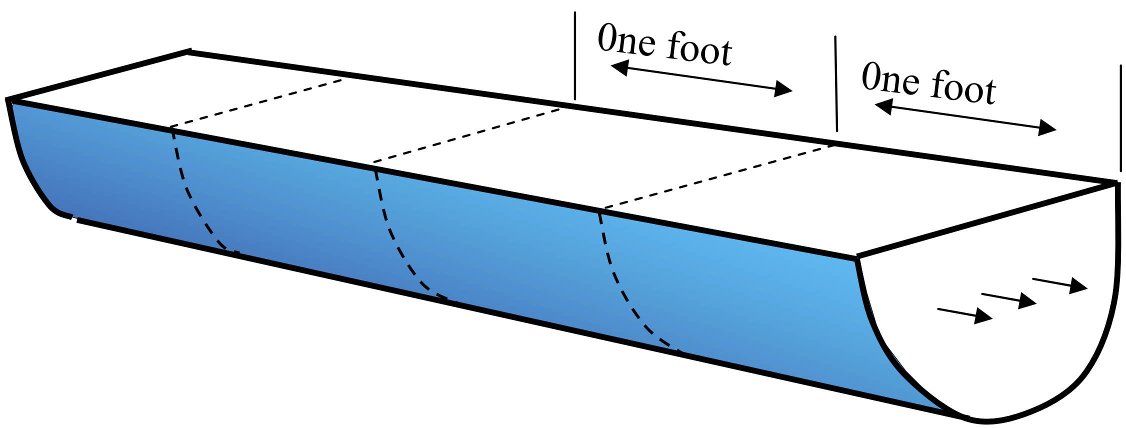
For steady open channel flow

$$Q = V A$$

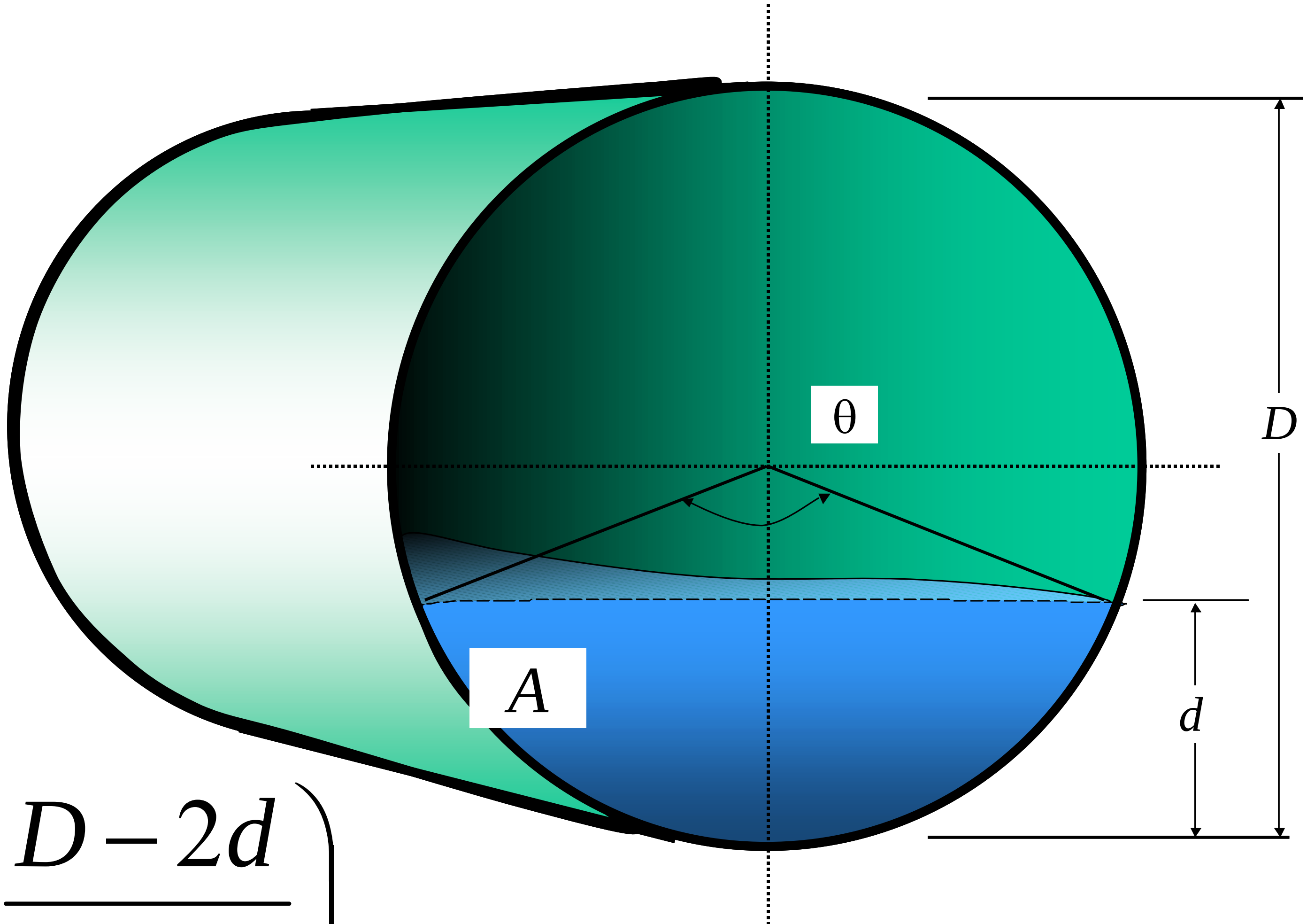
Volumetric Flow Rate equals the Average Advective Fluid Velocity times the Cross-Sectional Area of the flow perpendicular to the Velocity.

Pipe Flow

The velocity tells us the feet of water which passes a point every second.



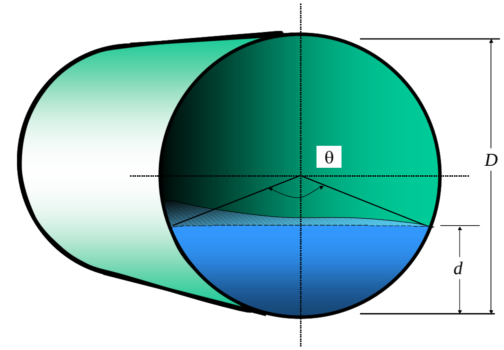
Calculating Area



$$\theta = 2\arccos\left(\frac{D-2d}{D}\right)$$

$$A = \frac{D^2}{8}(\theta - \sin\theta)$$

Calculating Area



For a 12" pipe flowing 4 inches deep,

$D = 12$ in, $d = 4$ in

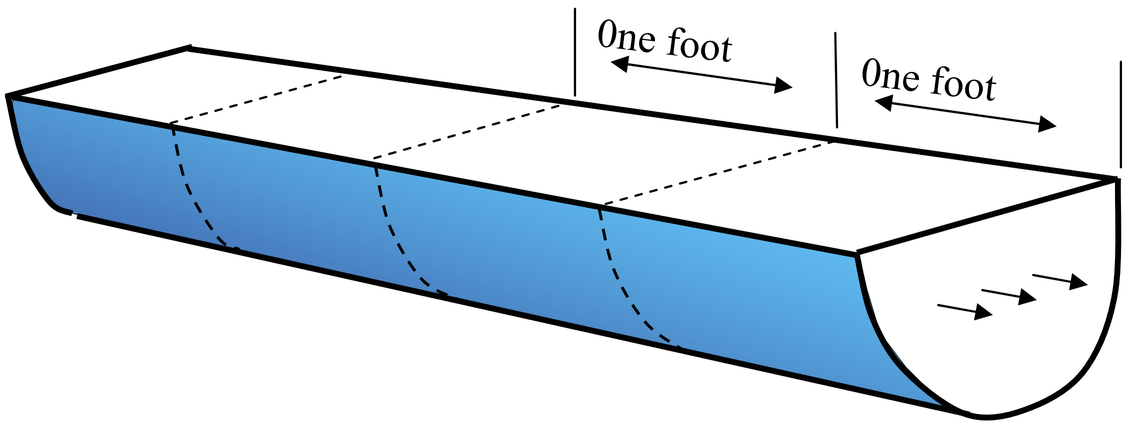
$$\theta = 2\arccos\left(\frac{12 - 2(4)}{12}\right) = 2\arccos(\frac{1}{3}) = 141^\circ = 2.46 \text{ rads}$$

$$A = \frac{D^2}{8}(\theta - \sin\theta) = \frac{12^2}{8}(2.46 - \sin(2.46)) = 18(1.83) = 33.0 \text{ in}^2$$

$A = 33.0$ in^2 or 0.229 ft^2

Calculating Flow

At $2.0 \frac{ft}{sec}$

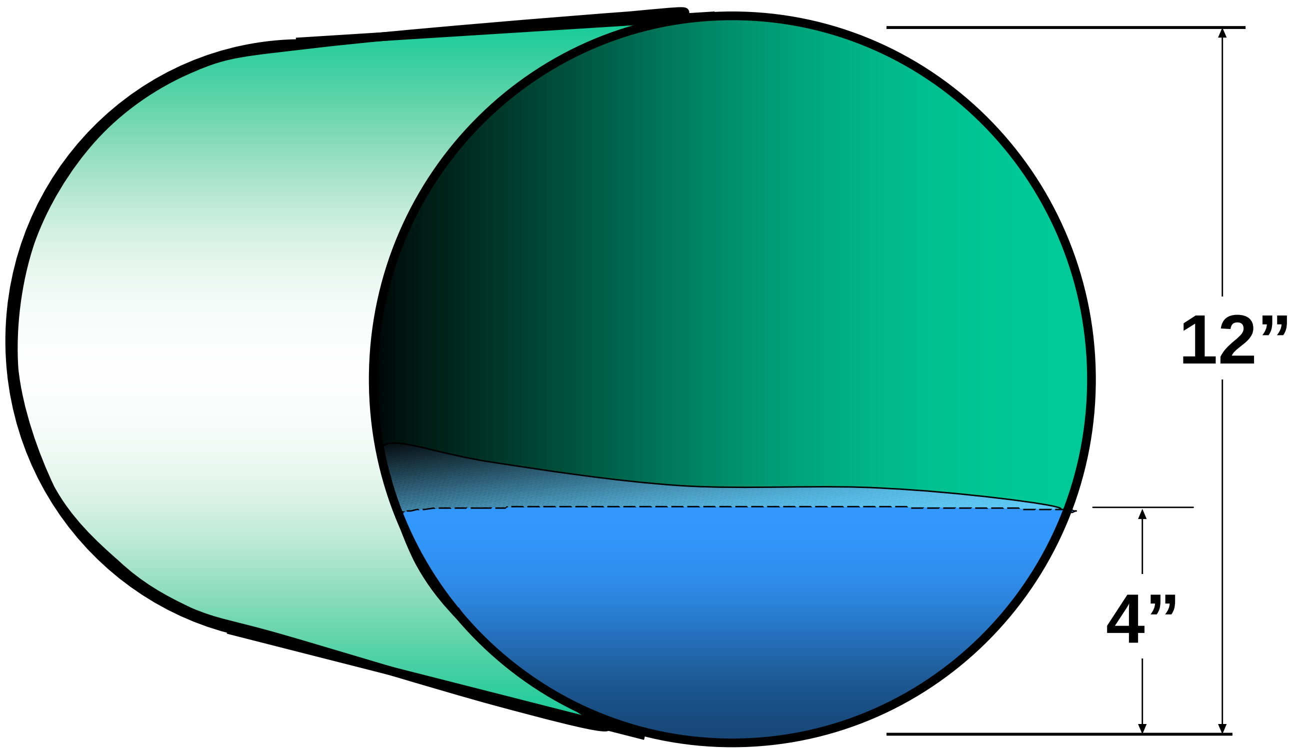


The volume every second is therefore,

$$Q = V\,A$$

$$Q = 2.0 \frac{ft}{sec} \;\; x \;\; 0.229\ ft^2 \;\; = \;\; 0.458 \frac{ft^3}{sec}$$

Example Answer

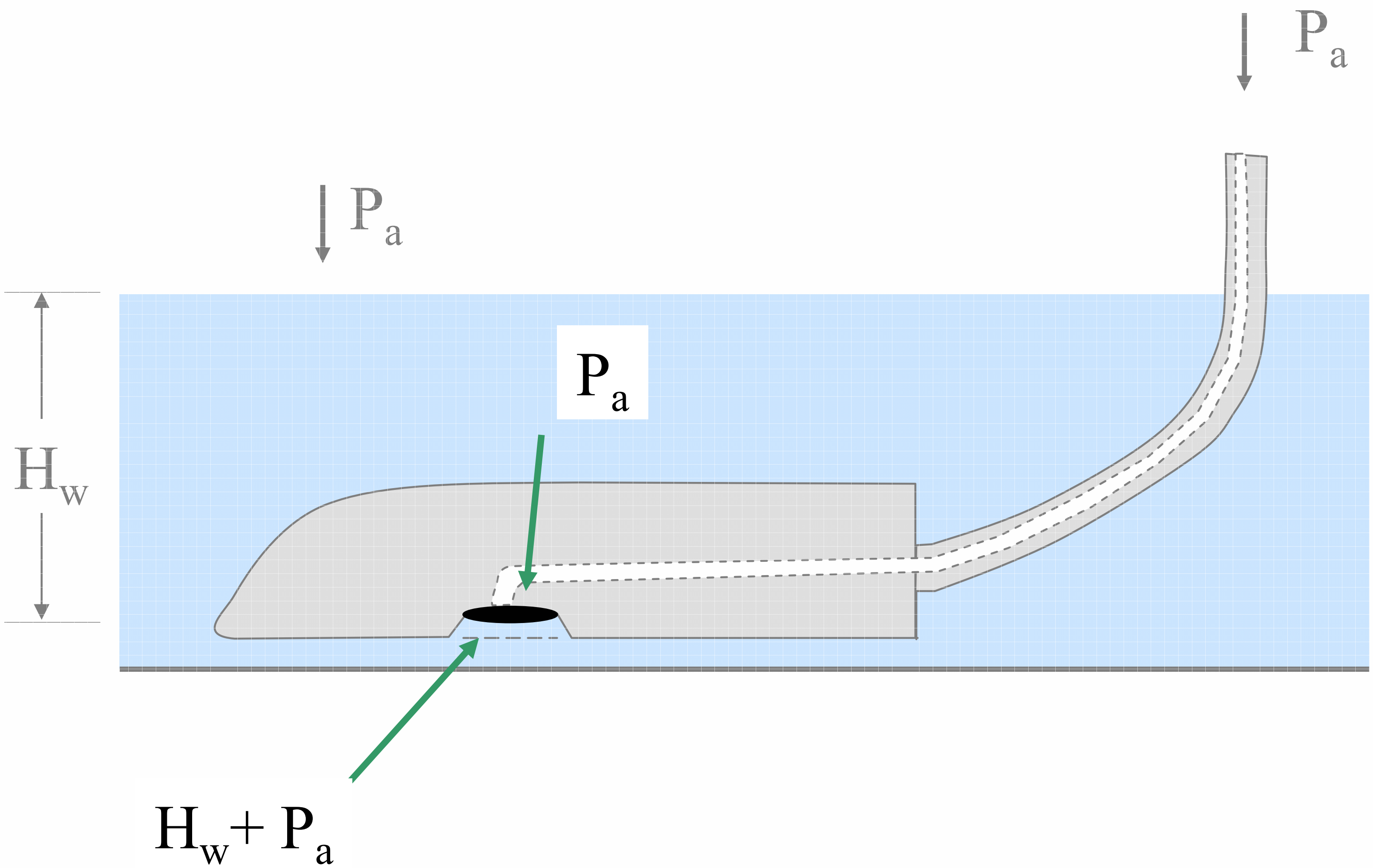


For the 12” pipe flowing 4 inches deep at 2 feet per second

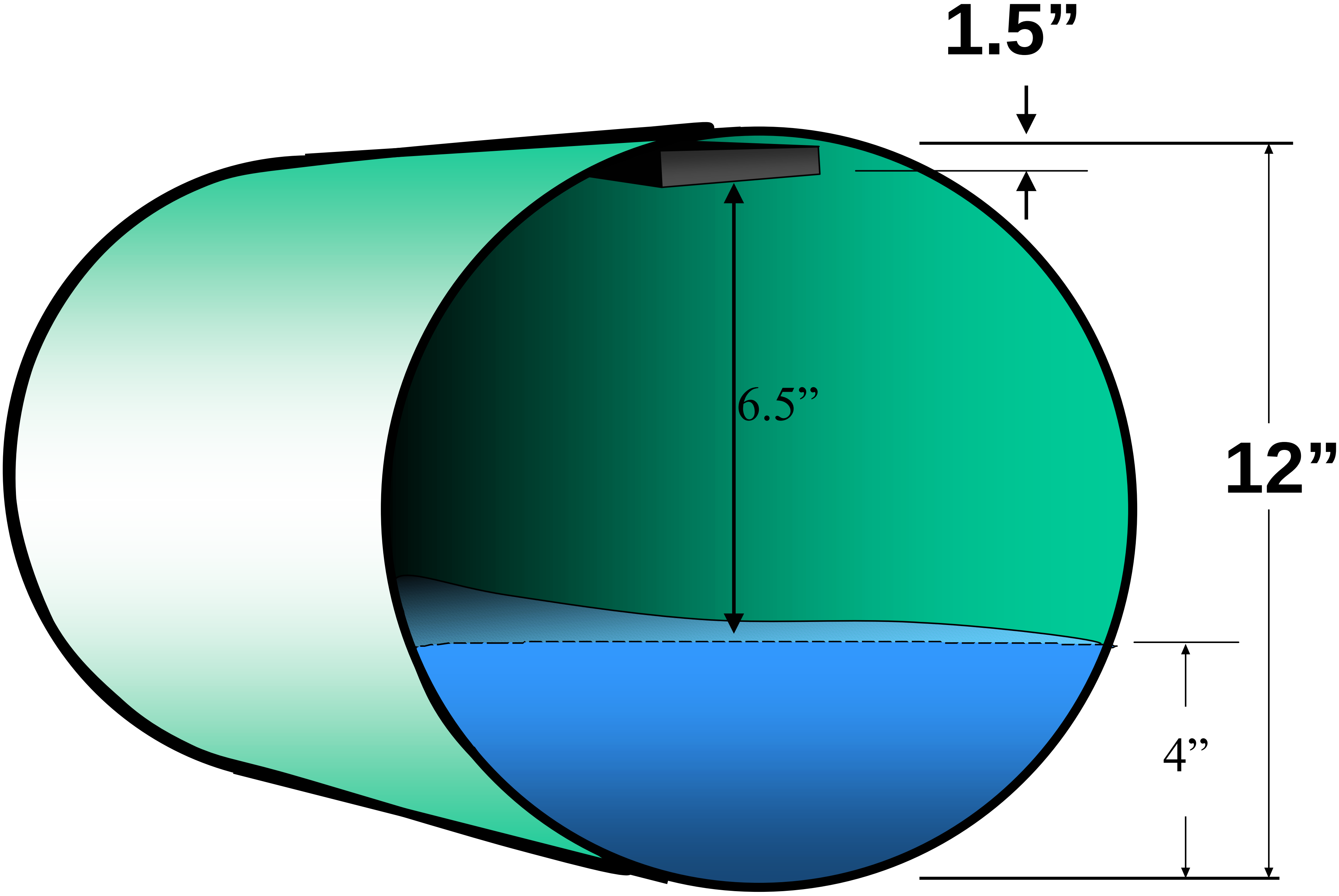
Flow = 0.458 cfs

Pressure Sensor

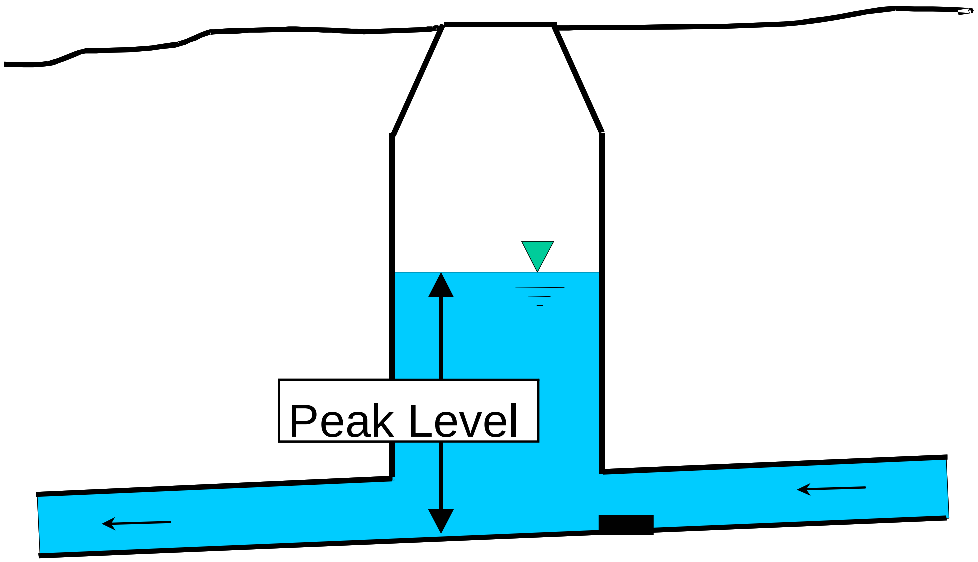
Level



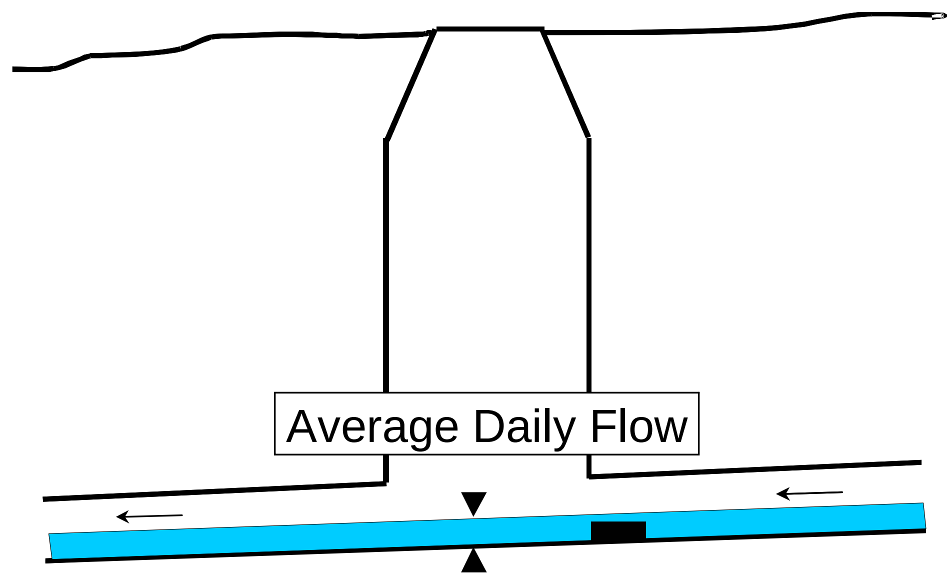
Ultrasonic Sensor



Level

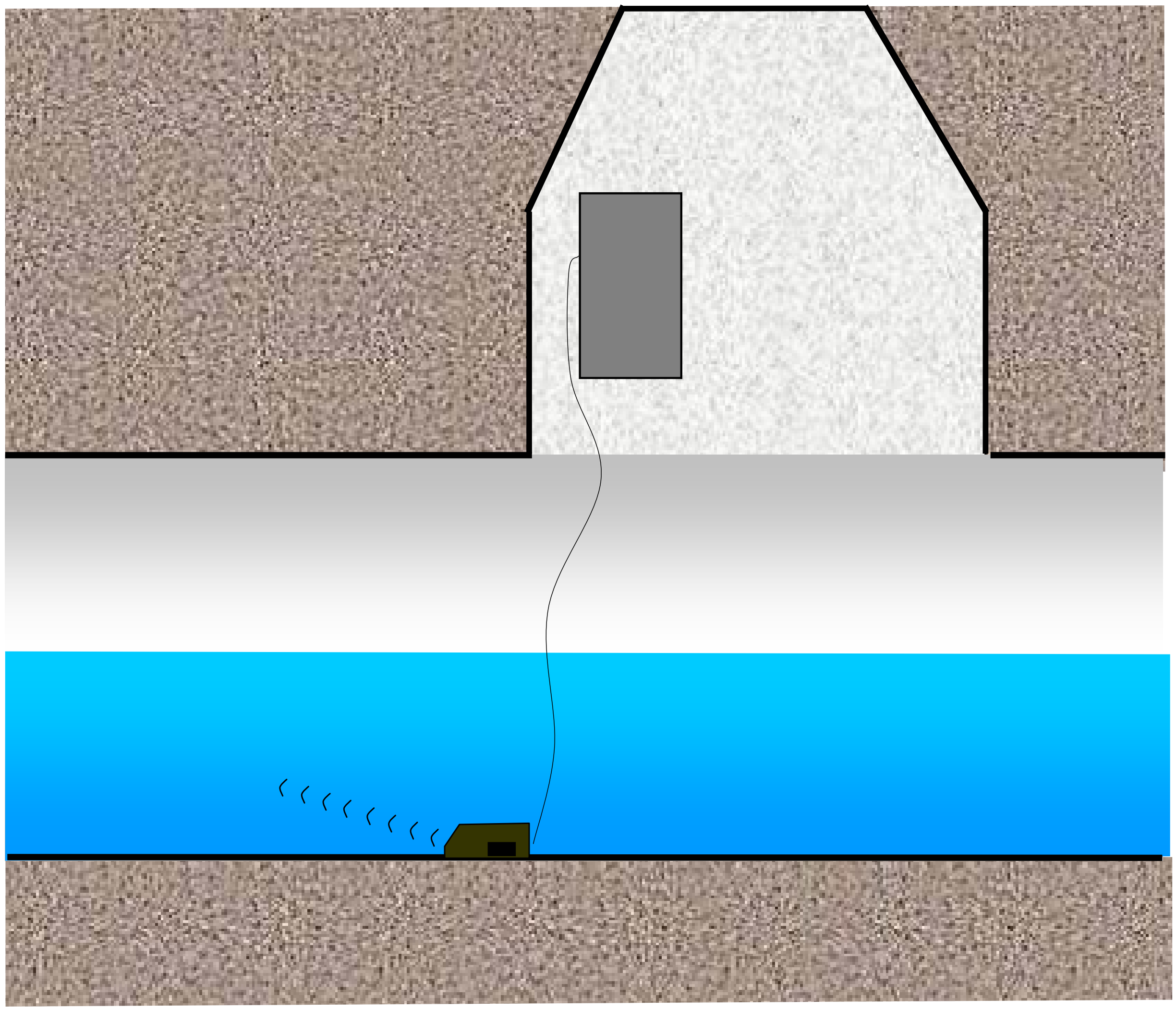


During surcharge, area of flow is constant, and previous equations do not apply.



Doppler Velocity

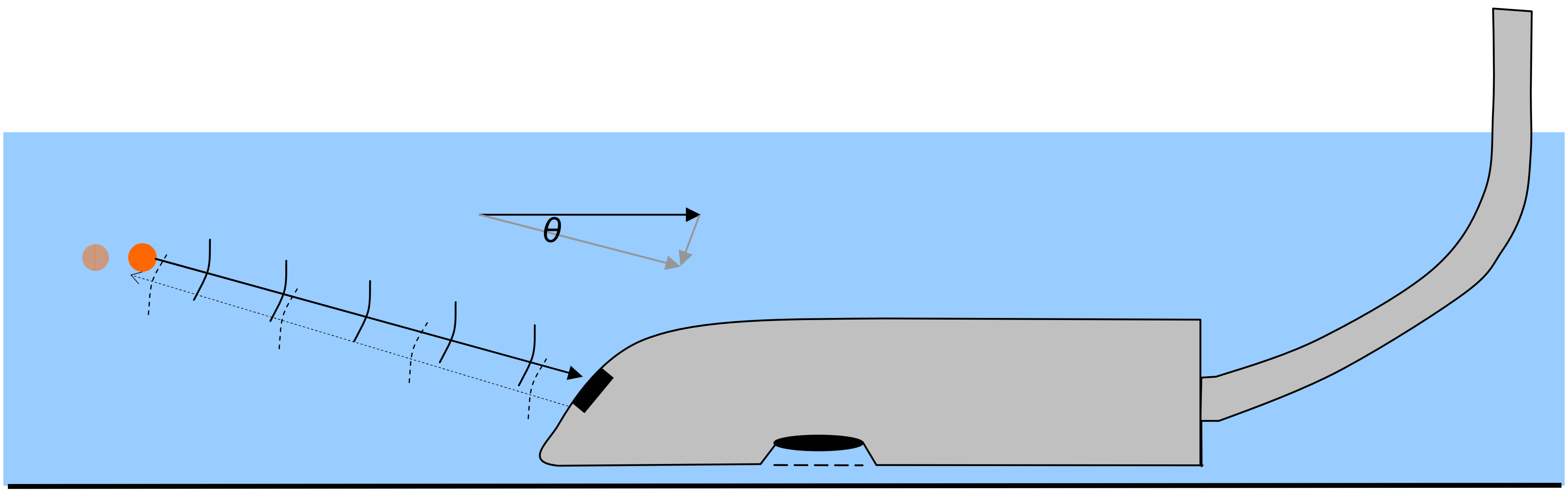
Velocity



Doppler Velocity

Velocity

The 1.0 MHz Ultrasonic Pulse is emitted by one sensor and recorded by the other



The faster the particle moves towards the probe, the higher the return frequency

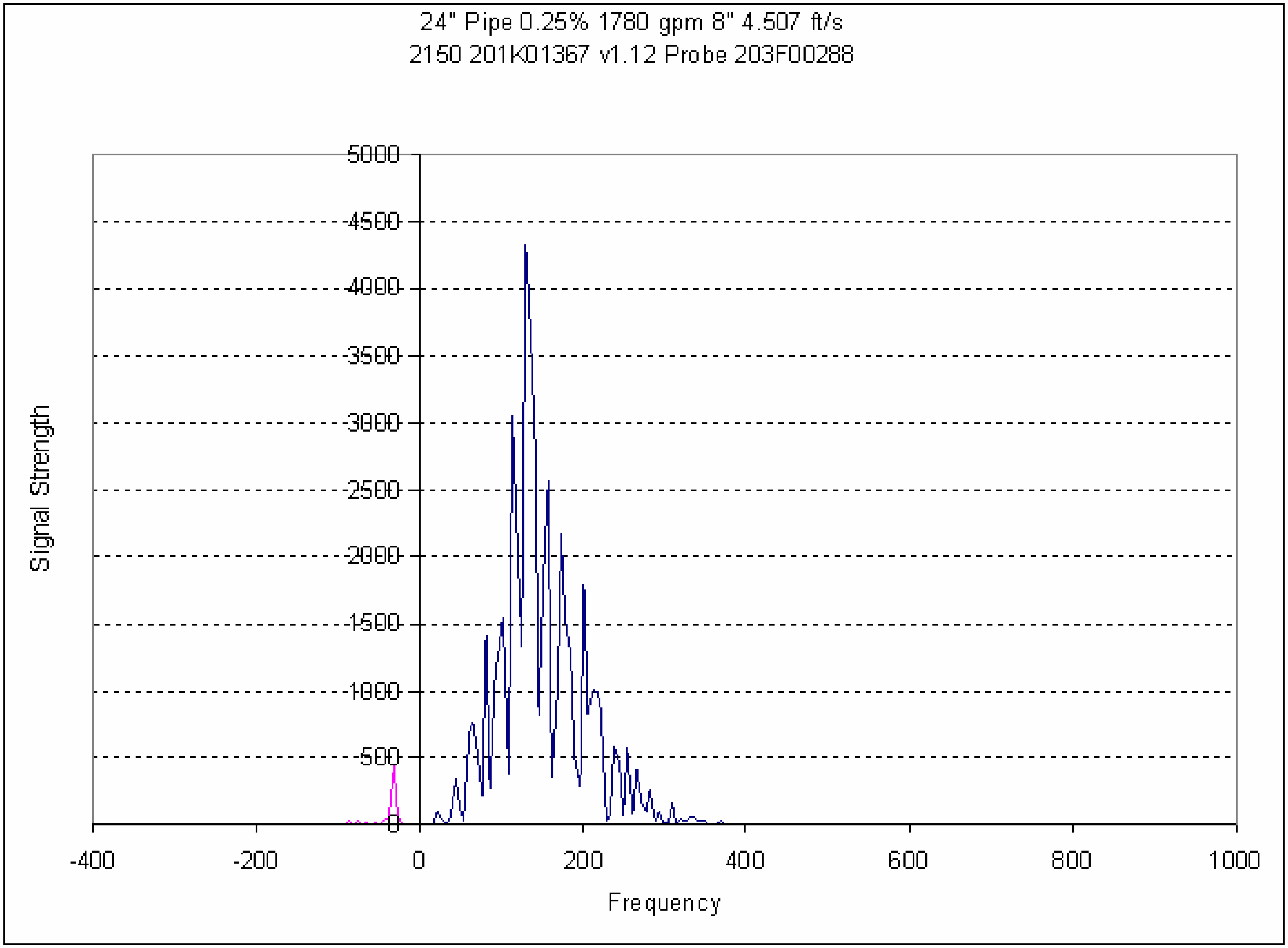
The bigger the particle, the greater the strength of the return signal

Frequency

Velocity

Return Spectrum

Relative power

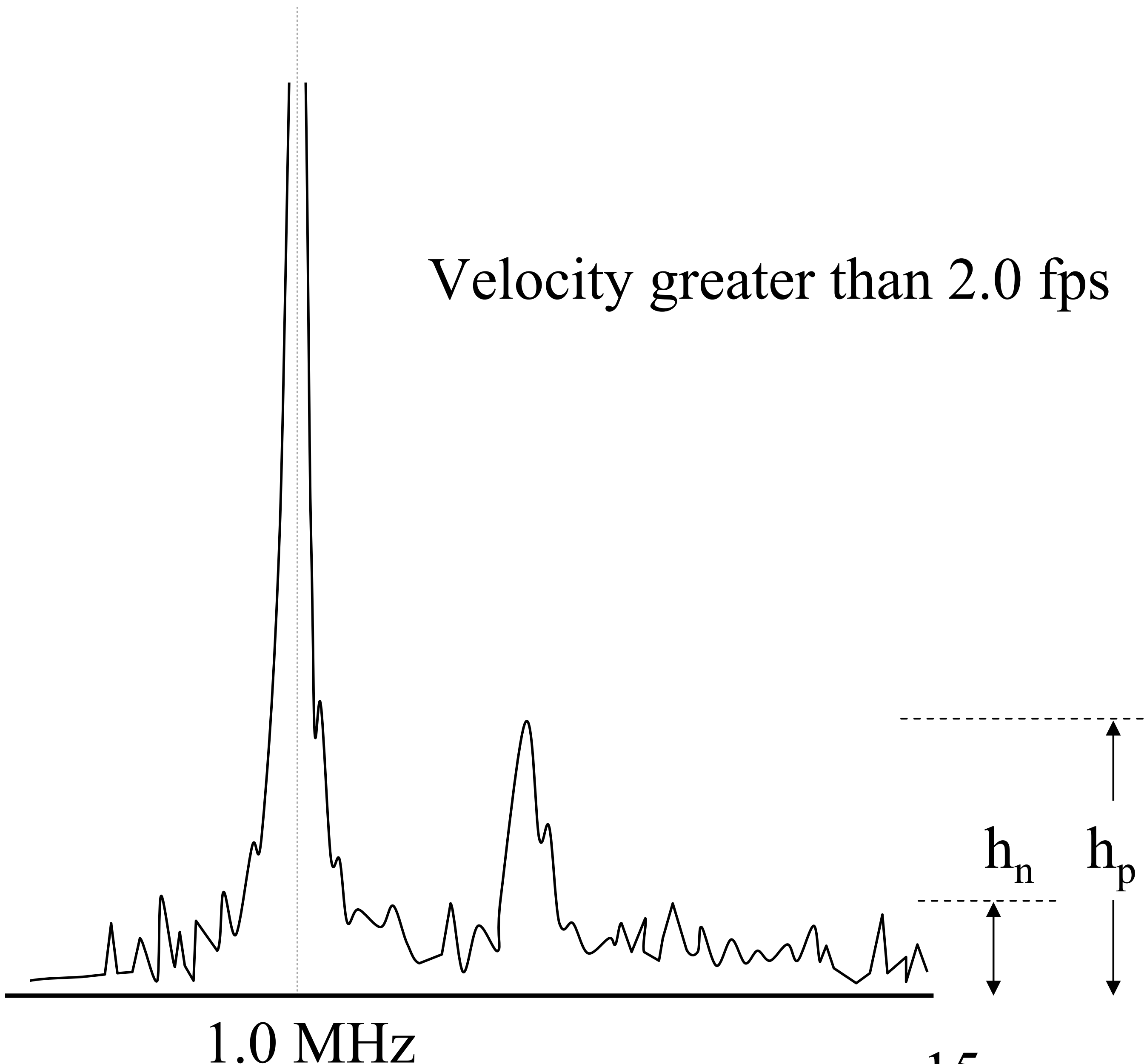


Frequency Shift (Hz)

Courtesy of Teledyne, ISCO

Frequency

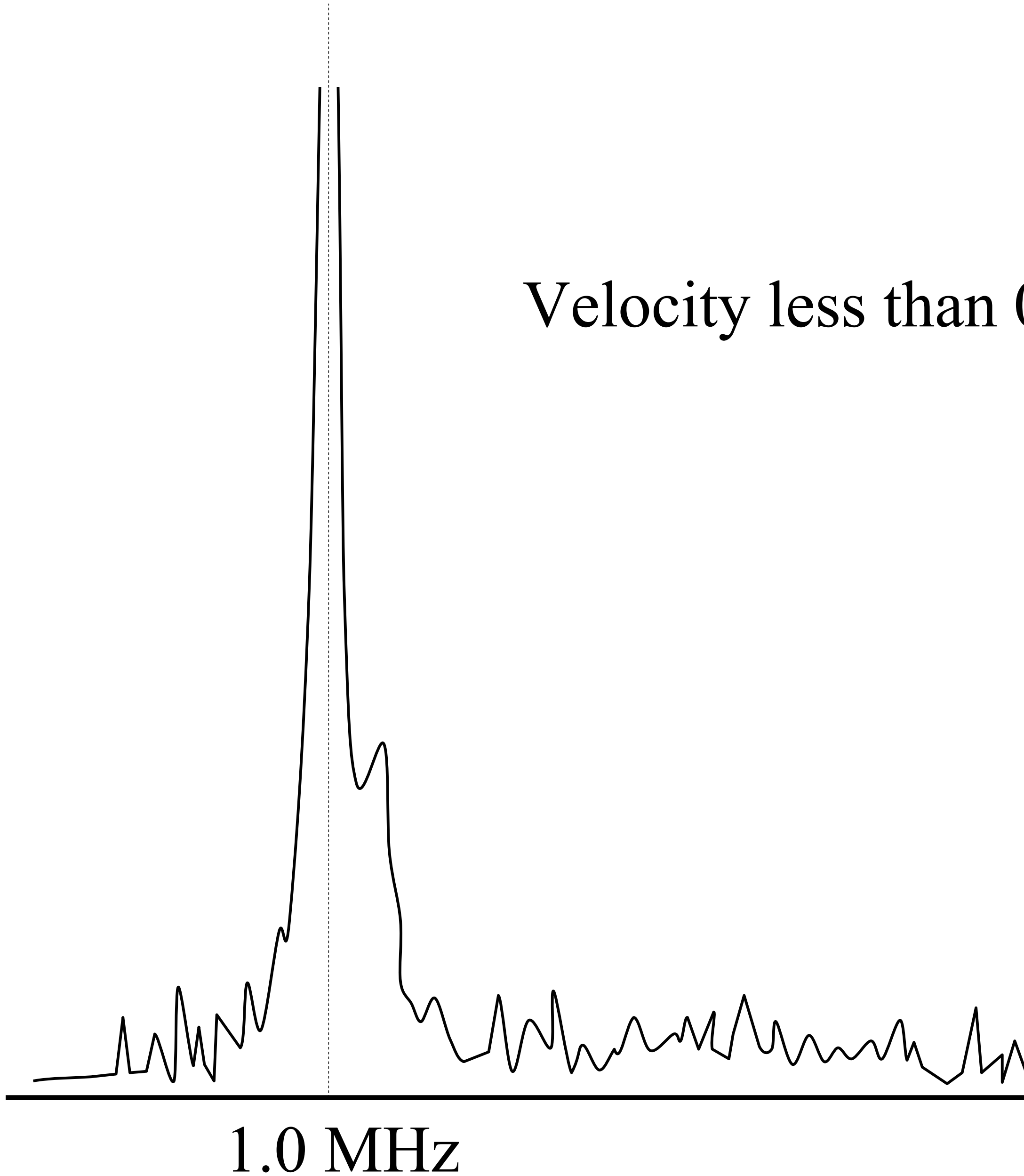
Velocity



Frequency Slow Flow

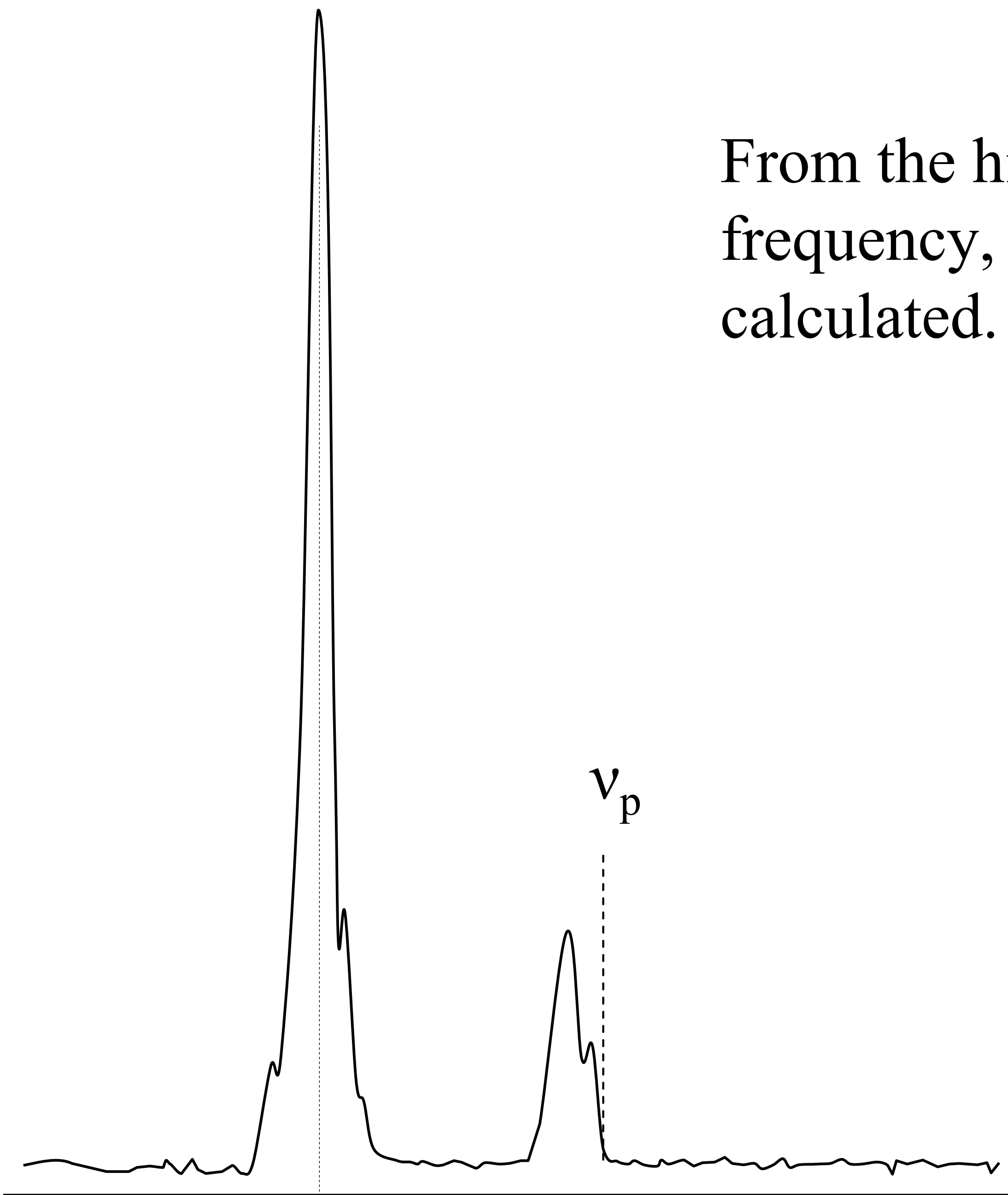
Velocity

Velocity less than 0.5 fps



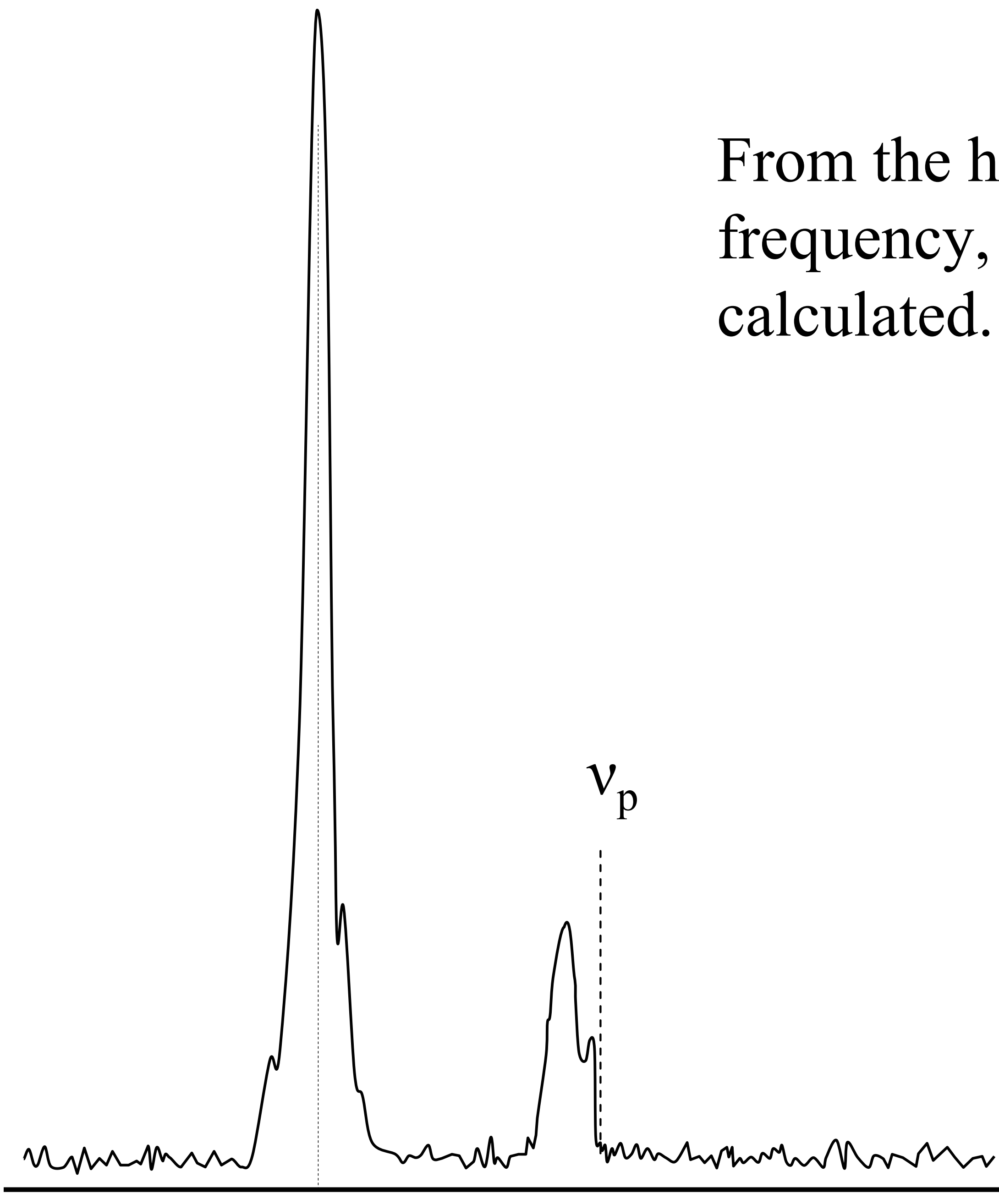
Peak to Average

Velocity



From the highest returned frequency, the Peak Velocity is calculated.

Peak to Average



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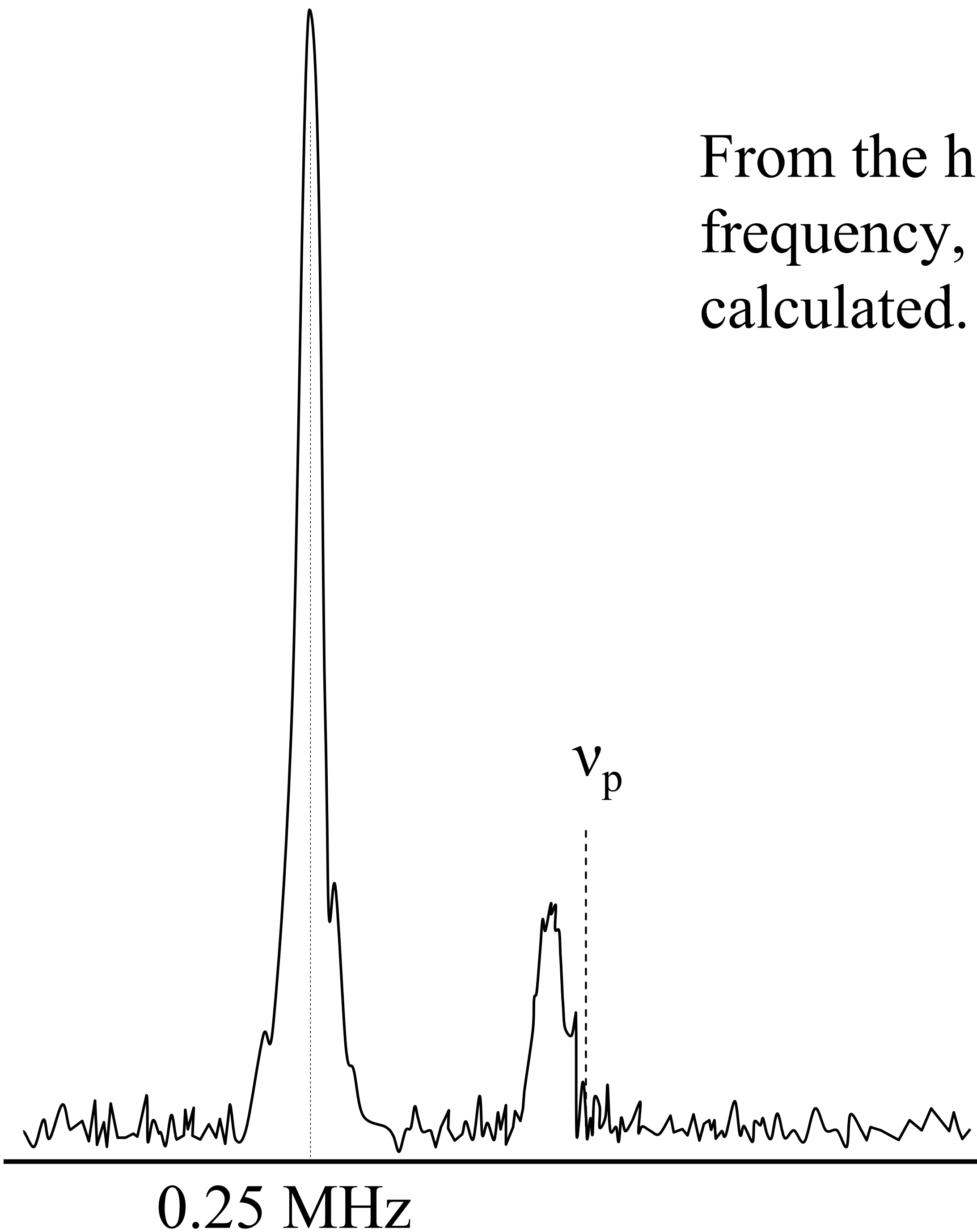
Peak to Average

Velocity



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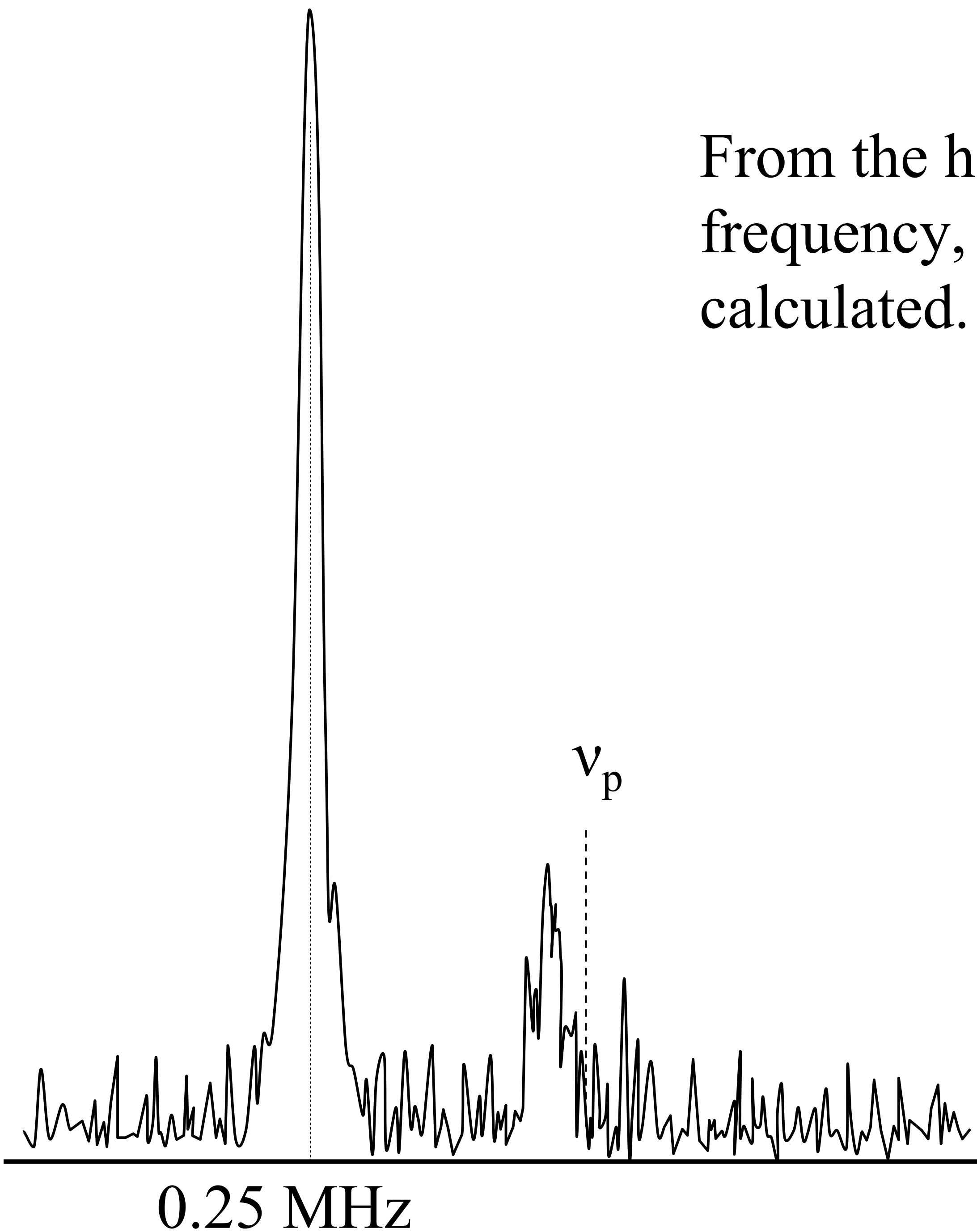
Peak to Average

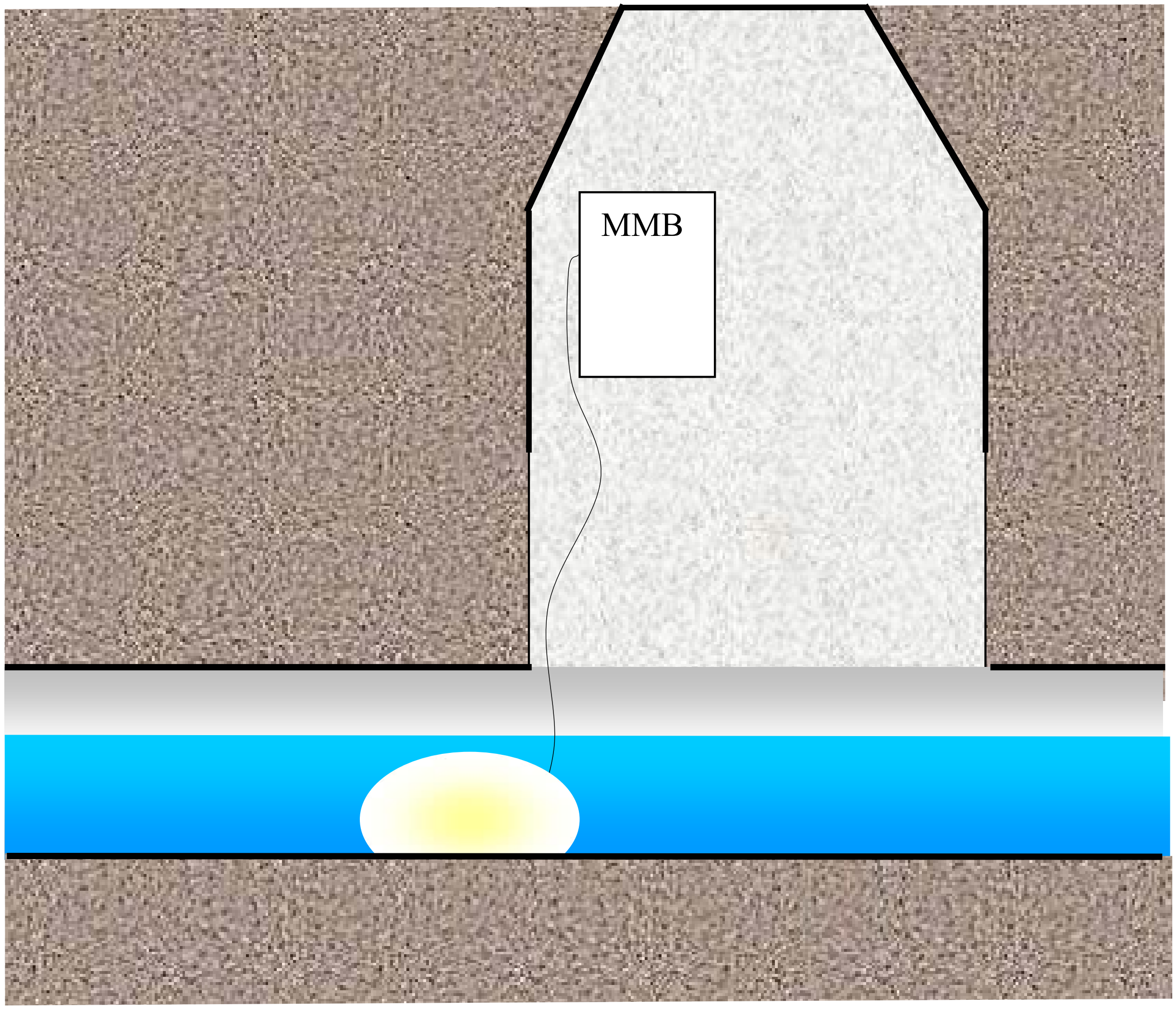
Velocity



From the highest returned frequency, the Peak Velocity is calculated.

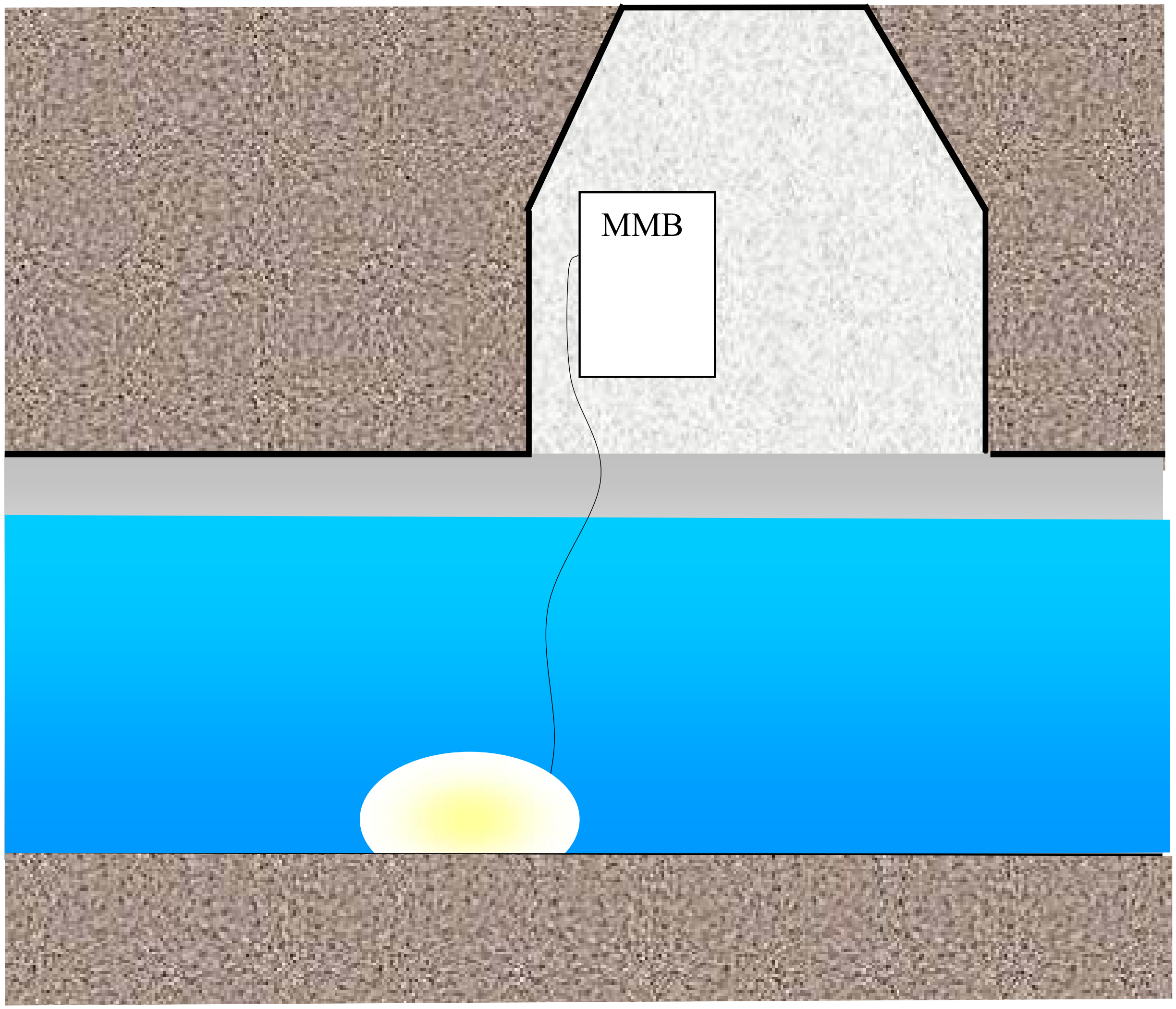
Faraday Velocity

Velocity

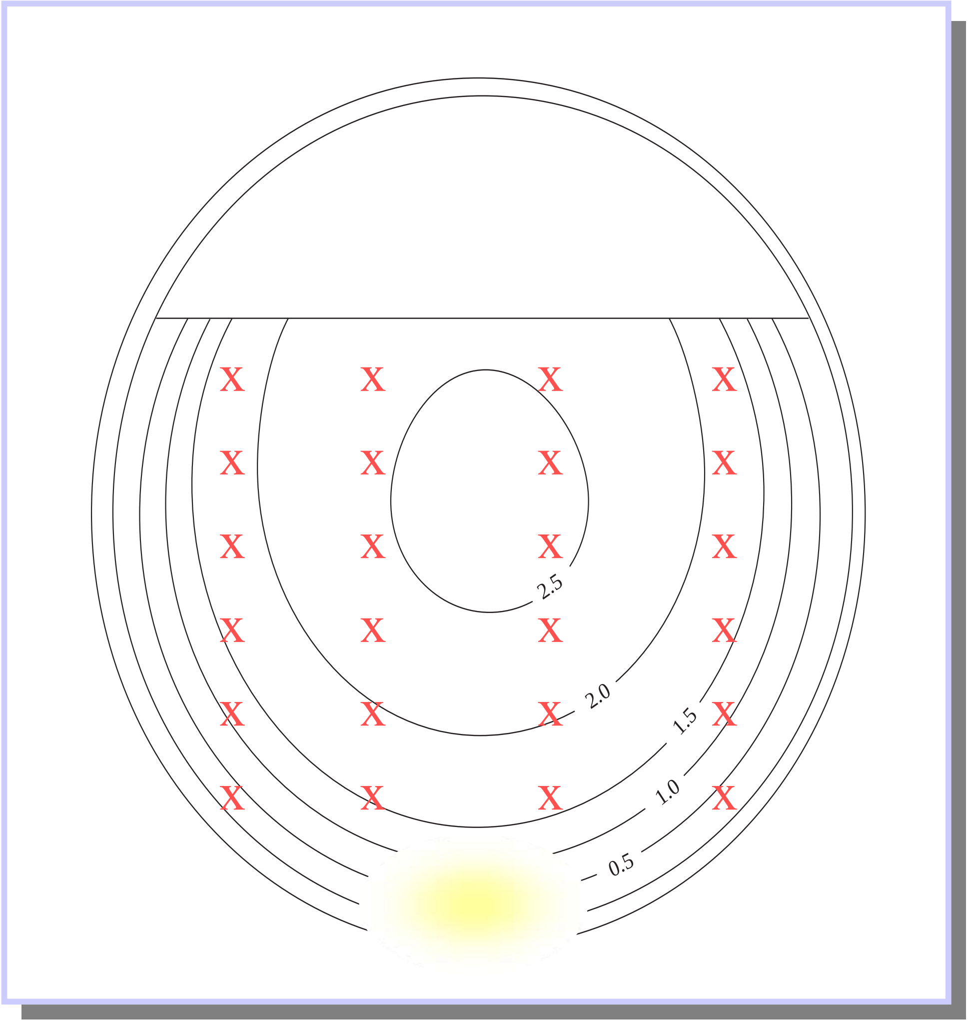


Faraday Velocity

Velocity



Faraday Velocity



The Calibration Coefficient relates the Sensed Velocity to the Average Velocity.

Equipment Type: SIGMA 910

Advantages

- Cost Effective
- Very easy to Use
- Hard to lose data
- Has a new Digital Probe

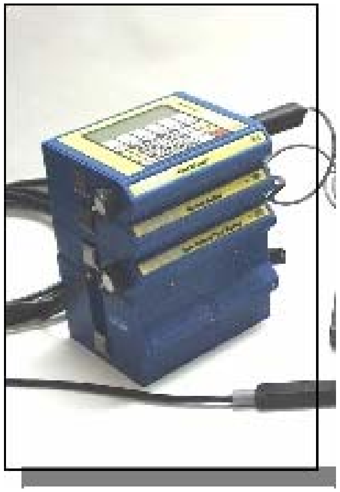
Disadvantages

- Limited data storage (21 days)
- Peak to average conversion
- Does not work well in variable hydraulics
- Does not work well in deeper flows

Equipment Type: ISCO 2150

Advantages

- Cost Effective (A little more than Sigma)
- Easy to Use (A little harder than Sigma)
- Good wireless capabilities
- Hard to lose data



Disadvantages

- Low flows not accurate
- Pressure transducer does not work during ramping
- Pressure Transducer can Drift

Equipment Type: MMI Flo-Tote 3

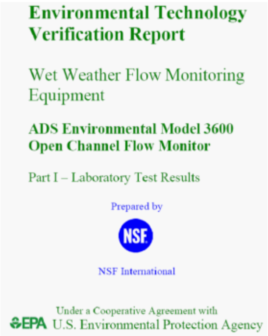
Advantages

- Works in very slow velocities
- Works in churning water
- Works in clear water

Disadvantages

- <u>Must be profiled to be accurate</u>
- Can be wrong and you don't know it
- Does not work well if flows do not continually cover the probe

Equipment Type: ADS FlowShark


Environmental Technology Verification Report

Wet Weather Flow Monitoring Equipment

ADS Environmental Model 3600 Open Channel Flow Monitor

Part I – Laboratory Test Results

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

Advantages

Small velocity probe

Can be made to work even in ramping (Two Bands)

Disadvantages

Very Complicated

Multiple Databases

Iif File Overwrite

BIN File Import

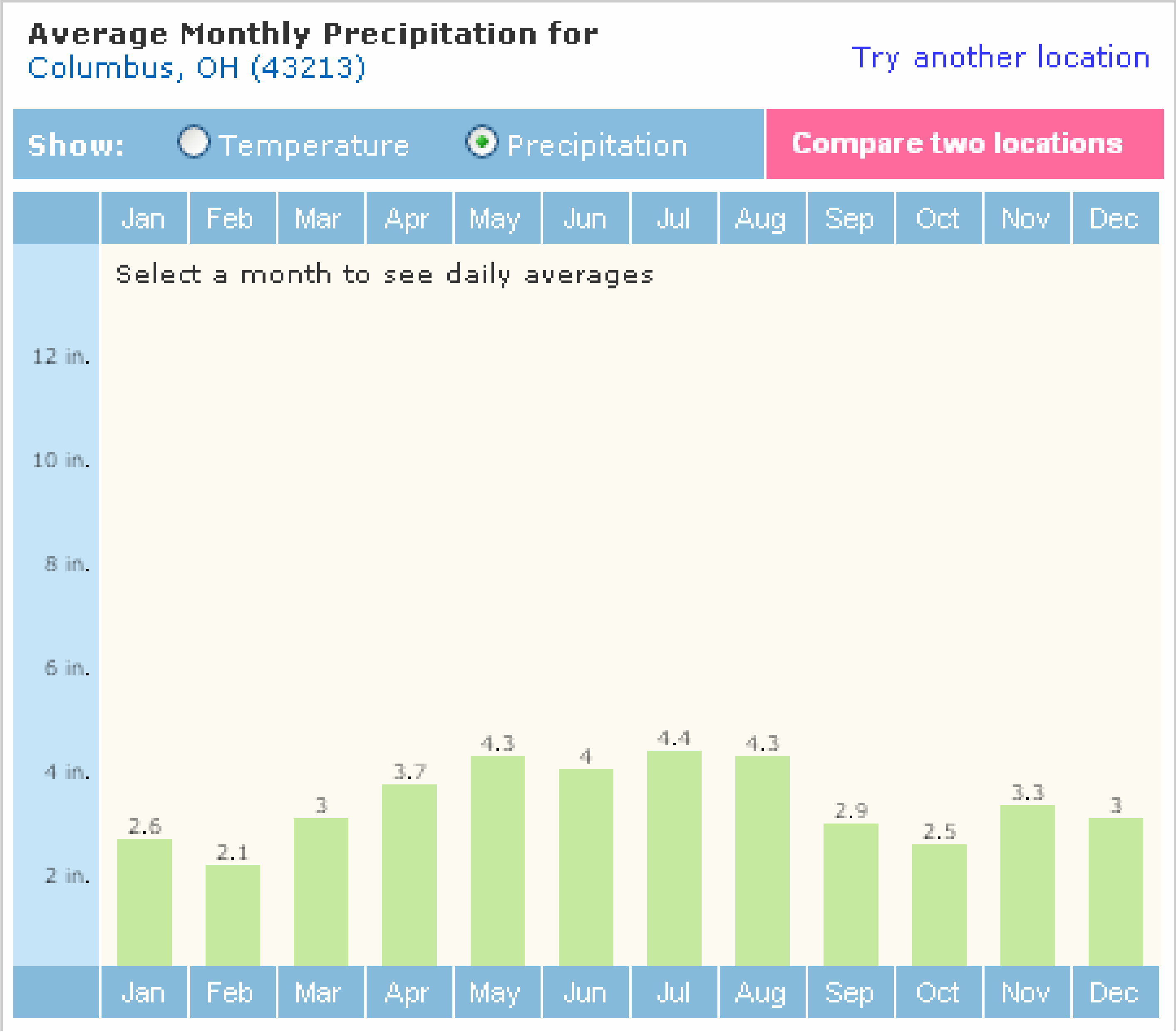
Ultrasonic and Velocity Pops

Pressure Transducer out of the Water

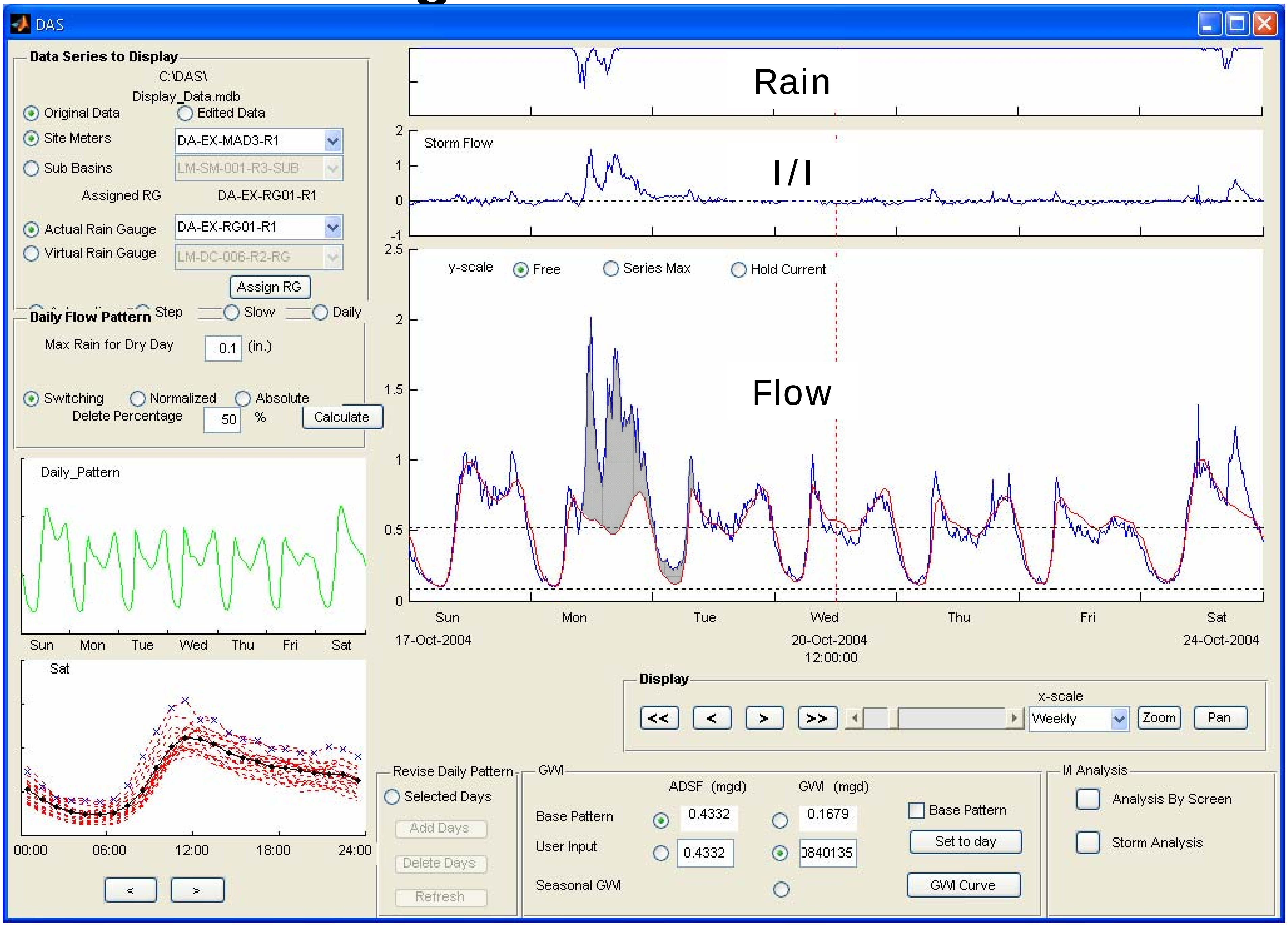
Requires velocity profiling!!!!!

Wet Season Response

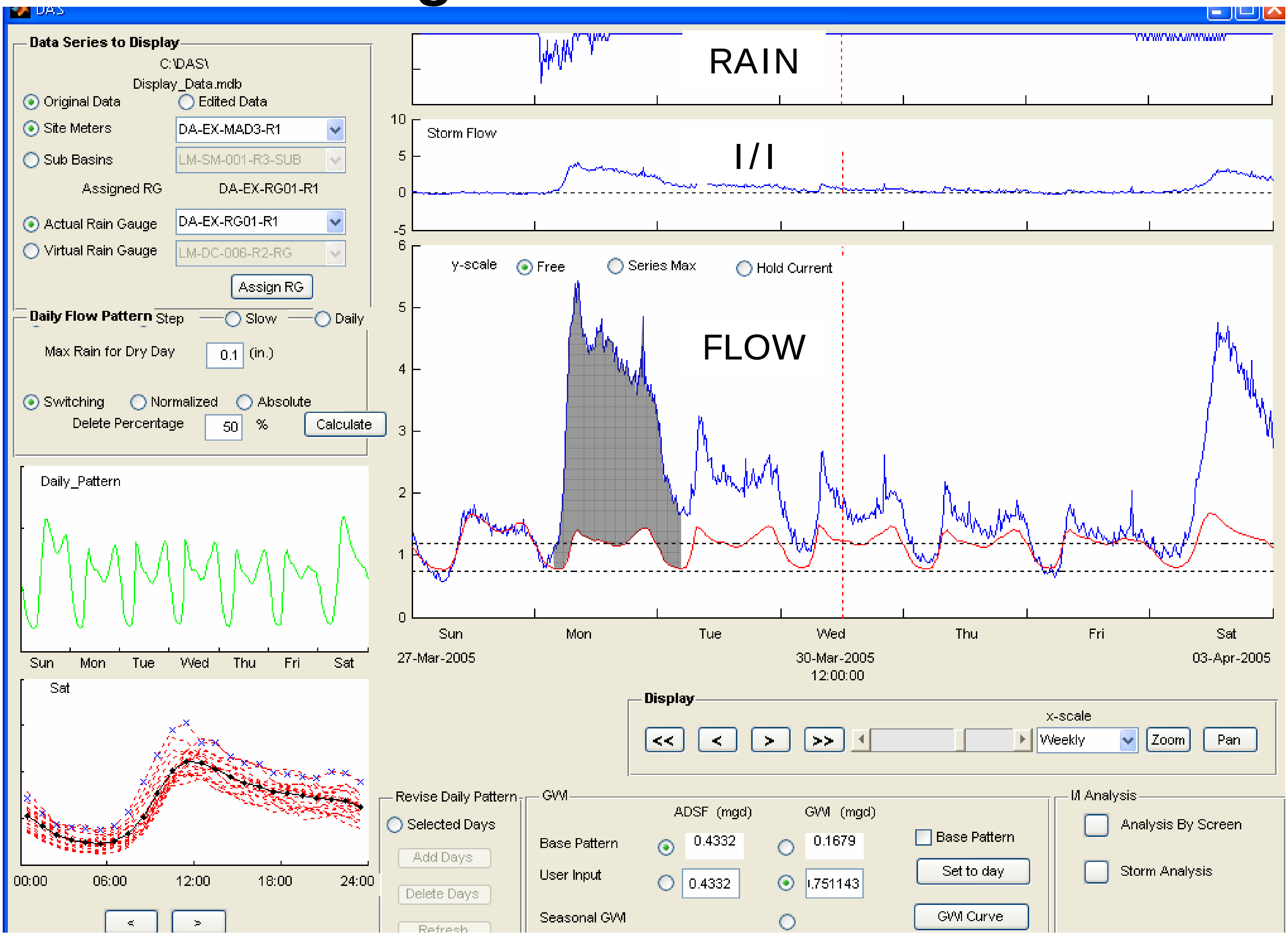
When Do I Begin?



When Do I Begin?



When Do I Begin?

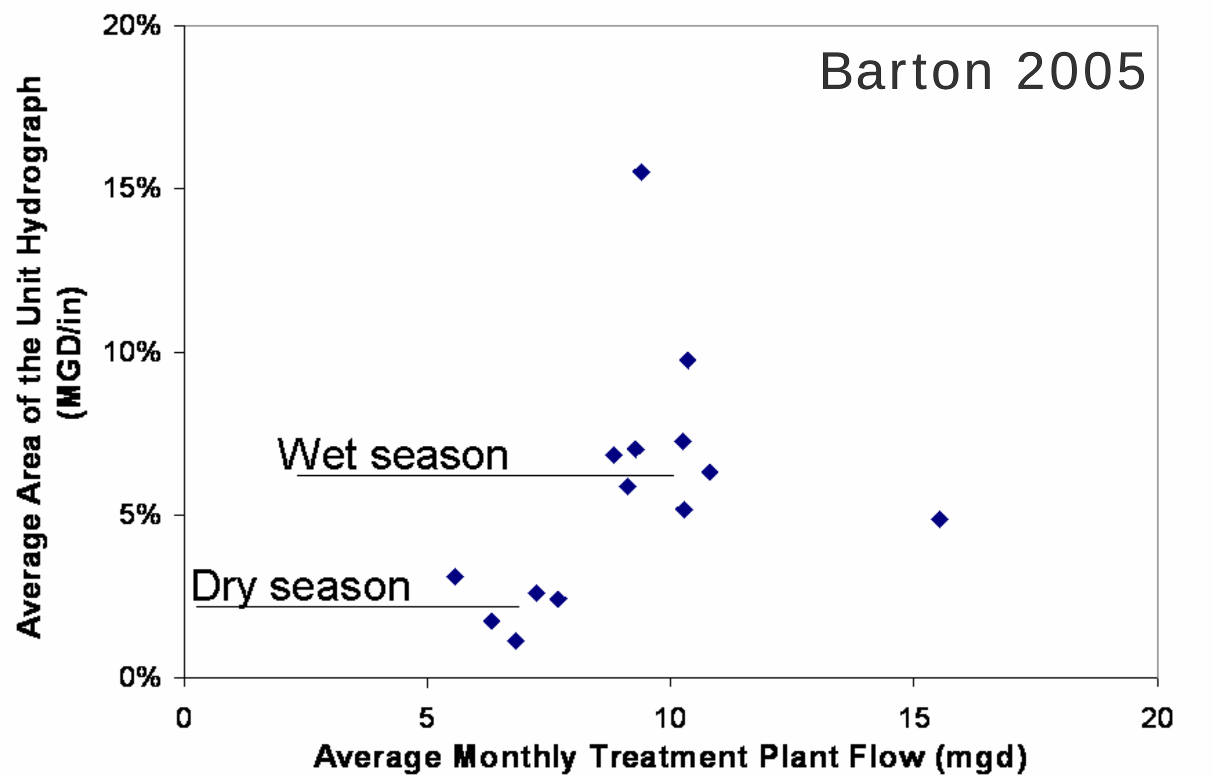


When Do I Begin?

Comparing Wet and Dry Seasons

SEASON	MONTH	RAINFALL	24 HOUR I/I
Dry	Oct	1.23 in	0.4 MG
Wet	Mar	0.97 in	2.5 MG

<u>Other studies</u> show I/I response characterized by two seasons



When Do I Begin?

Greater Response in March-May

- Greater Total Rainfall
- Larger Individual Storms
- Dormant Vegetation

Dry Season Flows are only needed if you are performing continuous simulations.

In which case, you should monitor a full year.

When Do I Begin (Summary)?

Flow Monitoring Period

Optimal: **January 1st – June 30th**

Minimum: February 15th – May 30th

Backing up your Start Date

Installation and checking

Inspection

Contract or Training

Inspect First or just Install?

Purpose:

Make sure we have the best manhole.

Modeling Objectives

Data Quality

Ease of Maintenance

Schedule & Budget

Data Quality

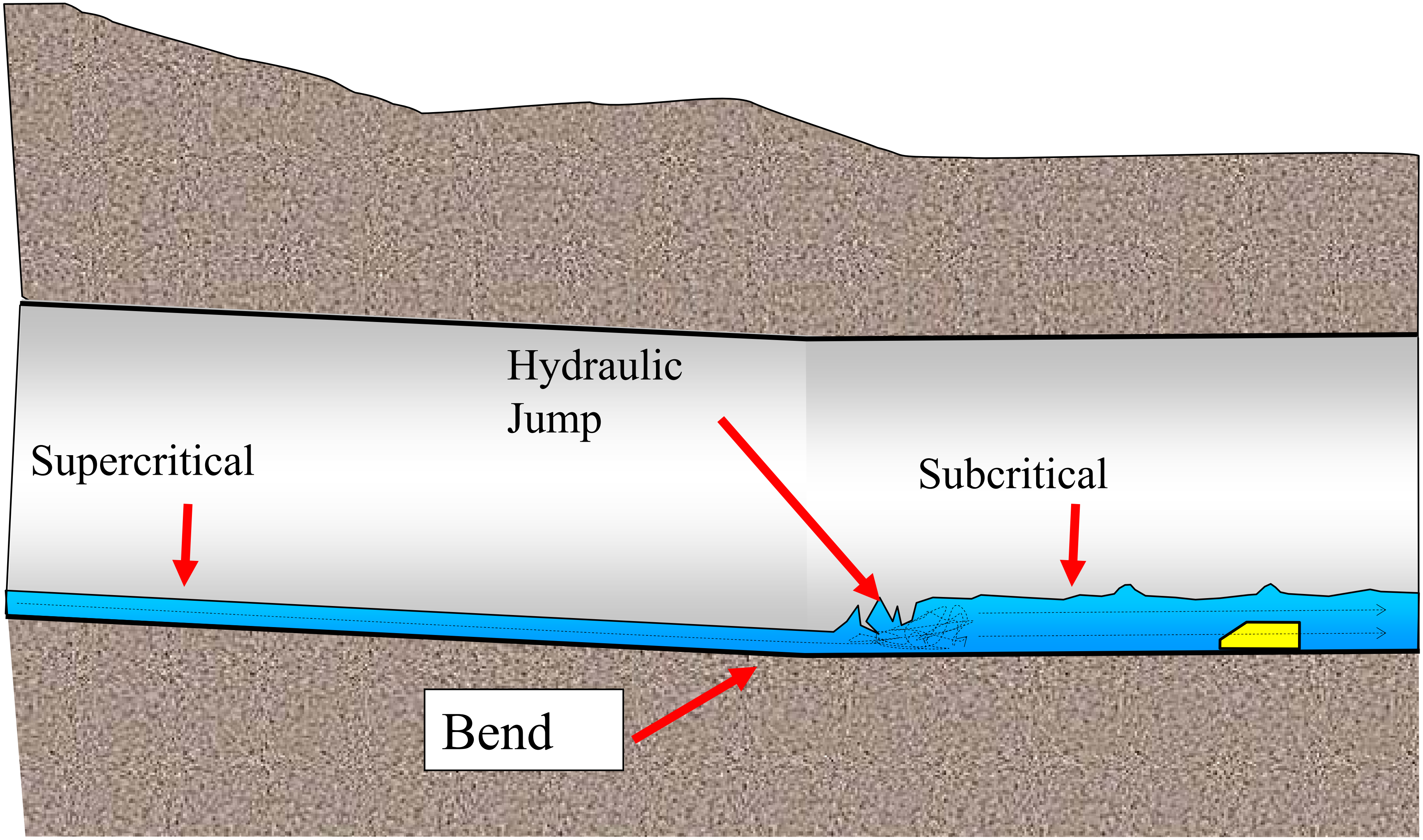
What am I missing without upstream pictures?

Velocity – Hydraulic Jump

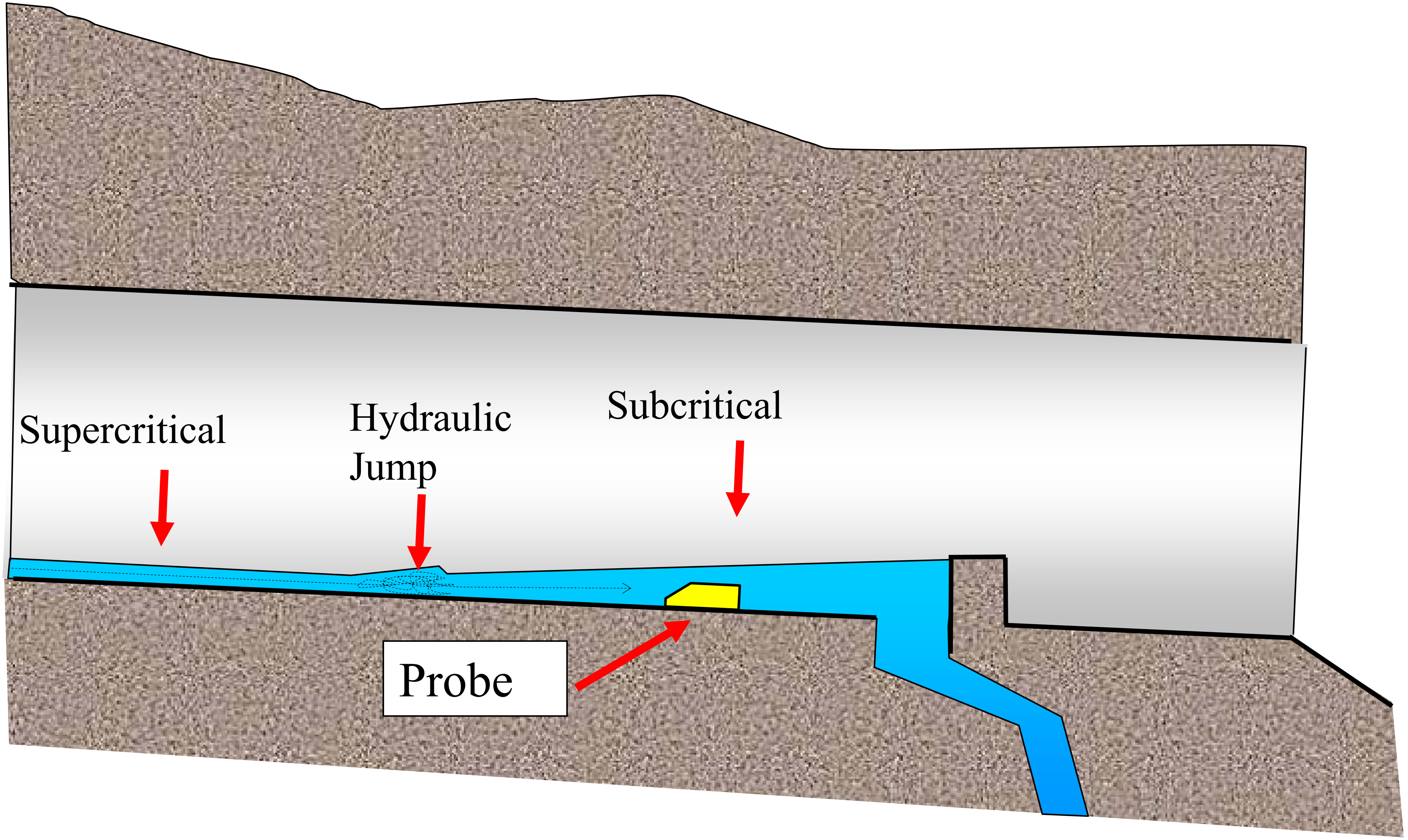
Look just out of Camera range

Move to new site or change equipment.

Hydraulic Jump



Hydraulic Jump



Effect of a Diversion Dam on Flow Regime

Inspection Summary

Number of Manholes

- 3-8 per location (average about 5)
- Inspect until two good found

Pictures

- Upstream: 3-5 pictures must be clear
- Downstream
- Manhole
- Site

Decision

- Make it in the office (review meeting)

Inspection Programs are a Critical Success Factor

Potential Errors: Logistical

Experienced Personnel are
a Critical Success Factor

Field Crew Leader

COMPLETION OF SCHEDULED DAILY WORK

All work on the Daily Assignment must be performed prior to returning to the office.

In the event that conditions prevent completion, FCL (Field Crew Leader) must notify the Field Services Manager (FSM) before leaving the project area. If the FSM is unavailable, a voice message must be left in his voice mail. FCL shall attach to turned in paperwork a written description of the reason for non-completion and a list of any paperwork that will be held over to the next visit. This written description of the non-completion shall be initialed by the FSM prior to submission.

SITE IN OPERATION

While at the site, FCL shall ensure that the equipment is operating properly and demonstrate that to EN by the information retrieved.

If the FLC is unfamiliar with the equipment, is unsure how to appropriately demonstrate proper operation, or encounters problems with the equipment operations, the FSM shall be called for instructions. In the event that the FSM is unavailable, the PM (Project Manager) shall be called. Do not leave the site unless

1. You have demonstrated proper operation, or
2. Have notified the FSM or the PM and been told to leave the site, or
3. You have left voice messages with both FSM and PM with no response.

EN (Engineering) shall typically supply a form appropriate to each piece of equipment to assist in demonstrating proper operation. These are typically included in the scheduling packages. Remember it is not enough to confirm that the equipment is operating properly, you must demonstrate this in the data and information that you turn in.

PAPERWORK

All paperwork must be properly completed and submitted in a timely manner. The expectation is that the paperwork will be turned in the day work was performed.

This includes papers, photos, computer files. Paperwork shall be turned into the EN in the one folder or envelope, or to the specified locations on the computer. If directed by the FSM, all data shall be turned over to the FSM for review prior to submission.

Don’t Leave a site until You can demonstrate it is working properly.

Field Crew Leader	Problem
F-1	Did not have spare meters on truck
F-2	Did not have essential field equipment on truck
F-3	Did not read schedule before leaving for sites
F-4	New .LIF file not updated into Profile before activation
F-5	No pictures taken at level check
F-6	Bad pictures
F-7	Did not replace battery at required voltage
F-8	Calibration points do not match readings,
F-9	no 2nd DL after adjustment
F-10	Incorrect level check performed
F-11	Incomplete on-site data review (or missed data problem)
F-12	Incomplete special maintenances
F-13	Left site without completing all work
F-14	Left site without documented permission
F-15	Did not turn in signed schedule
F-16	Did not replace damaged or not working equipment
F-17	General Installation error
F-18	Installation error - Scissor jack twisted, or not against pipe
F-19	Installation error - Pressure probe not close to Velocity Probe
F-20	Installation error - Incorrect Offset programmed (esp P+1)
F-21	Installation error - Did not put band at least 12" upstream
F-22	No pipe size or flow direction on manhole sketch
F-23	Cannot tell what meter will read when weir overflows
F-24	Wrong units programmed in meter

Field Services Manager

SCHEDULE OF DAILY WORK

FSM shall provide each FCL with a Daily Assignment of work to be completed that day.

FSM (Field Services Manager) shall review the Project Schedule provided by EN (Engineering). FSM shall assign appropriate resources to the completion of the work. The FSM shall clearly designate on a copy of the Project Schedule the Daily Assignments of work to be performed by each crew on each day. This must be turned in to EN no later than the morning of the day work is performed in the field.

For FCL (Field Crew Leader) failure to complete the Daily Assignment, the FSM shall initial the written description provided by the FCL and write on the form the time of the call in. If the Field Crew Leader failed to call in prior to leaving the project area, this must be clearly stated.

Keep the Field Crews Working!!

SITE IN OPERATION

If the FSM directs a FCL to leave a site without proof of proper operation, a Site Event must be recorded by FSM.

Paper and database forms for Site Events are both available from EN. Failure by a FCL to adequately demonstrate proper operation of the equipment will result in a 2 day Special Maintenance, and may have serious budget implications.

PAPERWORK

The FSM may elect to review the FCL paperwork prior to submission to EN.

The review by the FSM must not delay submission of the paperwork past 8:00 AM the day after the work was performed.

Field Services Manager	Problem
FSM-1	Failure to make needed equipment available to crew
FSM-2	Failure to have necessary reserve equipment and supplies
FSM-3	Failure to resolve Hazardous Gas issue
FSM-4	Failure to resolve site access problem
FSM-5	Failure to resolve Special Equipment problem

Engineering

QA/QC

SCHEDULE OF DAILY WORK

EN (Engineering) shall prepare a Project Schedule and ensure that each crew completed Daily Assignments.

Each Project Schedule shall contain the summary list of required items per site. Attached shall be all paperwork for those items, and all Special Maintenance forms.

EN shall report to PM (Project Manager) all deviations from the Daily Assignments, unless FCL (Field Crew Leader) has included a written description of the deviations initialed by the FSM (Field Services Manager).

SITE IN OPERATION

EN shall confirm proper operation of all equipment.

EN shall review all data and information provided by the FCL. In the event that proper operation of the equipment cannot be confirmed by the EN, a 2 day Special Maintenance shall be issued. With flow monitoring equipment, proper operation shall be checked from the review of the data file. With other equipment (samplers, rain gauges) EN is responsible to set forth standards for the demonstration of proper operation.

PAPERWORK

EN must ensure that paperwork is provided for all scheduled work.

EN shall promptly confirm that all paperwork, data and photographs, have been received according to the schedule. After that the paperwork and data shall be processed. Special Maintenances shall be issued for missing work. PM shall be notified (e-mail, fax, or printout) of all Special Maintenances that were not performed by the scheduled completion date.

After each download a copy of all graphs must be review and initialed by either a senior flow monitoring engineer (D.L. or JB.) or the Project Manager. Site Event forms must be completed for all discussions regarding data quality or actions to take (including Under Review).

QA/QC

EN shall establish specific QA/QC documentation including site coefficients, new parameters, etc. This shall be tabulated for all sites, reviewed with the PM, and filed for later reference.

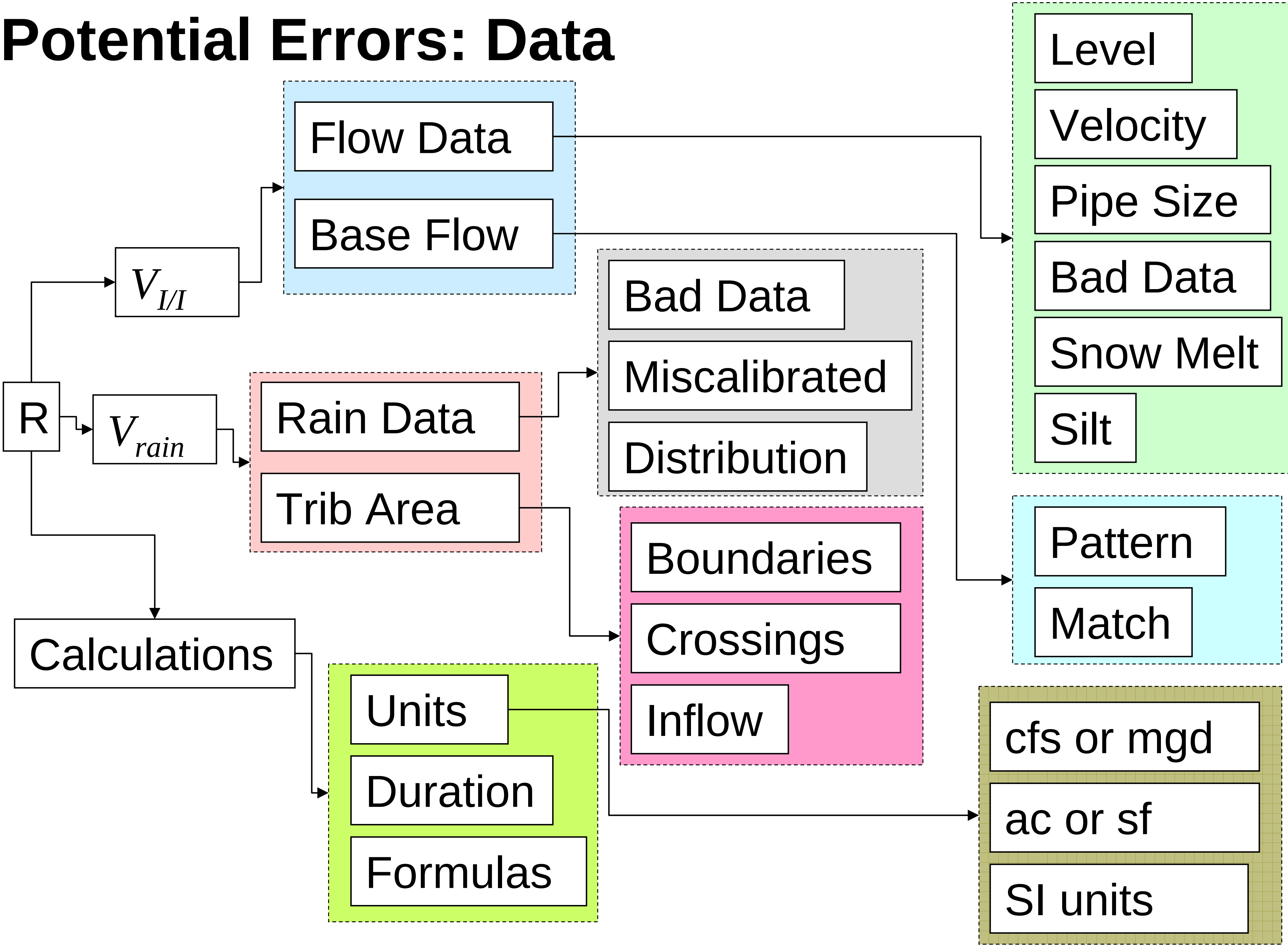
Scheduler	Problem
S-1	Failure to follow up on crew call off
S-3	Did not provide crew with schedule
S-4	Failure to reschedule immediate action sites from call-off
S-5	Exceeding 14 days between level check (or assigned value)
S-6	Failure to respond to Antenna not connect in 3 days

Transfer	Problem
T-1	No data for site in file by Close of Businnes
T-2	No Paperwork transferred by Close of Business
T-3	Pictures have wrong name (dash/underscore, 0/O)
T-4	Photos not renamed and put in folder by close of business

Review	Problem
R-1	Paperwork / pictures not properly re-sized or renamed
R-2	Activities not processed by noon of following day
R-3	Internal Review not completed by close of following day
R-4	SM not closed
R-5	Follow-up SM not issued
R-6	Did not issue SM for Battery issue
R-7	Did not put problem sites in correct data status
R-8	Did not Review Pipe Size after activation

Data	Problem
D-1	All data properly not imported to Profile
D-2	All data not properly imported with correct units
D-3	Missing data not identified or not tracked.
D-4	Calibration points not deleted from meter data
D-5	Critical sites not completed in 48 hours
D-6	Data anomalies not clearly noted
D-7	Failure to Import of ISCO data to Profile
D-8	Failure to note re-occurring problems as site note.

Potential Errors: Data



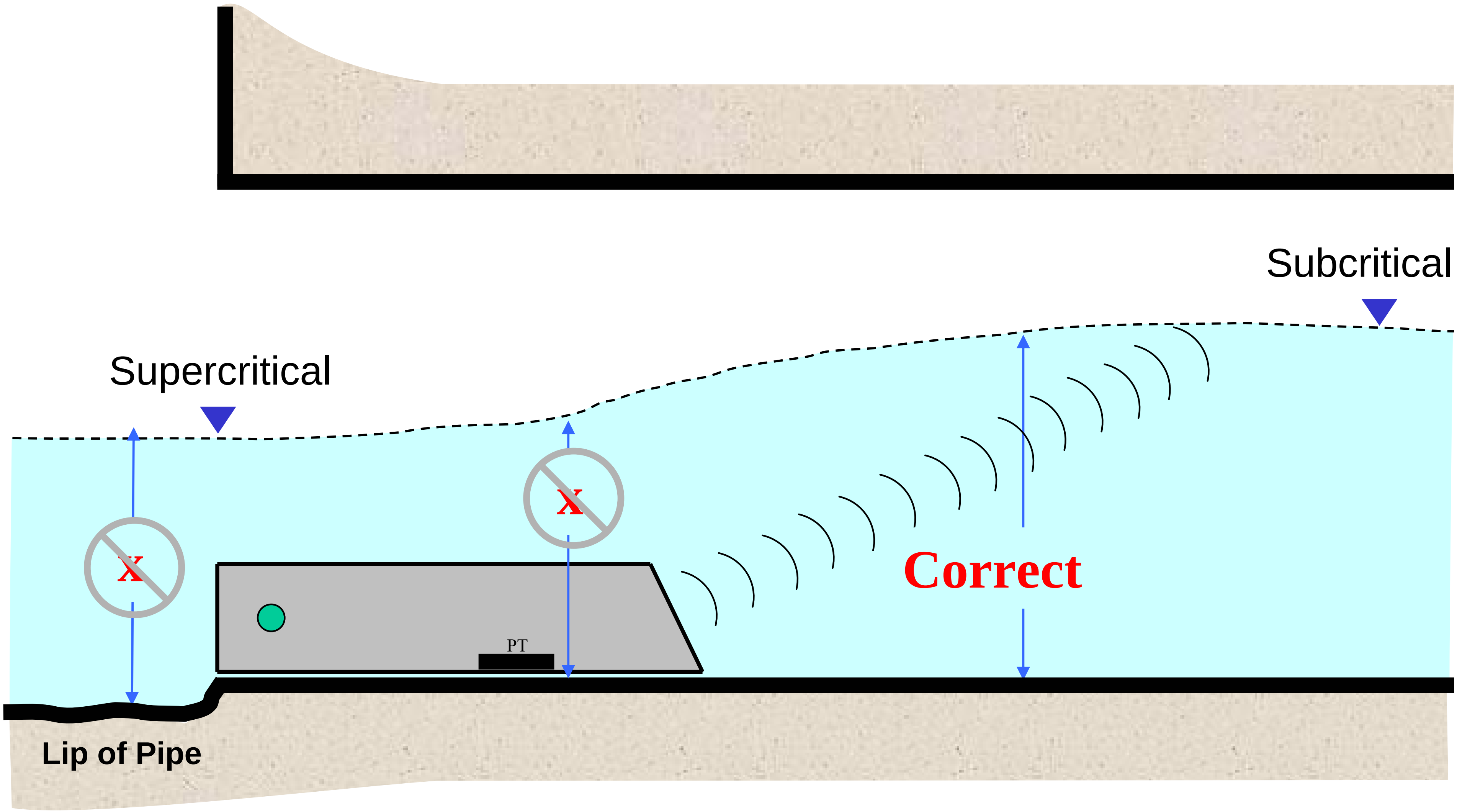
Level

Static Tank Prior to Deployment.

Level

Field Check of Level after Installment

Level



Level measurements should be taken a couple of inches in front of the probe at the location the velocity is measured. Level measurements behind or at the probe are subject to flow pattern changes, particularly downstream because of the lip of pipe .

Level Downstream Underestimated

When the flow changes from subcritical to supercritical, level measurements made downstream or at the probe will significantly underestimate the flow.

Velocity

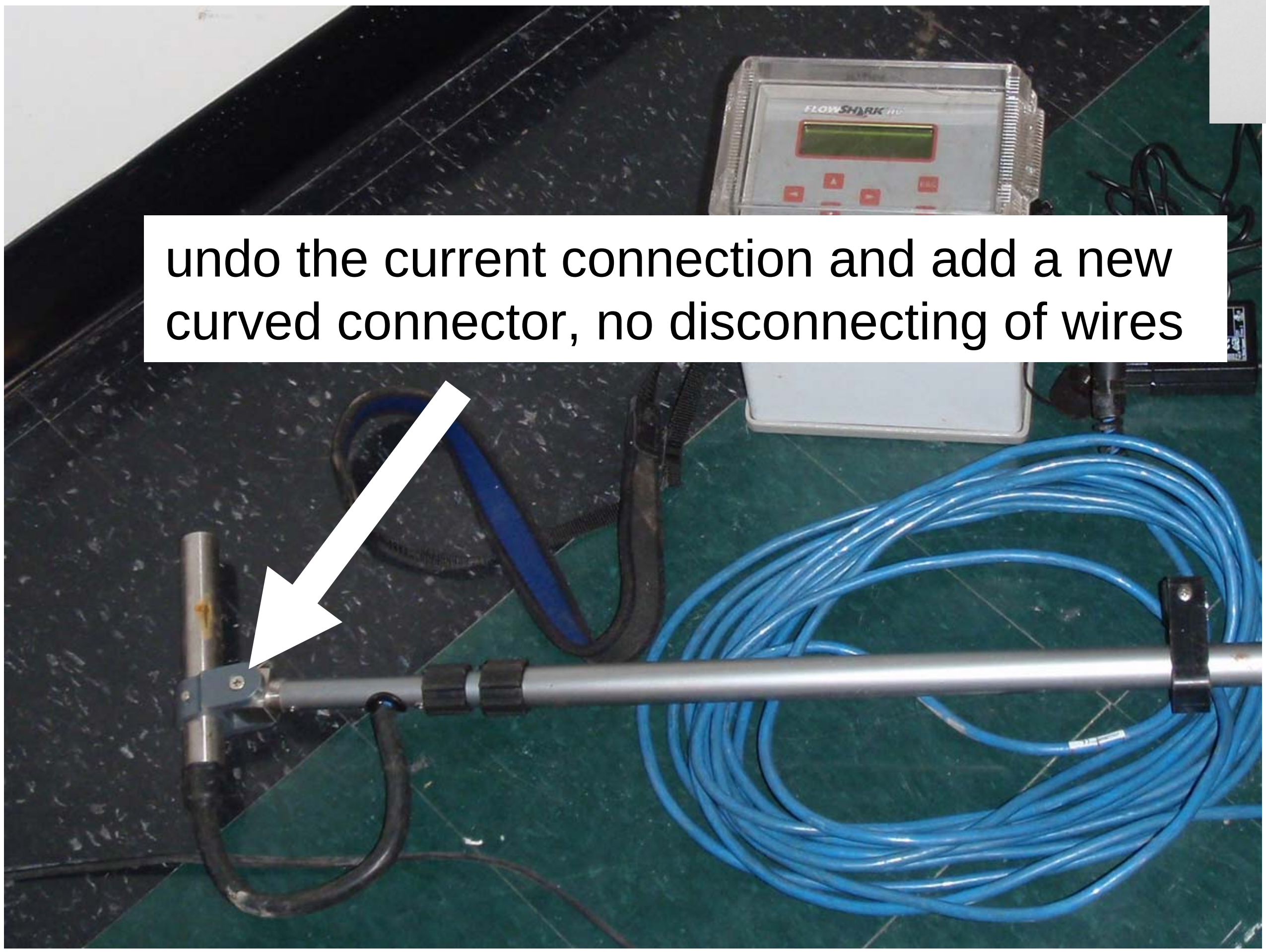
ISCO's Bubbler tube in Lincoln, Nebraska

Velocity - Field Check

PVM works best in 3 or more inches of flow. Profiles of flow should be collected for 5” or over.

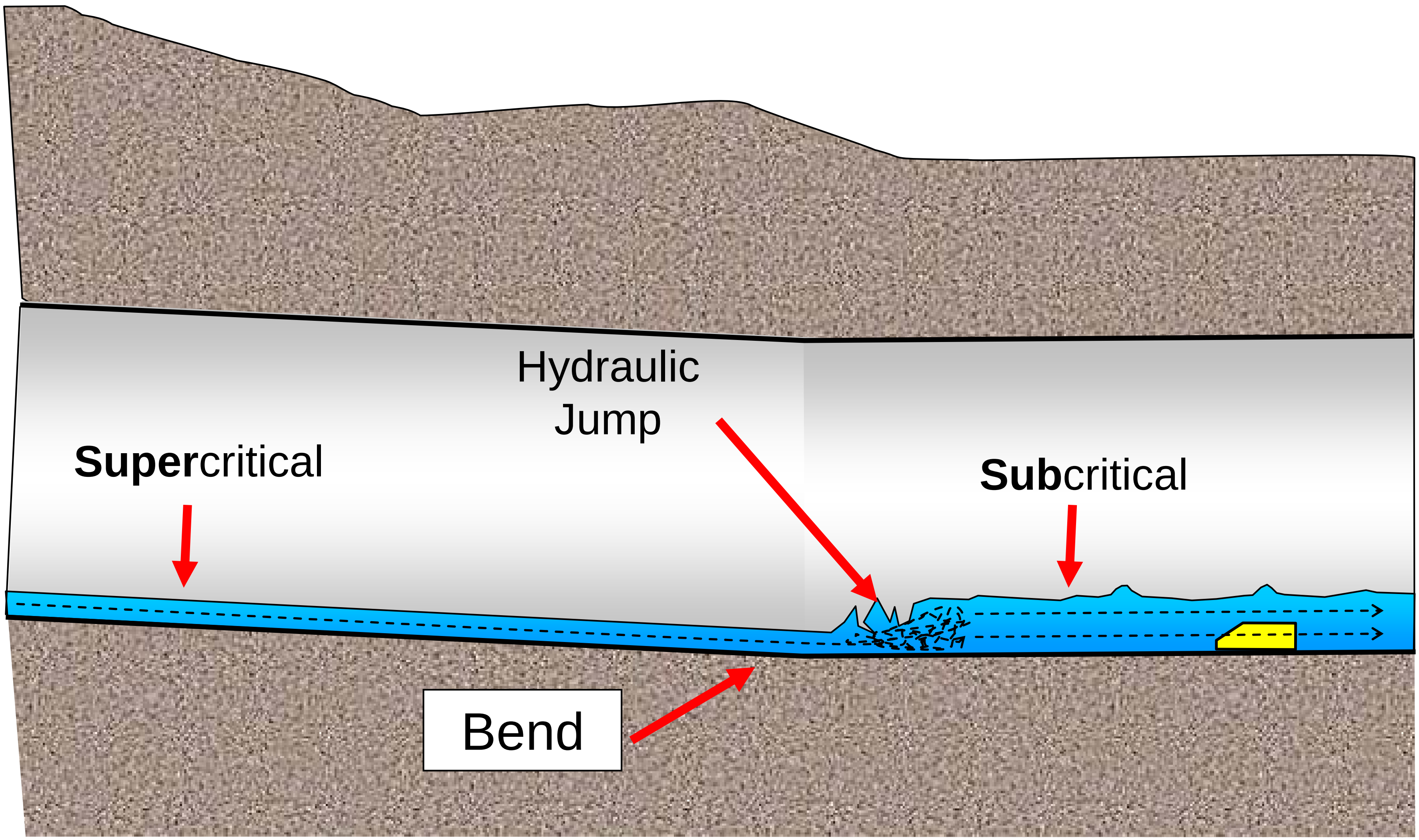
Add Brake Line to MMI’s PVM

Velocity - Field Check



The Flowshark HV is more accurate and can work in lower flows. But it needs to be modified to get in front of the probe

Velocity – Hydraulic Jump



Can I do it Myself?

Recommend Easy to Use Flow Monitors

Must have a Champion

- Must be capable
- Must really want to do it.
- Must inspire field crews to careful work
- Must not have other priority projects.

Should be planning to do ongoing flow monitoring.

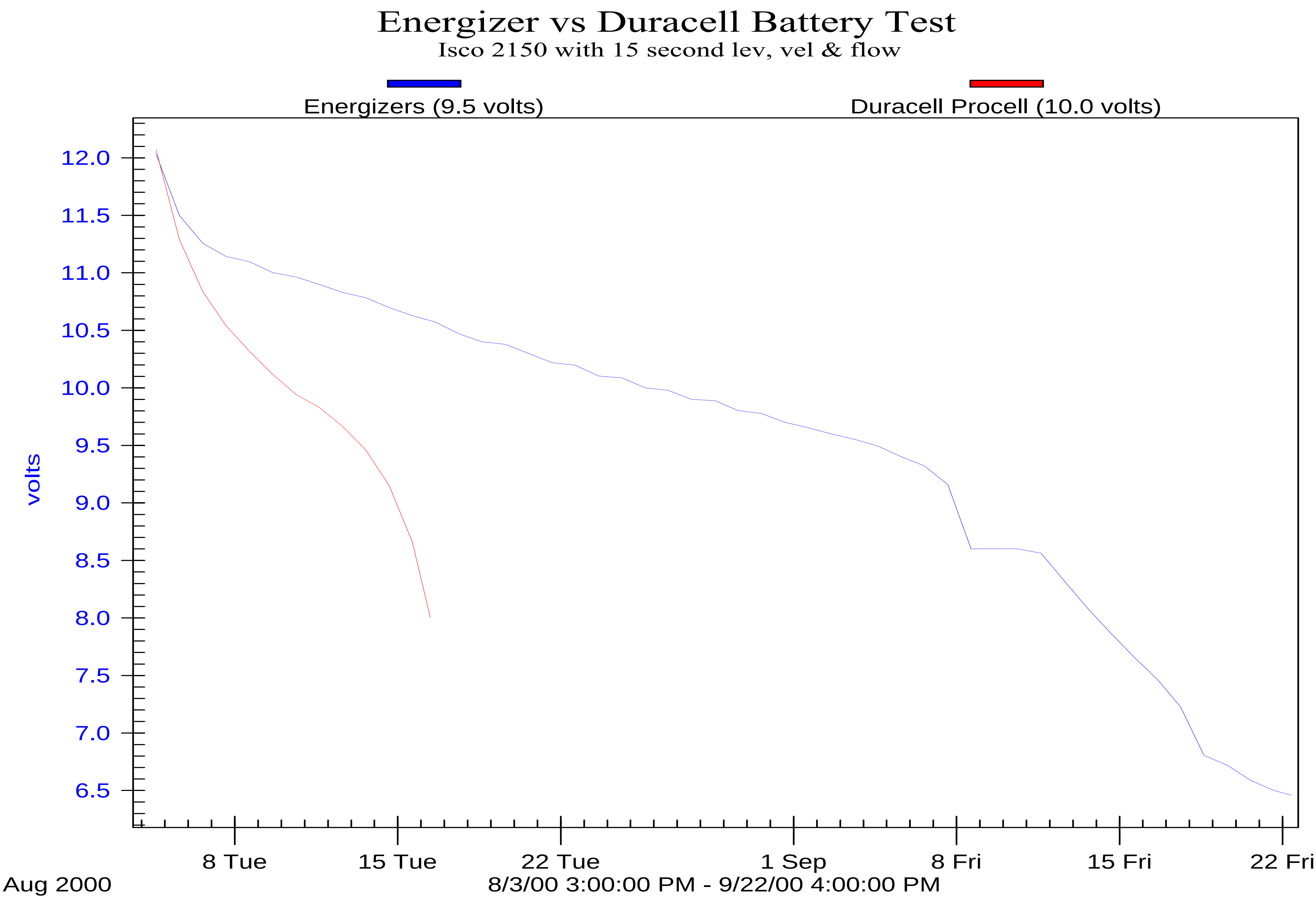
Top Three Critical Success Factors

1.) Having a **Champion**

2.) Using **Experience Personnel**

3.) Having an Effective **Inspection Program**

Batteries


Energizer vs Duracell Battery Test
Isco 2150 with 15 second lev, vel & flow
Energizers (9.5 volts)
Duracell Procell (10.0 volts)
volts
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
8 Tue
15 Tue
22 Tue
1 Sep
8 Fri
15 Fri
22 Fri
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Questions?