EPA Clean Water Act National Compliance Initiative Series

Flow Measurement

Presented Live:

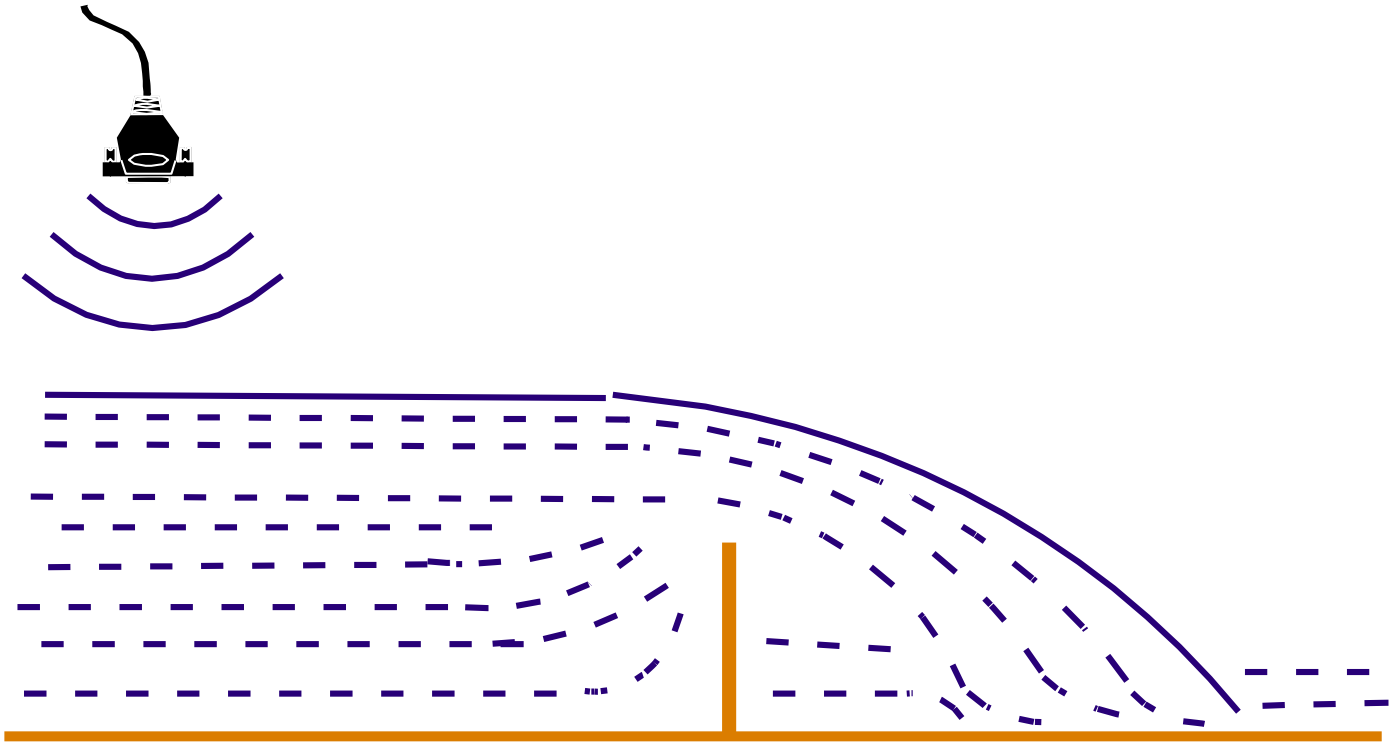
December 8, 2020

US EPA Office of Compliance Technical Assistance Webinar Series

Introduction: Peter Bahor, US EPA Office of Compliance (bahor.peter@epa.gov)

- Webinar series supports the national EPA and state initiative to reduce noncompliance among CWA-NPDES permitted facilities. Focus is on helping wastewater system operators return their facilities to compliance, and those interested in fine-tuning their systems.
- The webinar will be recorded for future viewing.
- A link to download a Certificate of Attendance will be emailed to attendees 24 hours after the webinar's conclusion.
- You will be in "listen only mode."
- Use the chat box to ask questions and to suggest other training ideas.
- Speakers do not necessarily reflect EPA positions or policy.
- We strive for continuous improvement. Please complete the post webinar survey.

Understanding Flow Measurement



Why is it important to have accurate flow at the effluent discharge?

Importance of Accurate Flow

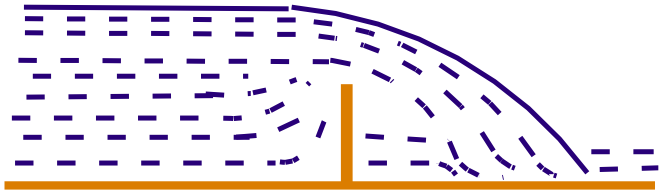
- Permit requirement
- Provides data for mass loading calculations
- Critical for long-term planning and design
- Provides operating and performance data

Requirement

- “Flow measurement systems should be calibrated by an source at least once a year” ***(NPDES Permit).***
- “The flow meter should record to an accuracy of ±10 percent of actual flow” ***(NPDES Permit).***

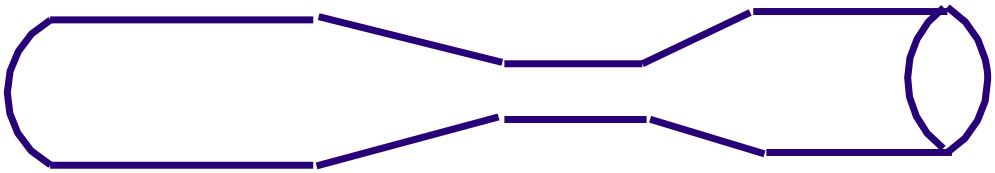
Common Flow Devices:

1. Open Channel Systems



Flumes

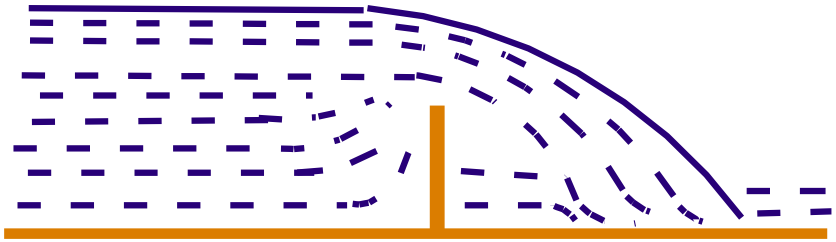
2. Closed Channel Systems



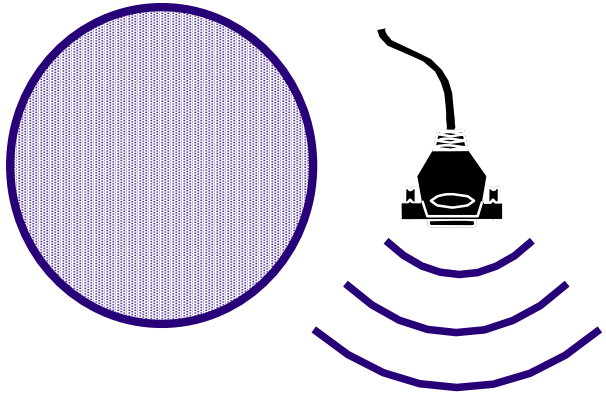
Venturi, Magnetic, Doppler

Flow Measurement Systems Components

- Primary Device



- Secondary Device



Flow Measurement System

Primary Device (Parshall Flume)

Secondary Device: (Flow sensor, Chart Recorder and Totalizer)

Open Channel Systems

- **Flumes**

Common flumes:

- Parshall Flume
- Palmer-Bowlus Flume
- H-Flume

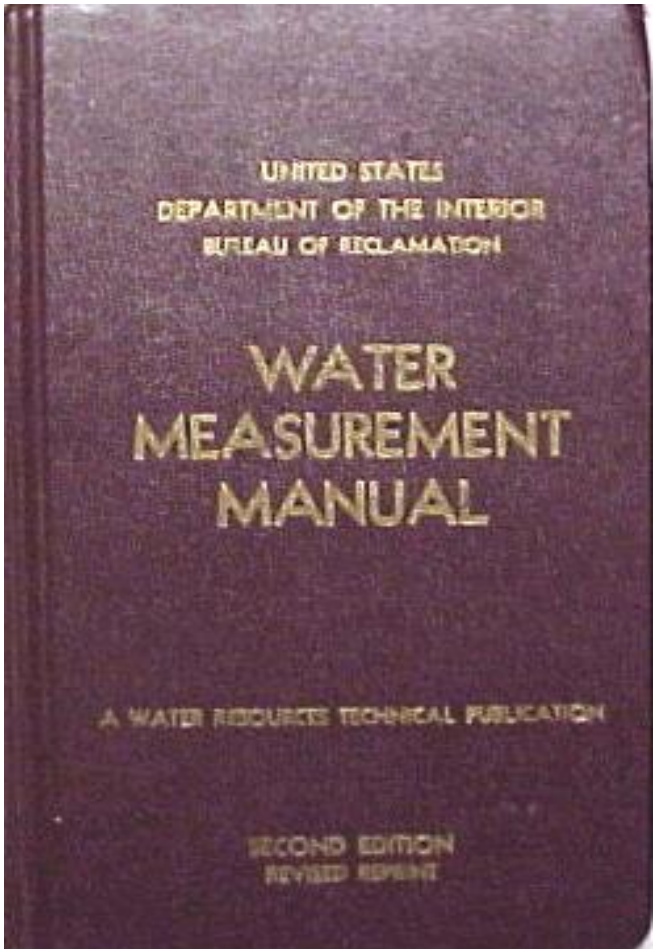
- **Weirs**

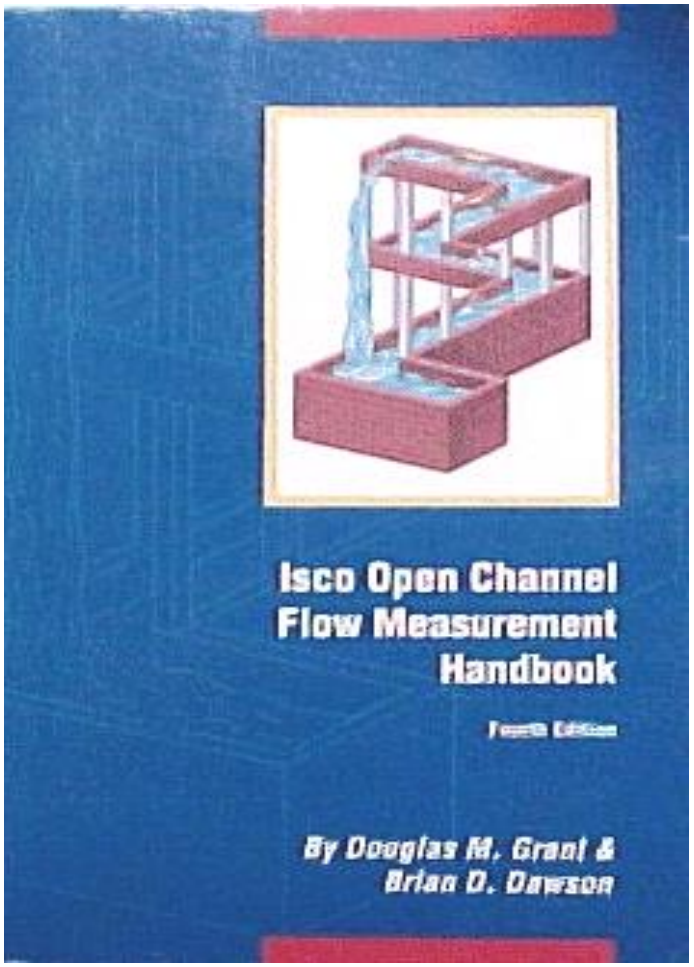
Common weirs:

- Rectangular Weir
- V-notch Weir
- Trapezoidal (Cipoletti) Weir

USDI Water Measurement Manual (Cited Reference)

ISCO Flow Measurement Handbook (Guidance)

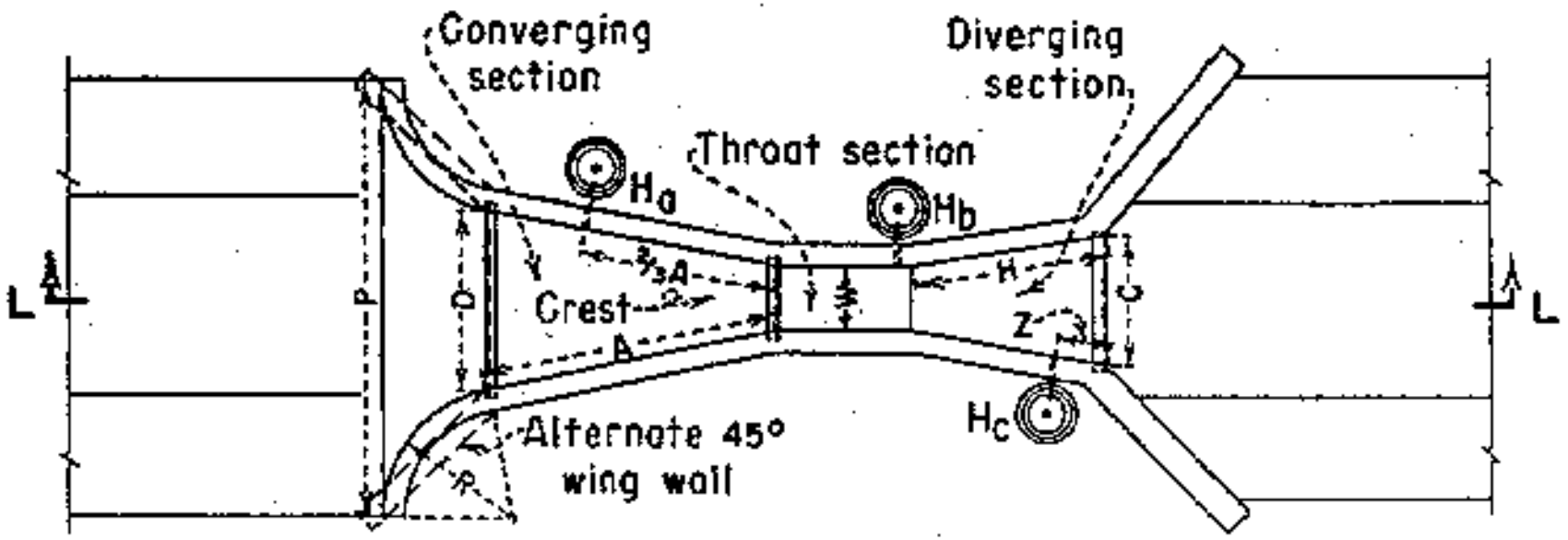




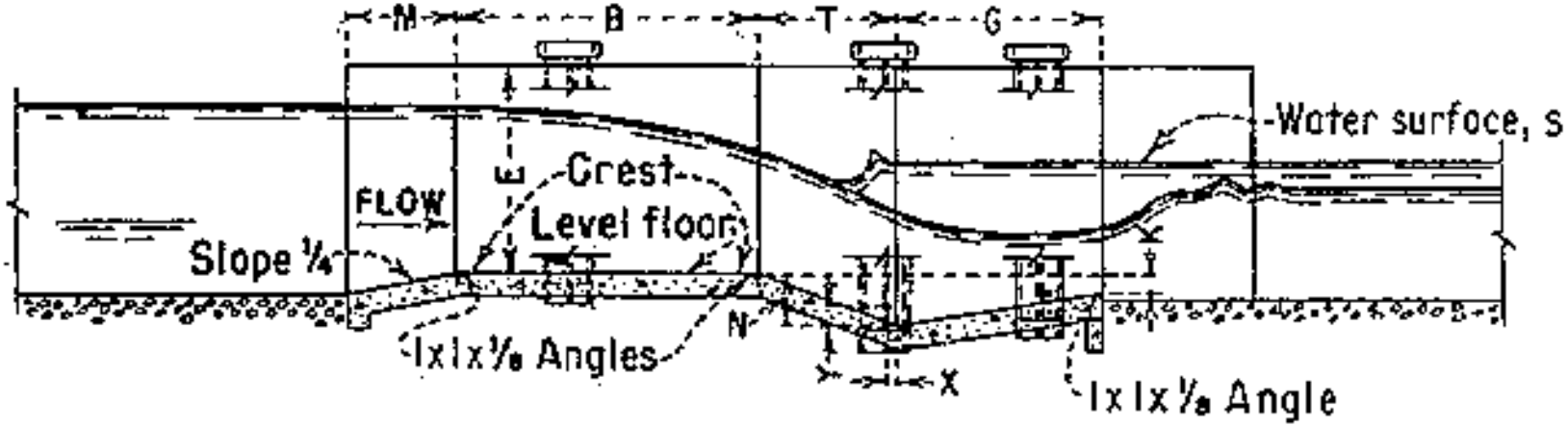
www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/cover.html

Parshall Flumes

- Very common in WTPPs
- Self-cleaning
- Operate under wide range of flows
- Simple to check for calibration



PLAN



SECTION L-L

	W		A		⅔A		B		C		D		E		T		G		H		K		M		N		P		R		X		Y		Z		FREE-FLOW CAPACITY	
																																					MINIMUM	MAXIMUM
	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	SEC.-FT.	SEC.-FT.
[2]	0	1[1]	1	2 3/32	0	9 17/32	1	2	0	3 31/32	0	6 19/32	0	6 to 9	0	3	0	8	0	8 1/8	0	3/4	-	-	0	1 1/8		-	-		0	5/16	0	1/2	0	1/8	0.01	0.19
		2[1]	1	4 5/16		10 7/8	1	4		5 5/16		8 13/32		6 to 10		4 1/2		10		10 1/8		7/8		-		1 11/16		-	-			5/8		1		1/4	.02	.47
		3[1]	1	6 3/8	1	1/4	1	6		7		10 3/16	1 to 1 1/2			6	1	0	1	5/32		1	-			2 1/4		-	-			1		1 1/2		1/2	.03	1.13
[3]	0	6	2	7/16	1	4 5/16	2	0	1	3 1/2	1	3 5/8	2	0	1	0	2	0	-		0	3	1	0	0	4 1/2	2	11 1/2	1	4	0	2	0	3	-		.05	3.9
		9	2	10 5/8	1	11/8	2	10	1	3	1	10 5/8	2	6	1	0	1	6	-			3	1	0		4 1/2	3	6 1/2	1	4		2		3	-		.09	8.9
	1	0	4	6	3	0	4	4 7/8	2	0	2	9 1/4	3	0	2	0	3	0	-			3	1	3		9	4	10 3/4	1	8		2		3	-		.11	16.1
	1	6	4	9	3	2	4	7 7/8	2	6	3	4 3/8	3	0	2	0	3	0	-			3	1	3		9	5	6	1	8		2		3	-		.15	24.6
	2	0	5	0	3	4	4	10 7/8	3	0	3	11 1/2	3	0	2	0	3	0	-			3	1	3		9	6	1	1	8		2		3	-		.42	33.1
	3	0	5	6	3	8	5	4 3/4	4	0	5	1 7/8	3	0	2	0	3	0	-			3	1	3		9	7	3 1/2	1	8		2		3	-		.61	50.4
	4	0	6	0	4	0	5	10 5/8	5	0	6	4 1/4	3	0	2	0	3	0	-			3	1	6		9	8	10 3/4	2	0		2		3	-		1.3	67.9
	5	0	6	6	4	4	6	4 1/2	6	0	7	6 3/8	3	0	2	0	3	0	-			3	1	6		9	10	1 1/4	2	0		2		3	-		1.6	85.6
	6	0	7	0	4	8	6	10 3/8	7	0	8	9	3	0	2	0	3	0	-			3	1	6		9	11	3 1/2	2	0		2		3	-		2.6	103.5
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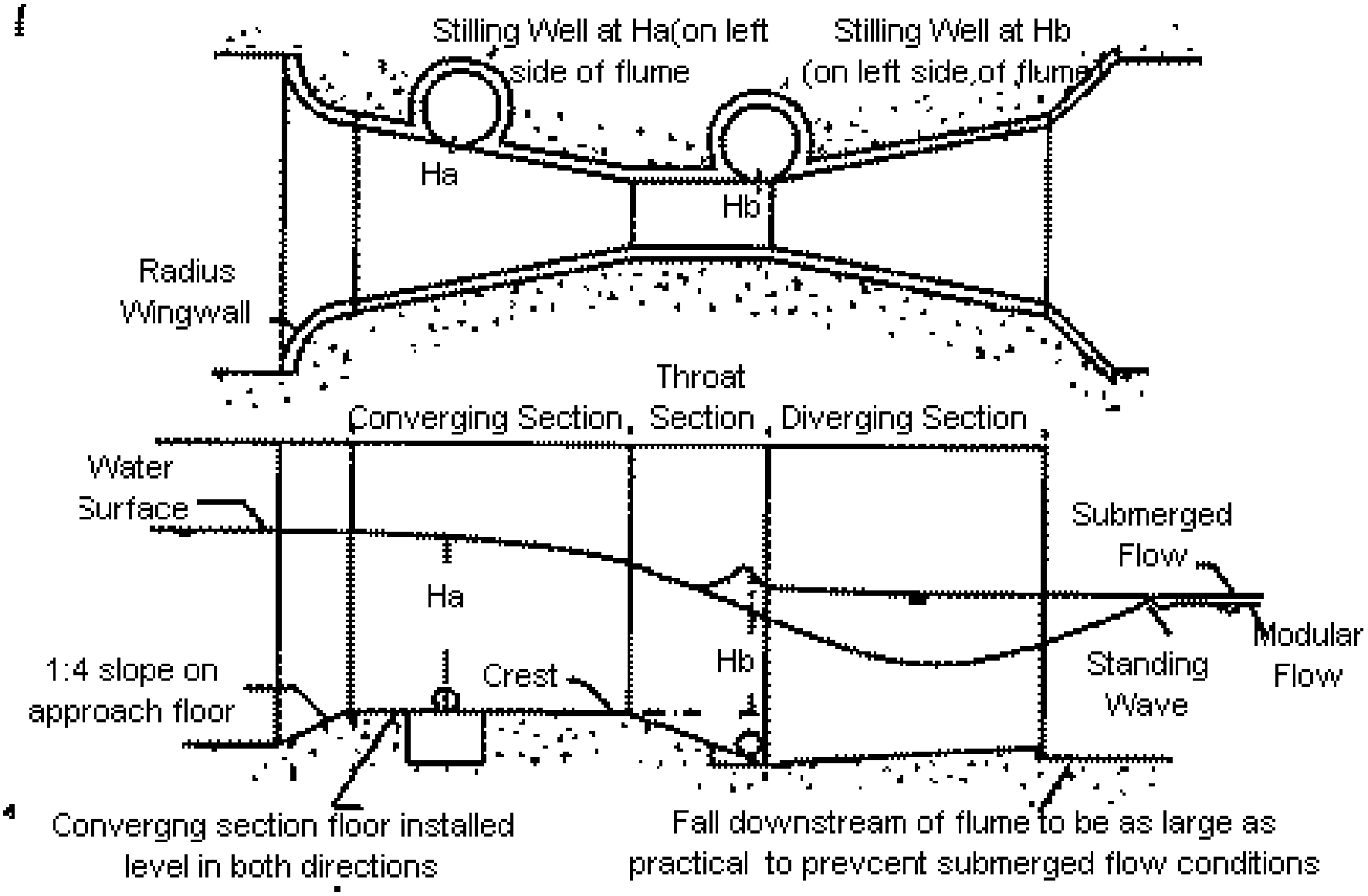
[4]	10	0	-		6	0	14	0	12	0	15	7 1/4	4	0	3	0	6	0	-		0	6	-		1	1 1/2	-		-		0	9	1	0	-		6	200
	12	0	-		6	8	16	0	14	8	18	4 3/4	5	0	3	0	8	0	-			6	-		1	1 1/2	-		-			9	1	0	-		8	350
	15	0	-		7	8	25	0	18	4	25	0	6	0	4	0	10	0	-			9	-		1	6	-		-			9	1	0	-		8	600
	20	0	-		9	4	25	0	24	0	30	0	7	0	6	0	12	0	-		1	0	-		2	3	-		-			9	1	0	-		10	1000
	25	0	-		11	0	25	0	29	4	35	0	7	0	6	0	13	0	-		1	0	-		2	3	-		-			9	1	0	-		15	1200
	30	0	-		12	8	26	0	34	8	40	4 3/4	7	0	6	0	14	0	-		1	0	-		2	3	-		-			9	1	0	-		15	1500
	40	0	-		16	0	27	0	45	4	50	9 1/2	7	0	6	0	16	0	-		1	0	-		2	3	-		-			9	1	0	-		20	2000
	50	0	-		19	4	27	0	56	8	60	9 1/2	7	0	6	0	20	0	-		1	0	-		2	3	-		-			9	1	0	-		25	3000

[1] Tolerance on throat width (w) ± 1/64 inch; tolerance on other dimensions ± 1/32 inch. Sidewalls of throat must be parallel and vertical.

[2] From Colorado State University Technical Bulletin No. 61.

[3] From U.S. Department of Agriculture Soil Conservation Circular No. 843.

[4] From Colorado State University Bulletin No. 426-A


Stilling Well at Ha(on left side of flume
Stilling Well at Hb (on left side,of flume
Ha
Hb
Radius Wingwall
Converging Section
Throat Section
Diverging Section
Water Surface
Ha
Hb
Submerged Flow
Modular Flow
Standing Wave
1:4 slope on approach floor
Crest
Convergng section floor installed level in both directions
Fall downstream of flume to be as large as practical to prevcent submerged flow conditions

When submergence is a problem

- 50 % for flumes 1, 2, and 3 inches wide
- 60 % for flumes 6 and 9 inches wide
- 70 % for flumes 1 to 8 feet wide
- 80 percent for flumes 8 to 50 feet wide

- At 95 % the flume is no longer useable

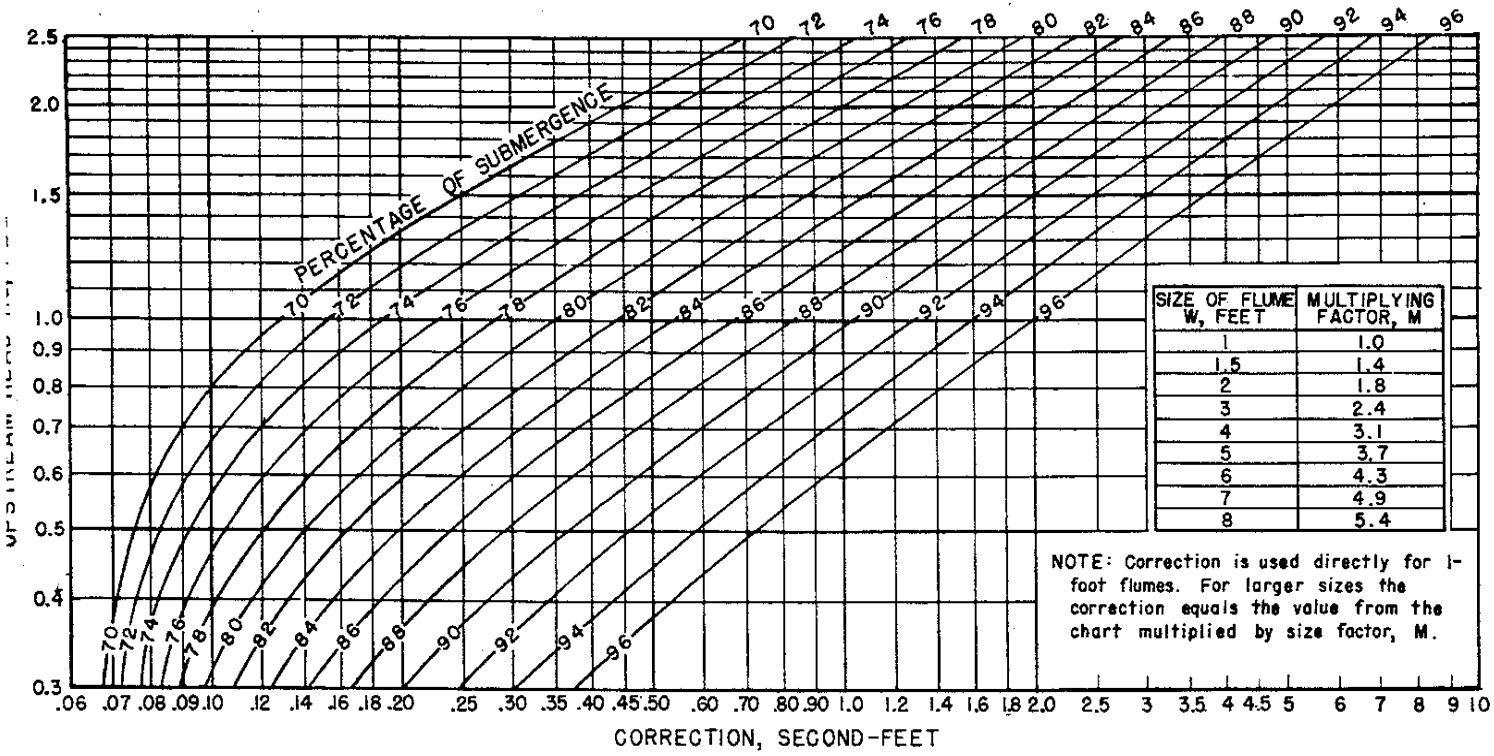


Figure 28.—Diagram for determining correction to be subtracted from free-discharge flow to obtain rate of submerged flow through Parshall flumes 1 to 8 feet wide. 103–D–875. (Courtesy U.S. Soil Conservation Service.)

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Requirements for Parshall Flumes:

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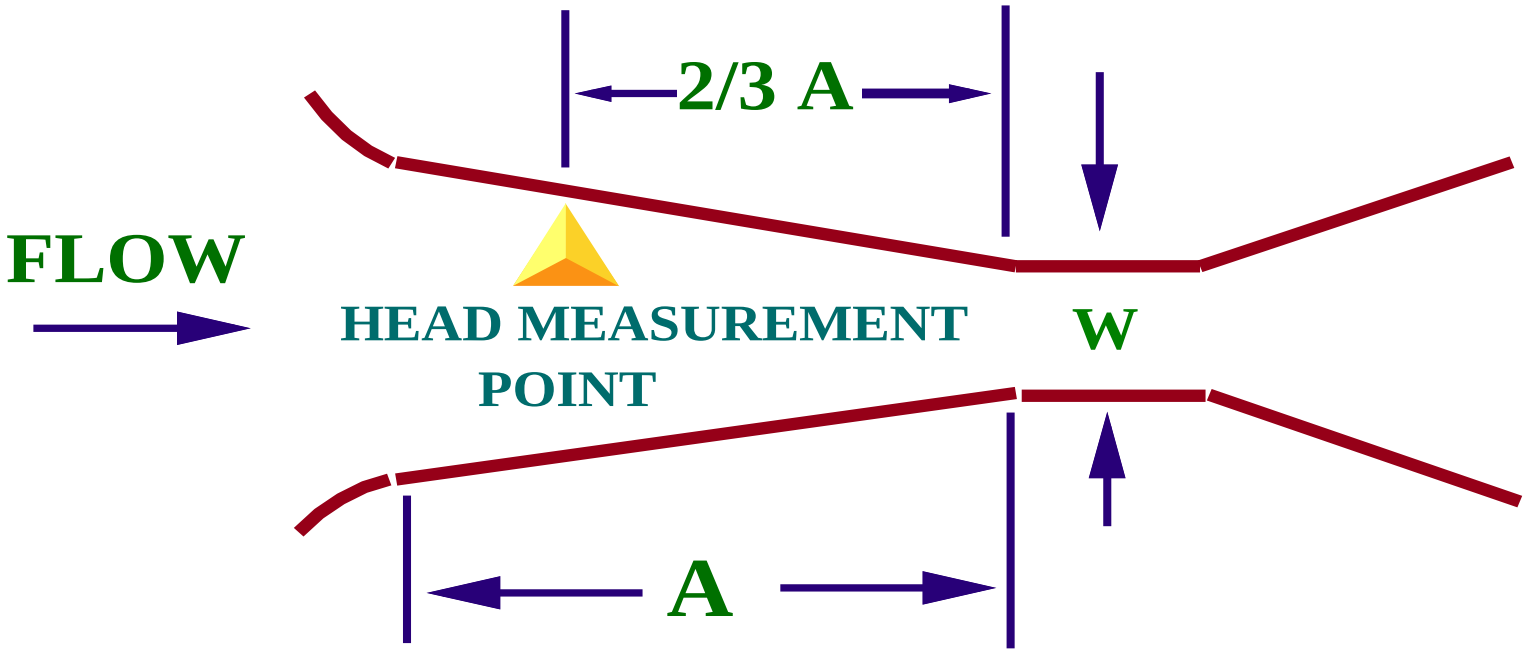
- The approach channel should be straight and uniform

Parshall Flume

Head Measurement: Parshall Flumes



- TOP VIEW -

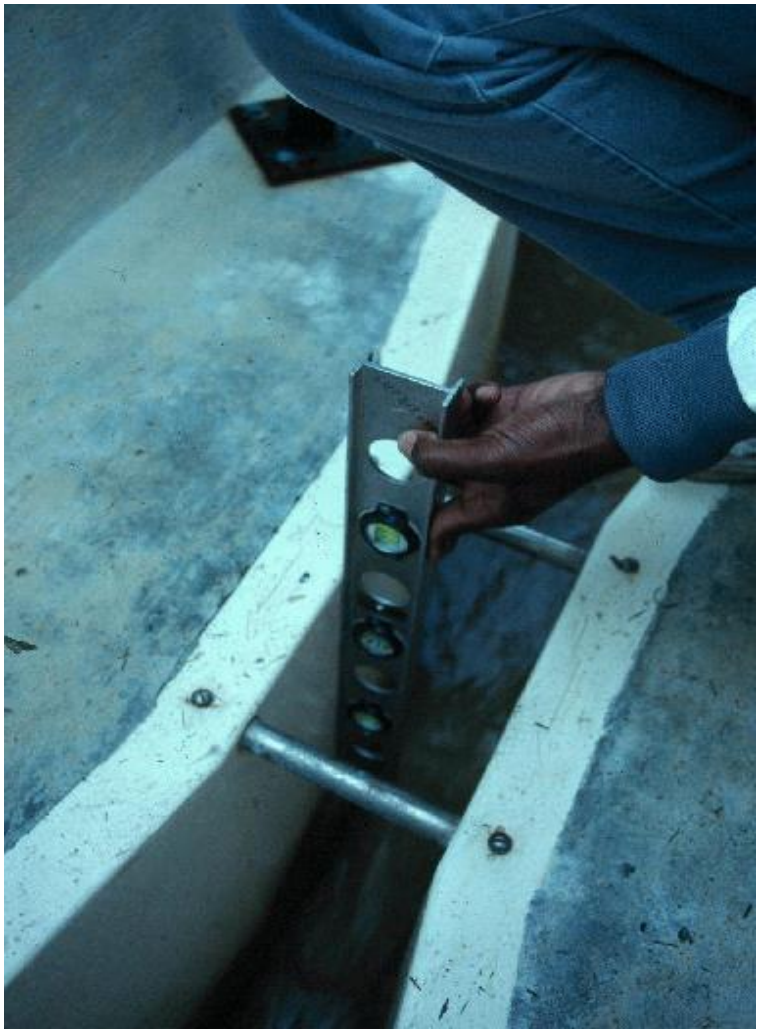
**Also see attached table (4-1A)

Throat width measurement of a Parshall Flume

Measurement of the “2/3 A” location

The flume should be level and the sidewalls vertical.

Parshall Flume




30
9
8
7
5
4
3
2
1
20
9
6
5
4
3
2
1
10
9
8
7

12-9: 3 ft. Parshall Flume Discharge Table

Formulas: $CFS = 12.00H^{1.566}$ $GPS = CFS \times 7.481$

$GPM = CFS \times 448.8$ $MGD = CFS \times 0.6463$

Head Feet	CFS	GPS	GPM	MGD	Head Feet	CFS	GPS	GPM	MGD
0.01	0.0089	0.0662	3.974	0.0057	0.51	4.181	31.27	1876	2.702
0.02	0.0262	0.1961	11.77	0.0169	0.52	4.310	32.24	1934	2.785
0.03	0.0495	0.3701	22.20	0.0320	0.53	4.440	33.22	1993	2.870
0.04	0.0776	0.5807	34.84	0.0502	0.54	4.572	34.20	2052	2.955
0.05	0.1101	0.8236	49.41	0.0712	0.55	4.705	35.20	2112	3.041
0.06	0.1465	1.096	65.74	0.0947	0.56	4.840	36.21	2172	3.128
0.07	0.1865	1.395	83.69	0.1205	0.57	4.976	37.23	2233	3.216
0.08	0.2298	1.719	103.2	0.1485	0.58	5.113	38.25	2295	3.305
0.09	0.2764	2.068	124.0	0.1786	0.59	5.252	39.29	2357	3.394
0.10	0.3260	2.439	146.3	0.2107	0.60	5.392	40.34	2420	3.485
0.11	0.3784	2.831	169.8	0.2446	0.61	5.534	41.40	2483	3.576
0.12	0.4337	3.244	194.6	0.2803	0.62	5.676	42.46	2548	3.669
0.13	0.4916	3.678	220.6	0.3177	0.63	5.820	43.54	2612	3.762
0.14	0.5521	4.130	247.8	0.3568	0.64	5.966	44.63	2677	3.856
0.15	0.6151	4.602	276.1	0.3975	0.65	6.112	45.73	2743	3.950
0.16	0.6805	5.091	305.4	0.4398	0.66	6.260	46.83	2810	4.046
0.17	0.7483	5.598	335.8	0.4836	0.67	6.409	47.95	2877	4.142

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Common Flume Deficiencies

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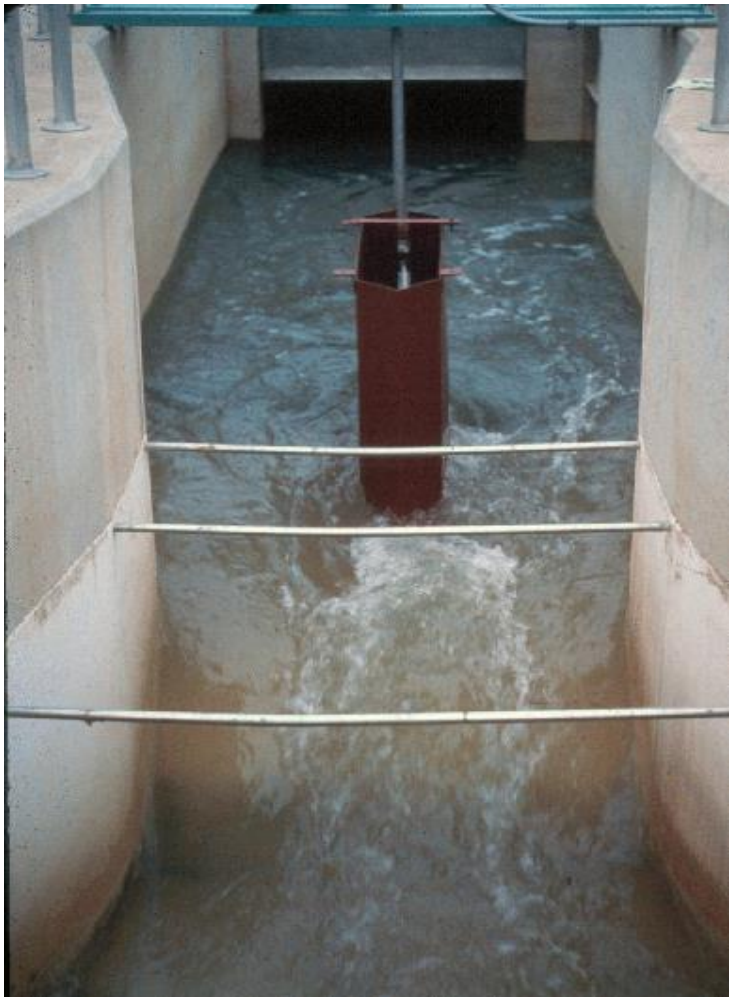
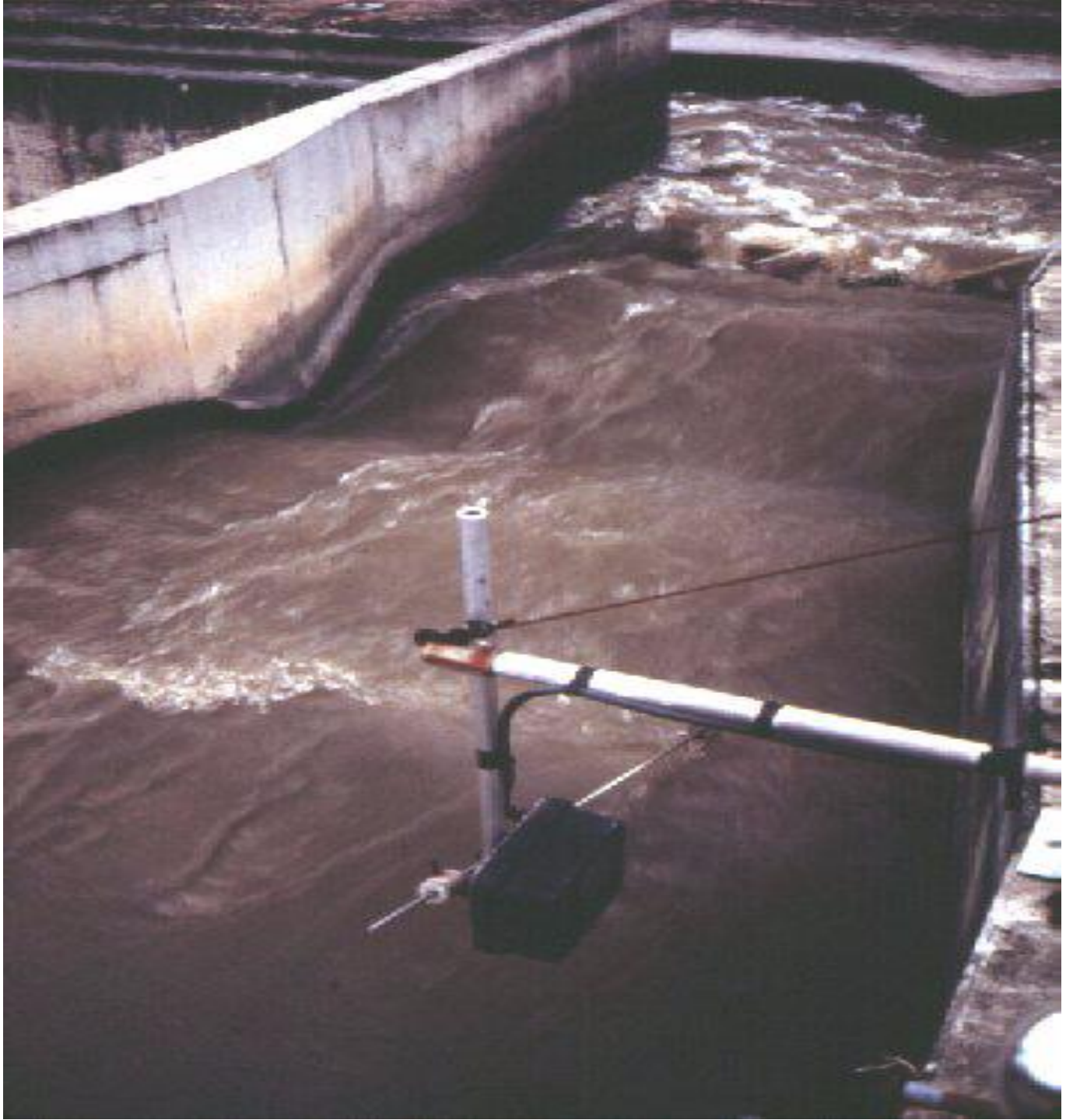
•Turbulent Flow Conditions





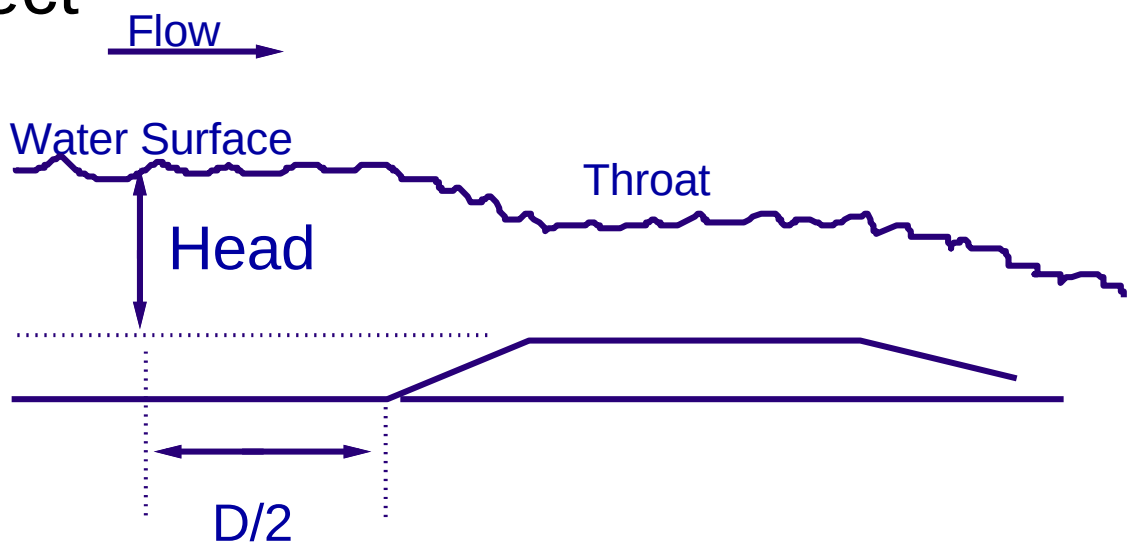
•Turbulent Flow Conditions

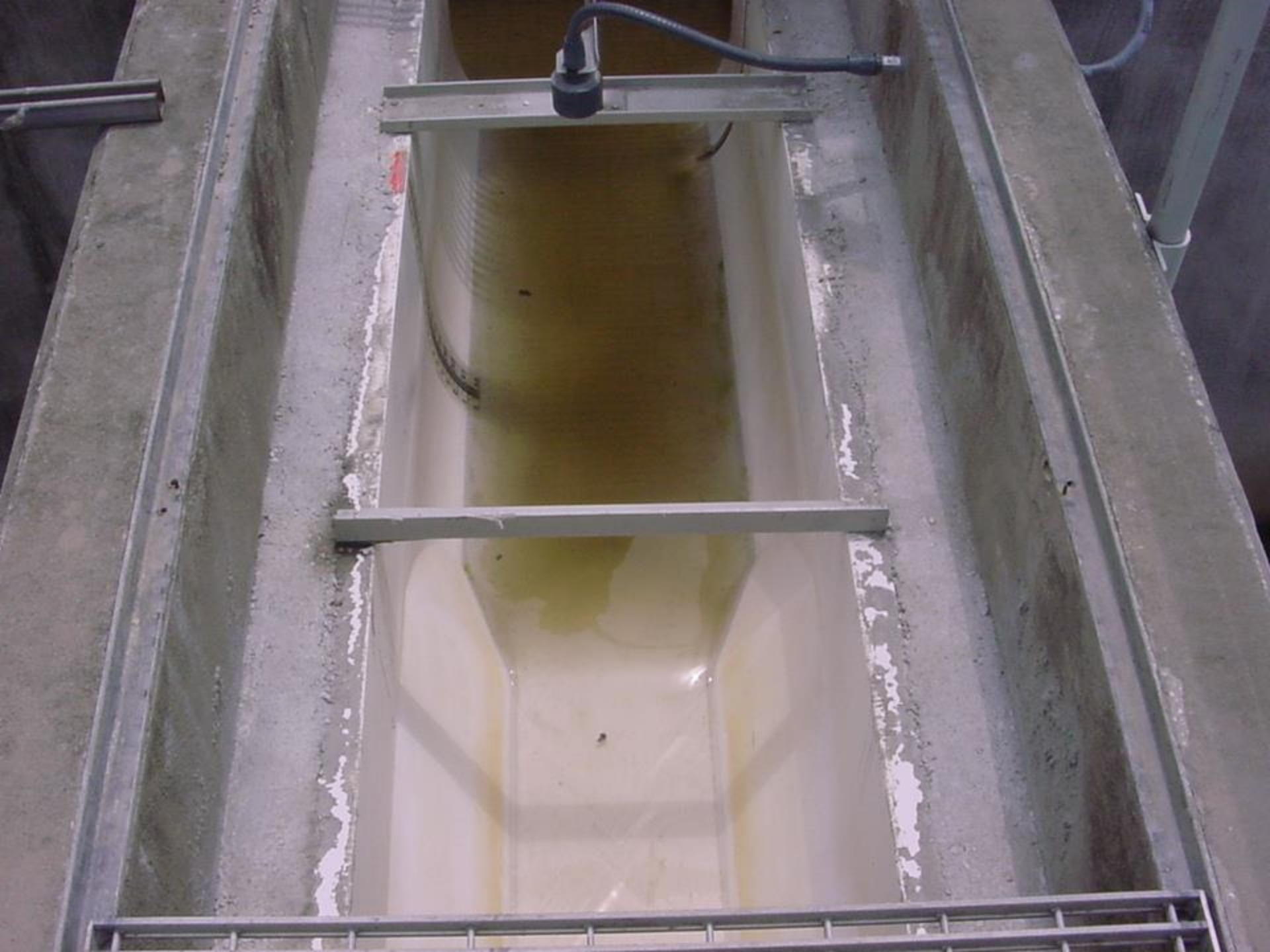
- Grating creates an obstruction, making flow measurements inaccurate.

What's wrong with this system?

Palmer-Bowlus Flumes

- Often used in manholes and temporary installations
- Easy to install in existing conduits
- Check that location and determination of head is correct

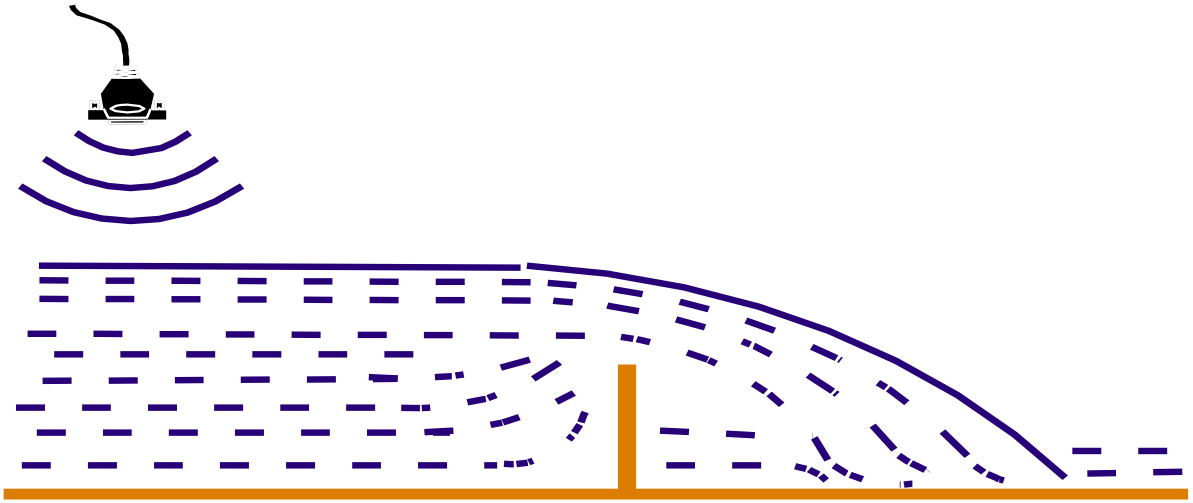


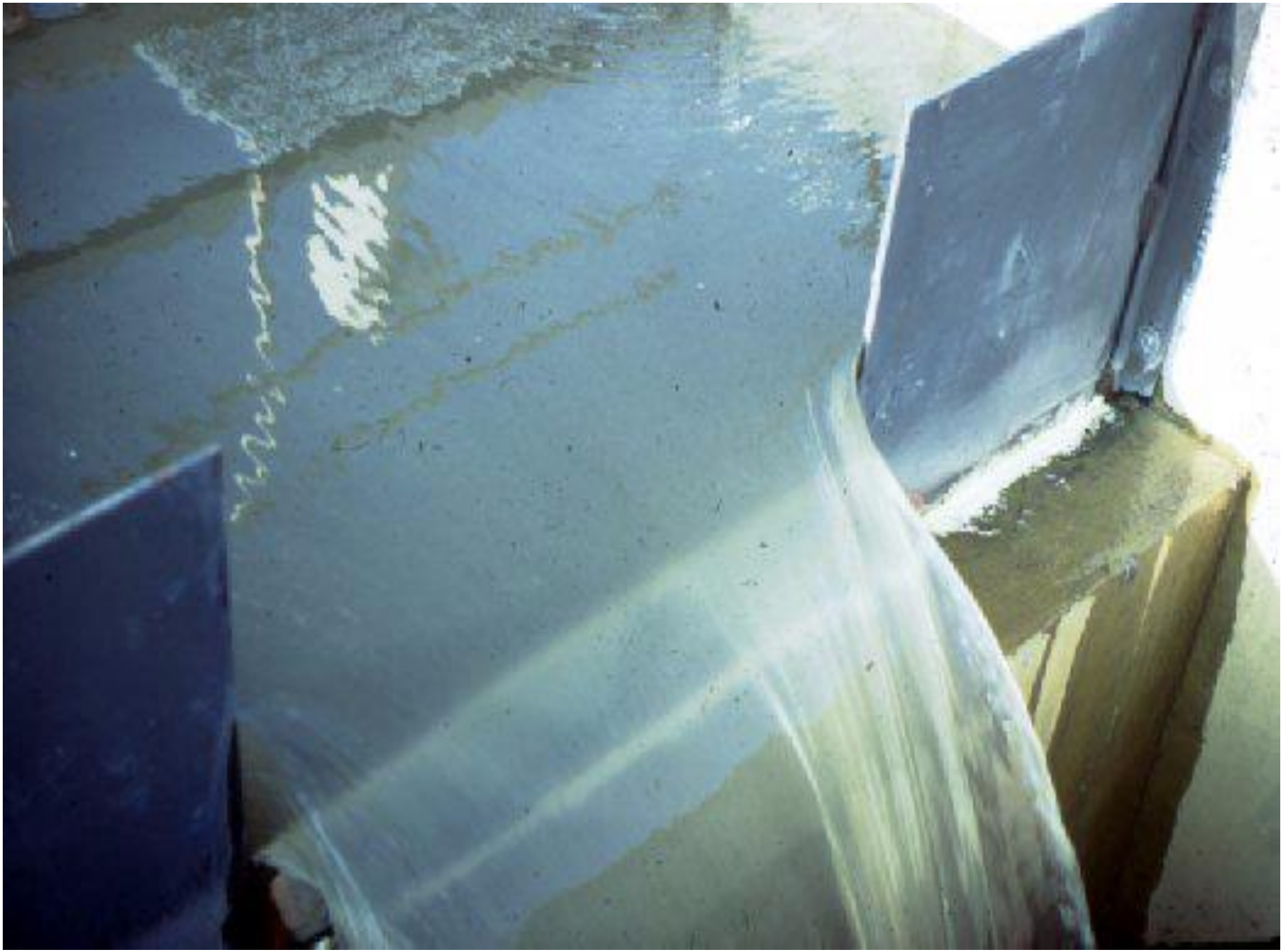


•Stormwater outfall contains debris and sediment in channel floor of H-flume

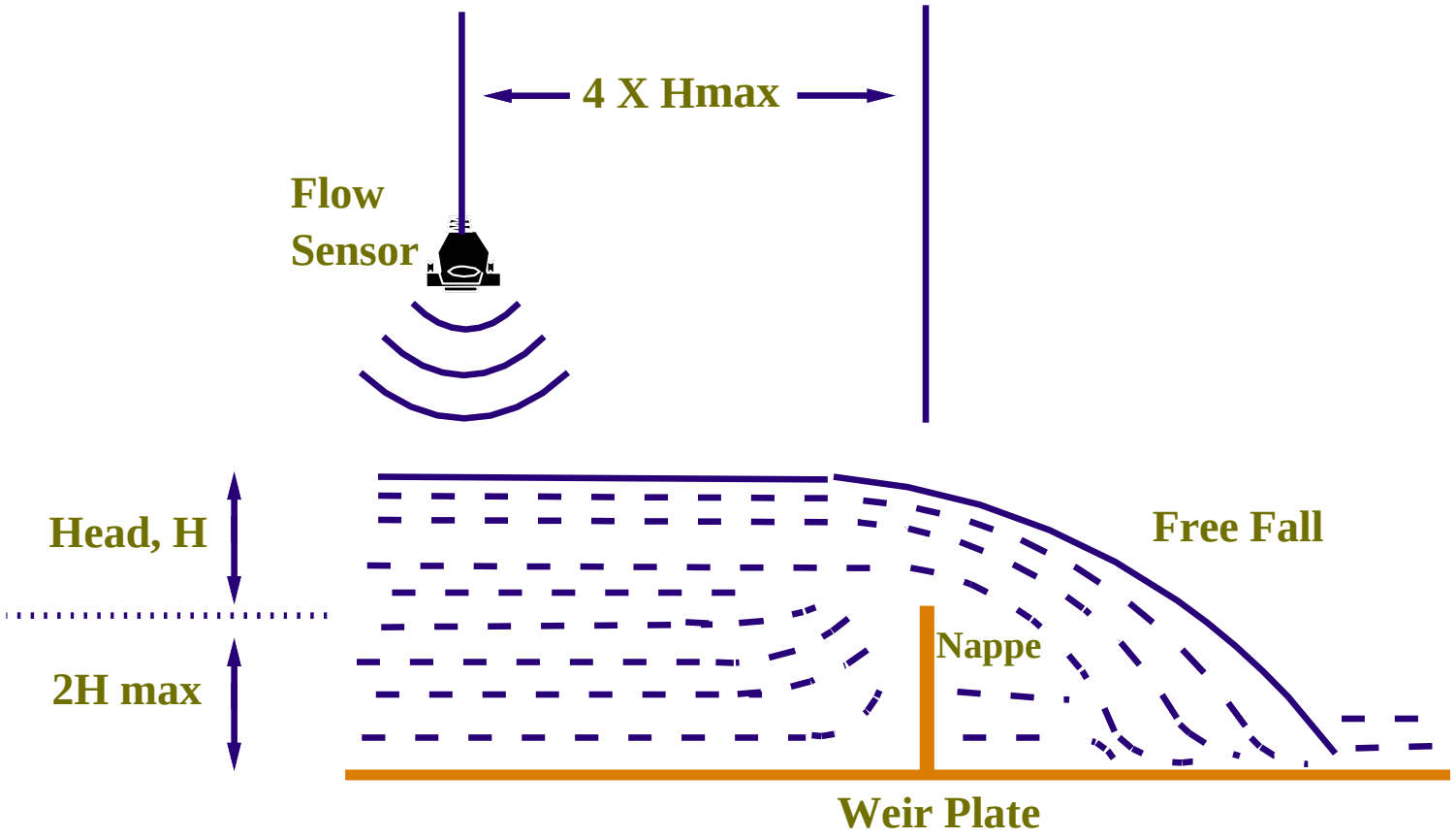
Weirs

- One of the most common open channel flow devices
- Simple to install and inexpensive
- Simple to check for calibration





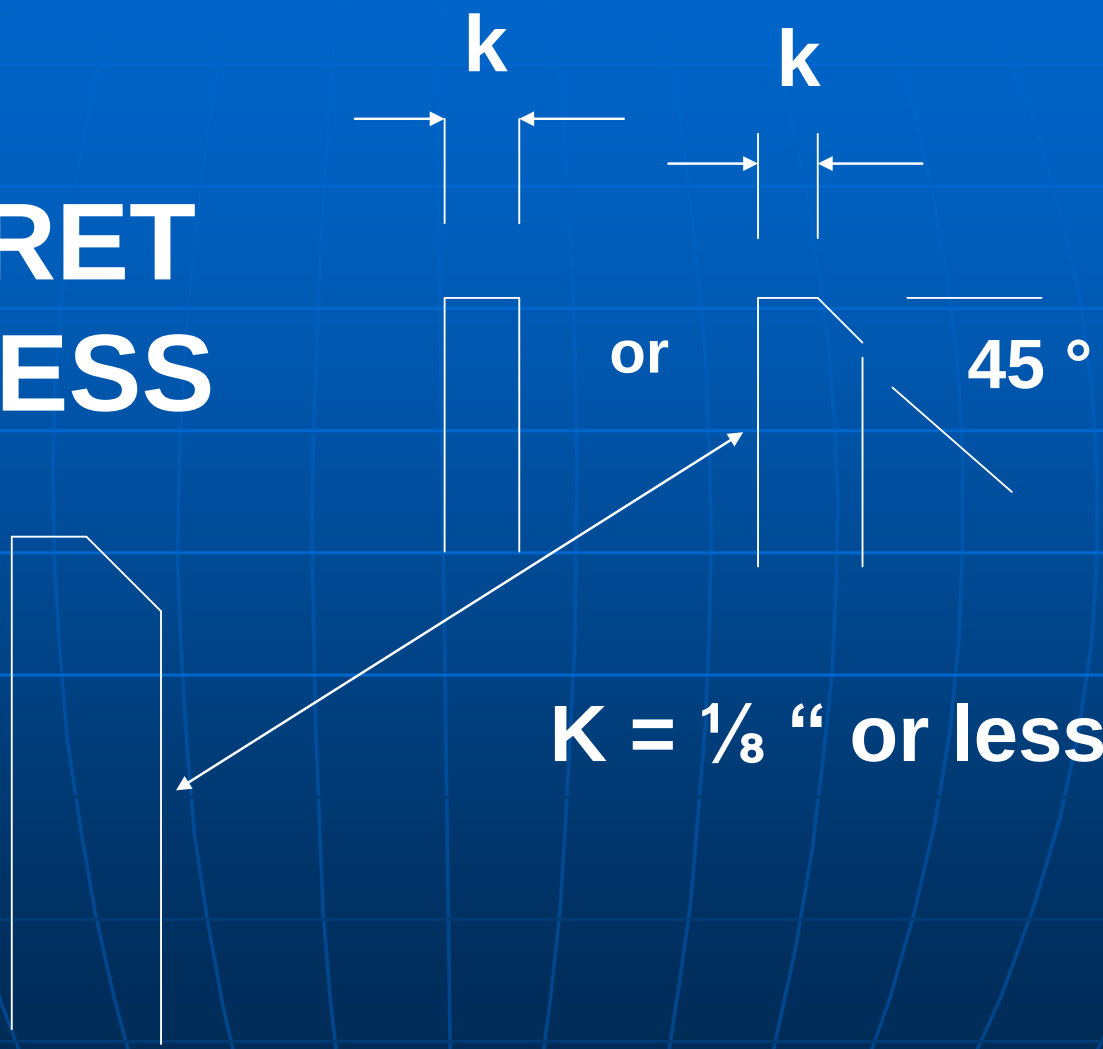
Standard Weir Specifications



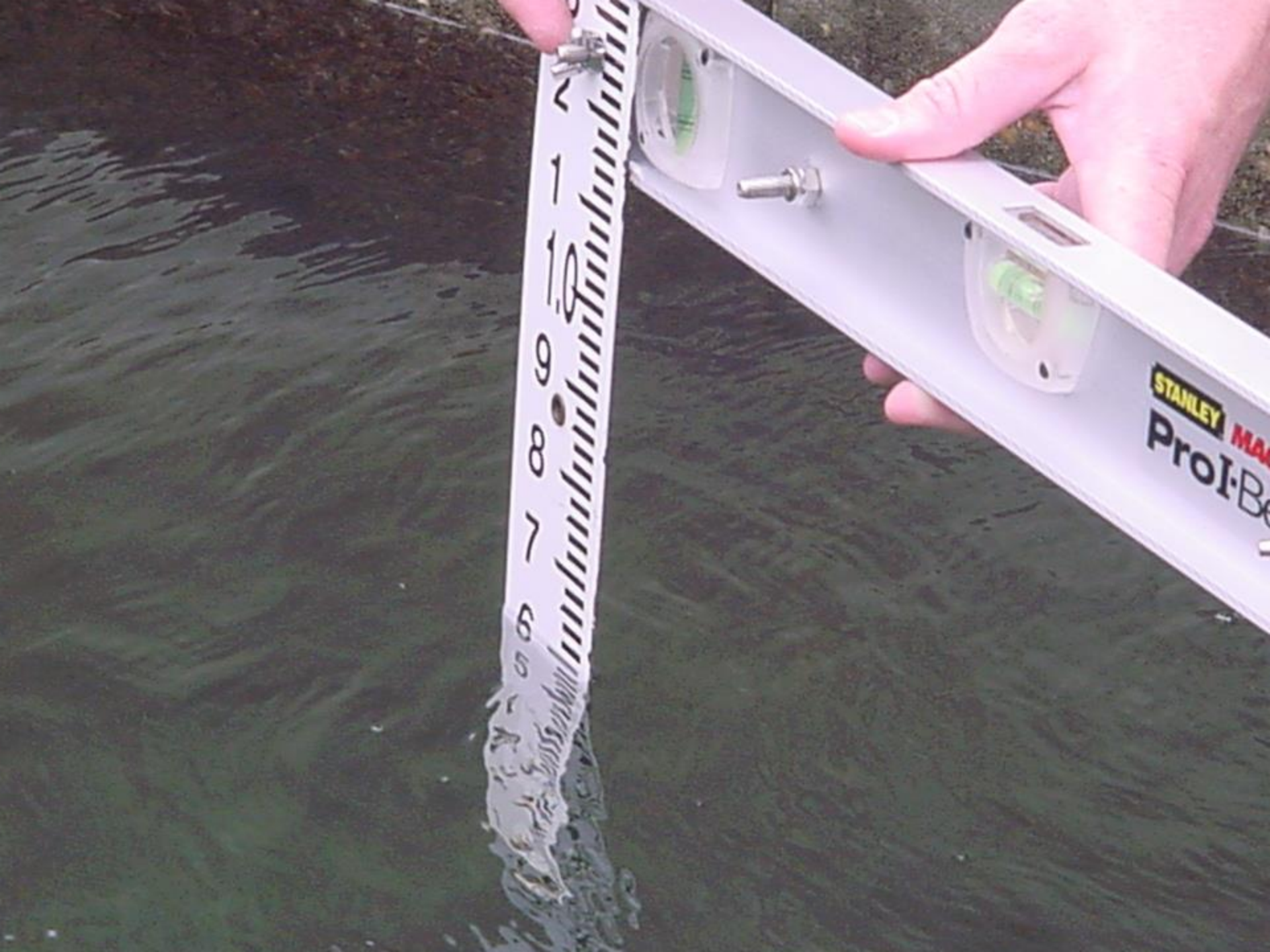
Requirements for Sharp Crested Weirs (continued)

- Weir crest should be 1/8-inch thick or less, or chamfered at 45 degrees so that the water springs free of the weir

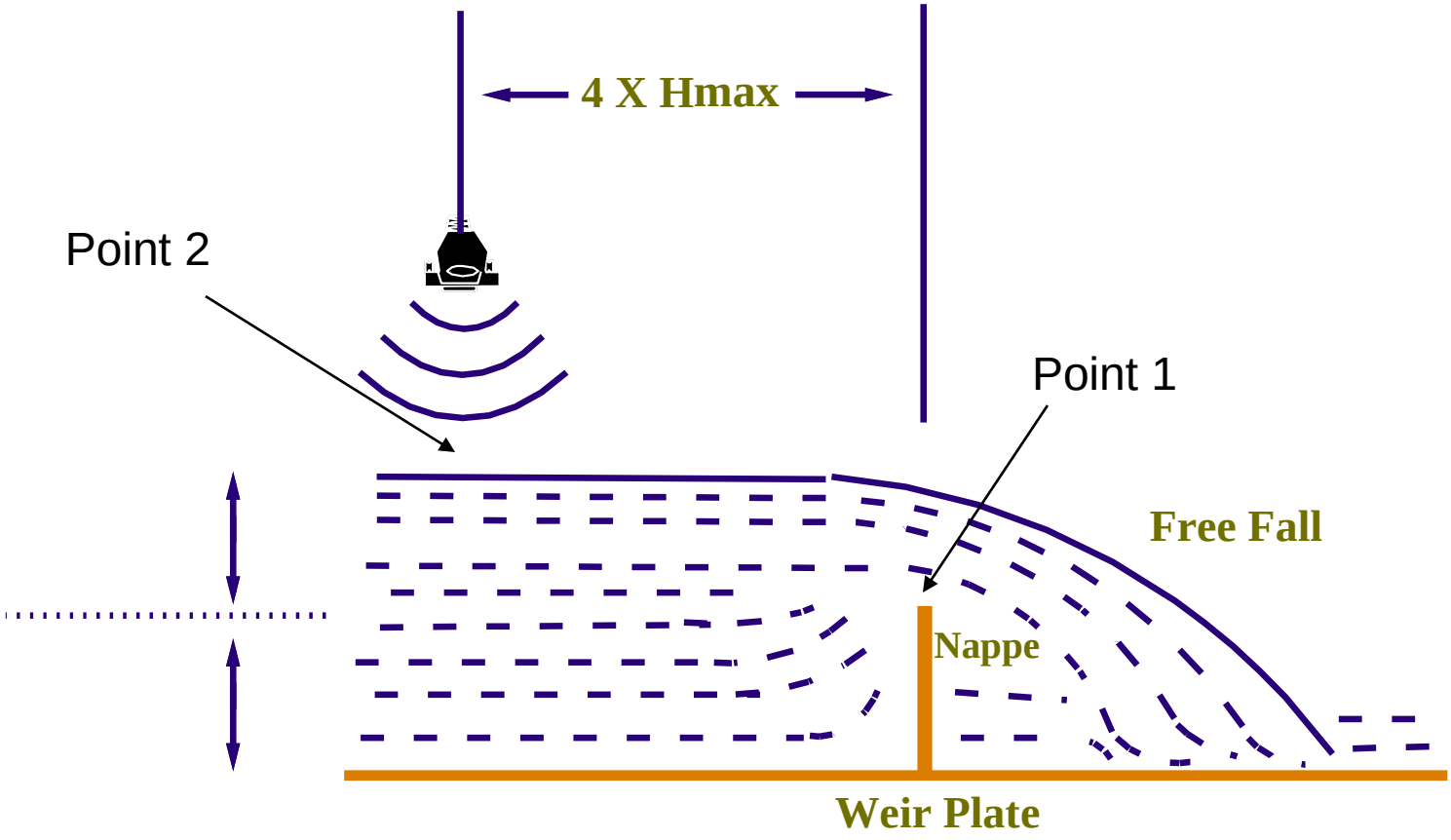
WEIR CRET THICKNESS

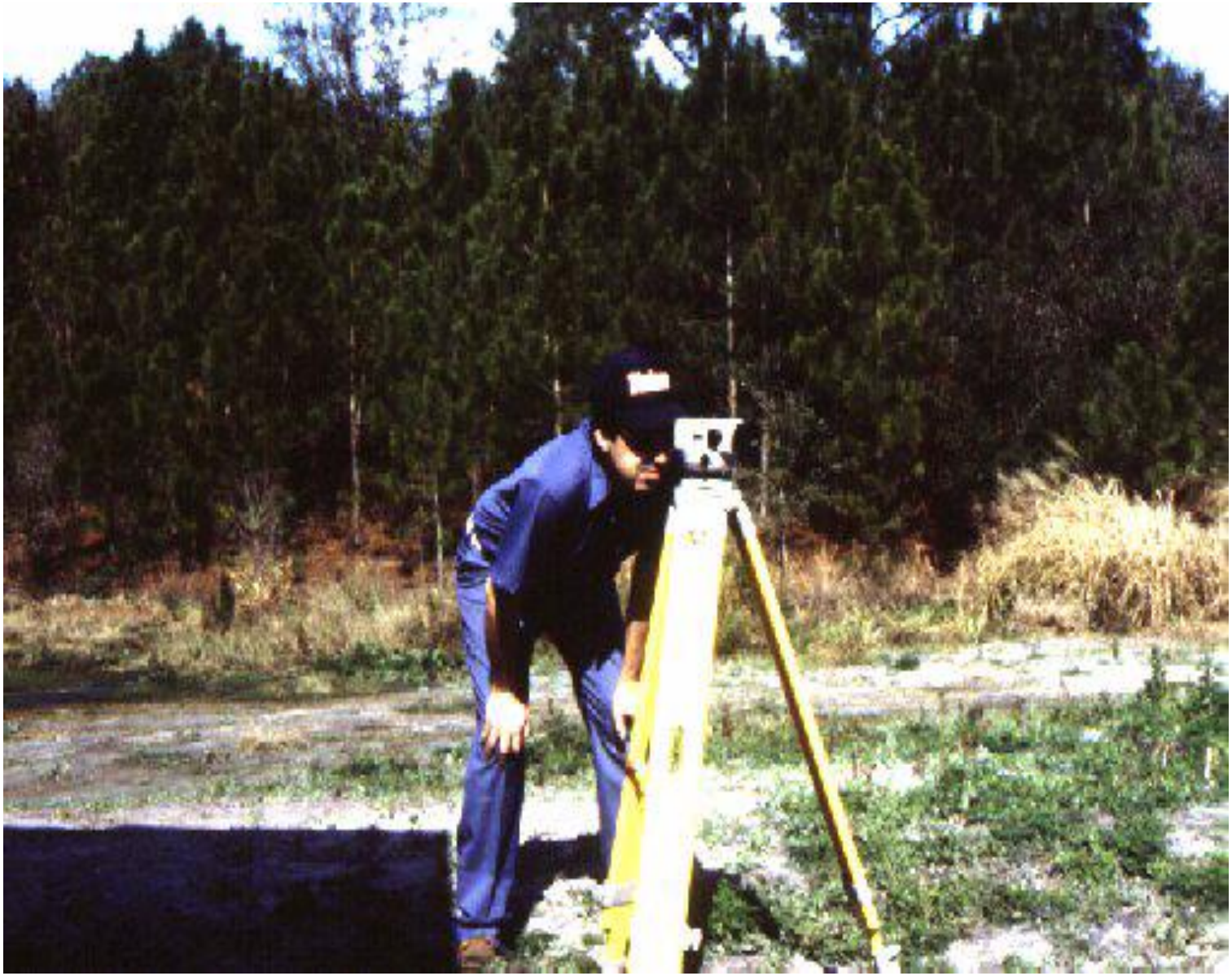


K = ⅛ “ or less


STANLEY

Using Survey Equipment
For Head Measurement





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DEFICIENCIES WITH WEIRS

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What's wrong?

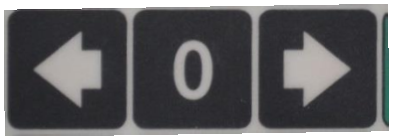
Broad-crested Weir Formula

- **Q = cLH1.5**
  - Q = cubic feet/second
  - L = length of crest (feet)
  - H = Head (feet)
  - C = Coefficient

ISCO 4210

Operation

- To move between option use the left right arrows
- To make a selection use the green “Enter/Program Step” button
- To enter a value type it in using the key pad.

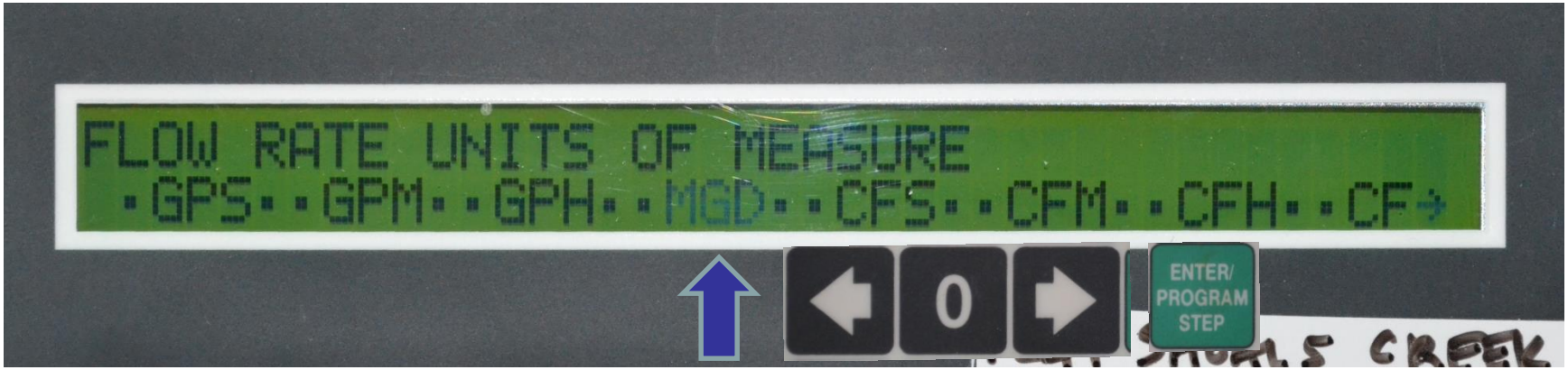


Program

Level

- Units of measure used are “FT” (not shown)

Flow Rate


FLOW RATE UNITS OF MEASURE
•GPS••GPM••GPH••MGD••CFS••CFM••CFH••CF
0
ENTER/
PROGRAM
STEP

Flow Measurement Type

Primary Measurement Device

Type of Weir


TYPE OF WEIR
•V-NOTCH••RECTANGULAR••CIPOLLETTI•
0
ENTER/
PROGRAM
STEP
FLAT SHOALS CREEK

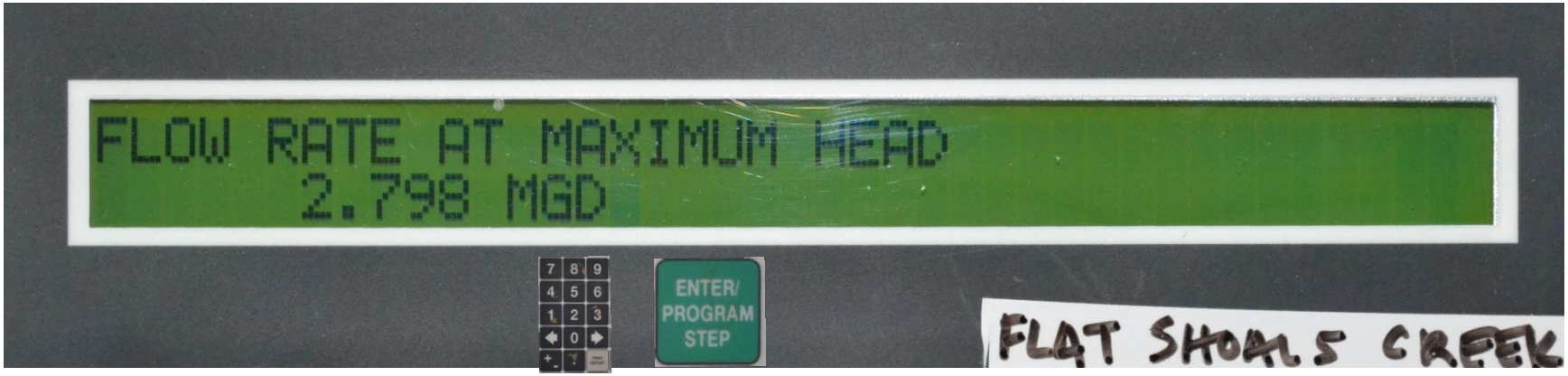
Weir Angle


V-NOTCH WEIR ANGLE (IN DEGREES)
·22.5··30··45··60··90··120·
0
ENTER/
PROGRAM
STEP
FLAT SHOALS CREEK

Maximum Head

- This number can be typed directly in from the key pad

Corresponding Flow Rate



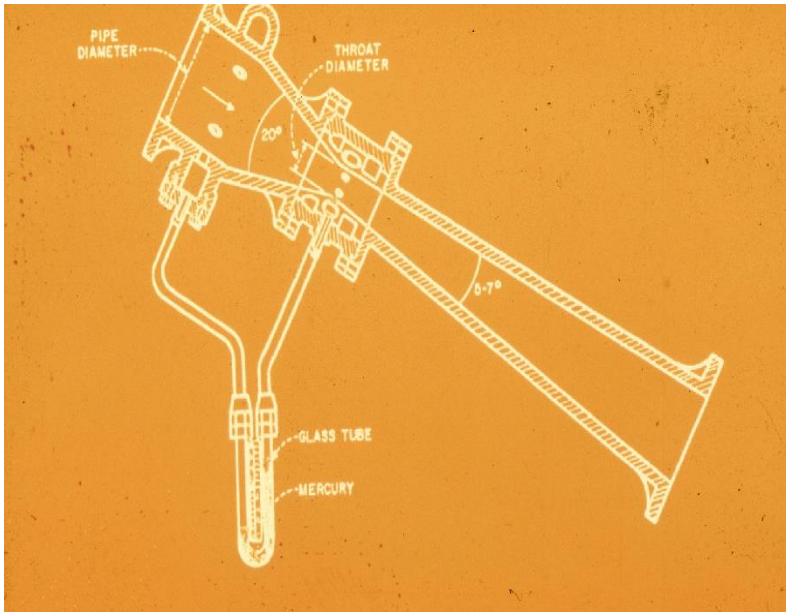
Current Water Level

- Determine height of water and type in

Closed Channel Systems

- *Common closed channel devices:*
- Venturi Meters
- Magnetic Flow Meters
- Doppler Flow Meters

Venturi Meters

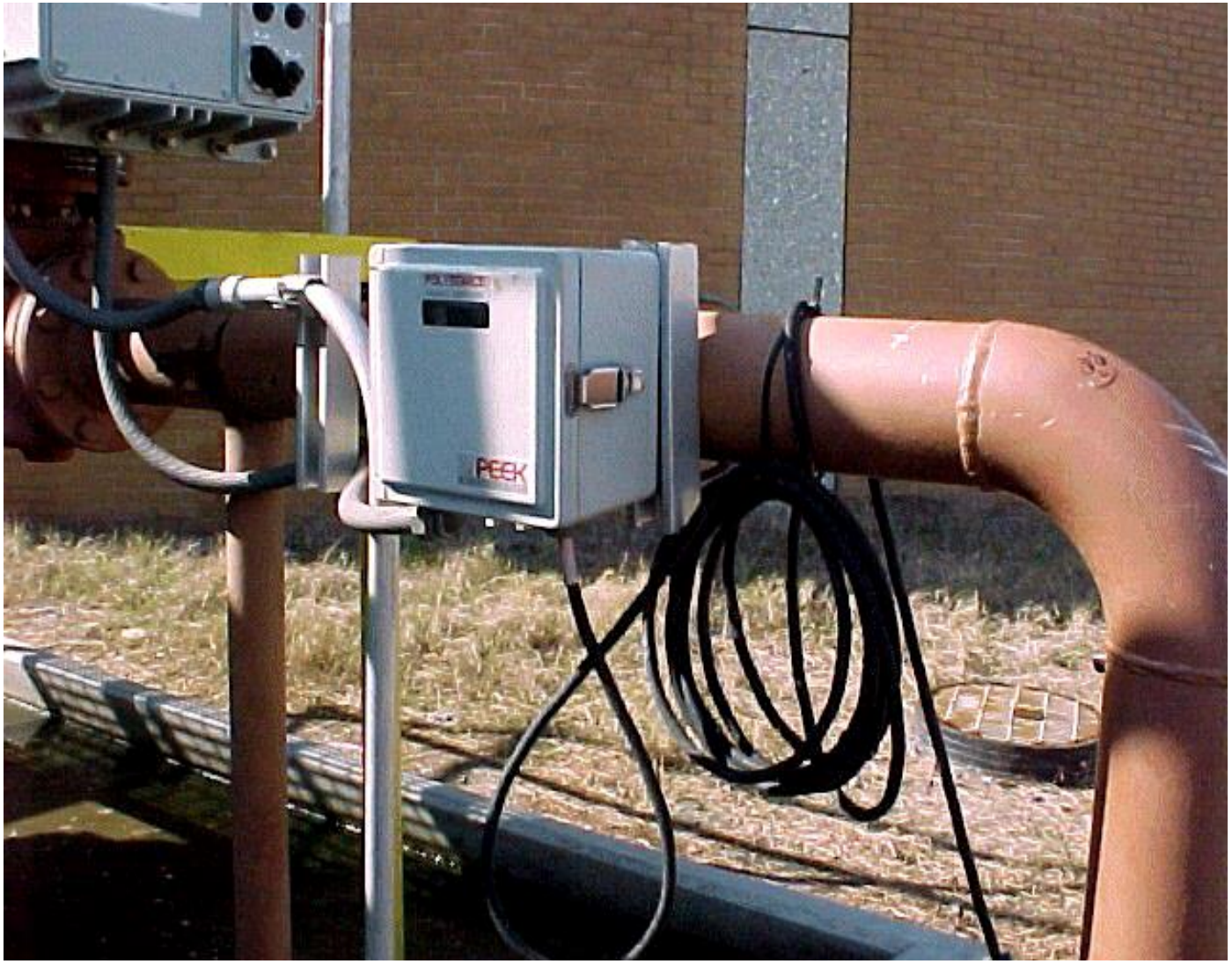


Cross-section of a Venturi Meter

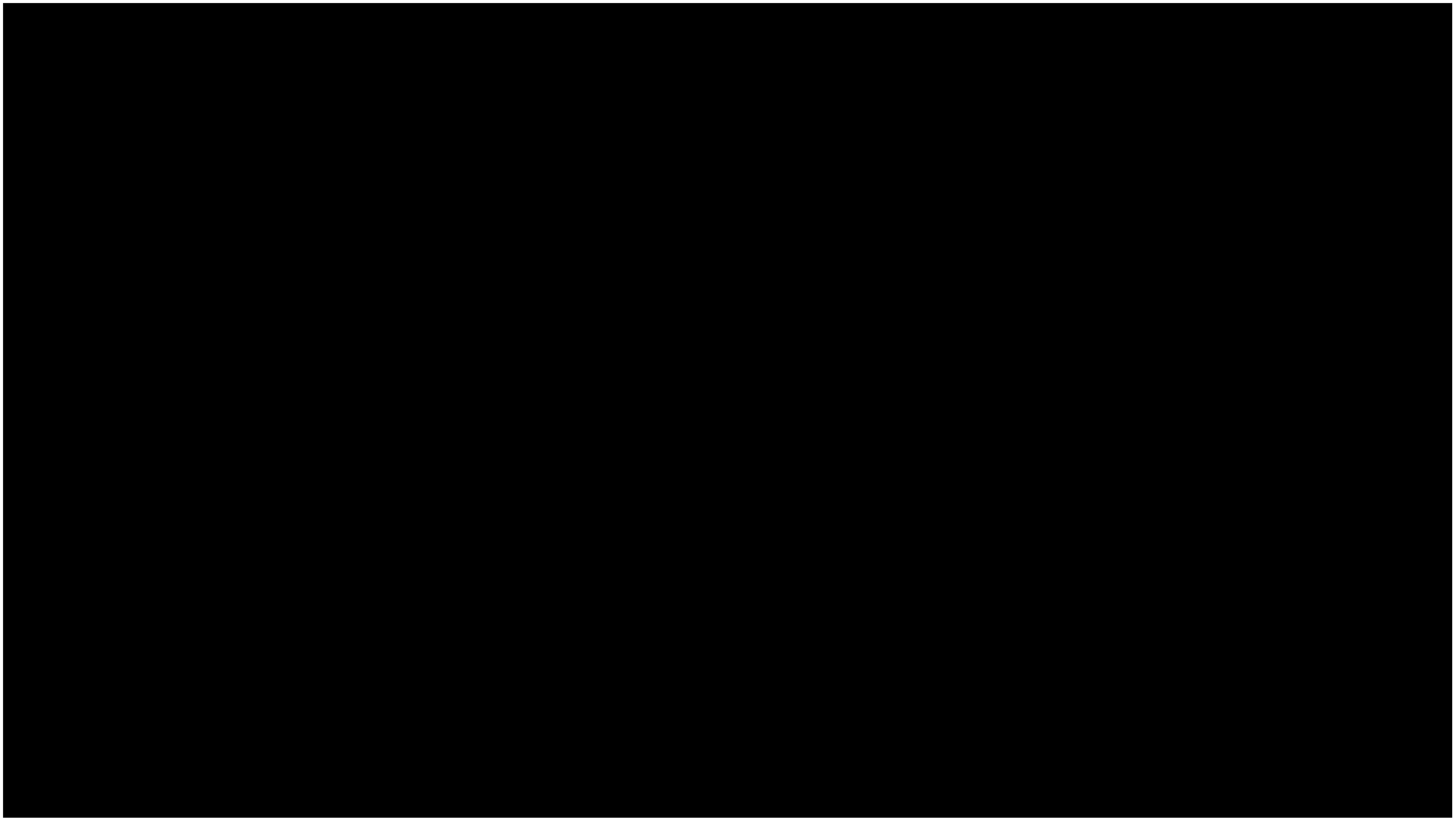
Venturi meter in operation

Magnetic Flow Meter

Doppler Flow Meter



Ultrasonic / Transit Time



General Requirements: Closed Channel Systems

- Full pipe flow conditions
- Straight length of pipe for 5 to 20 diameters
- Calibrated annually