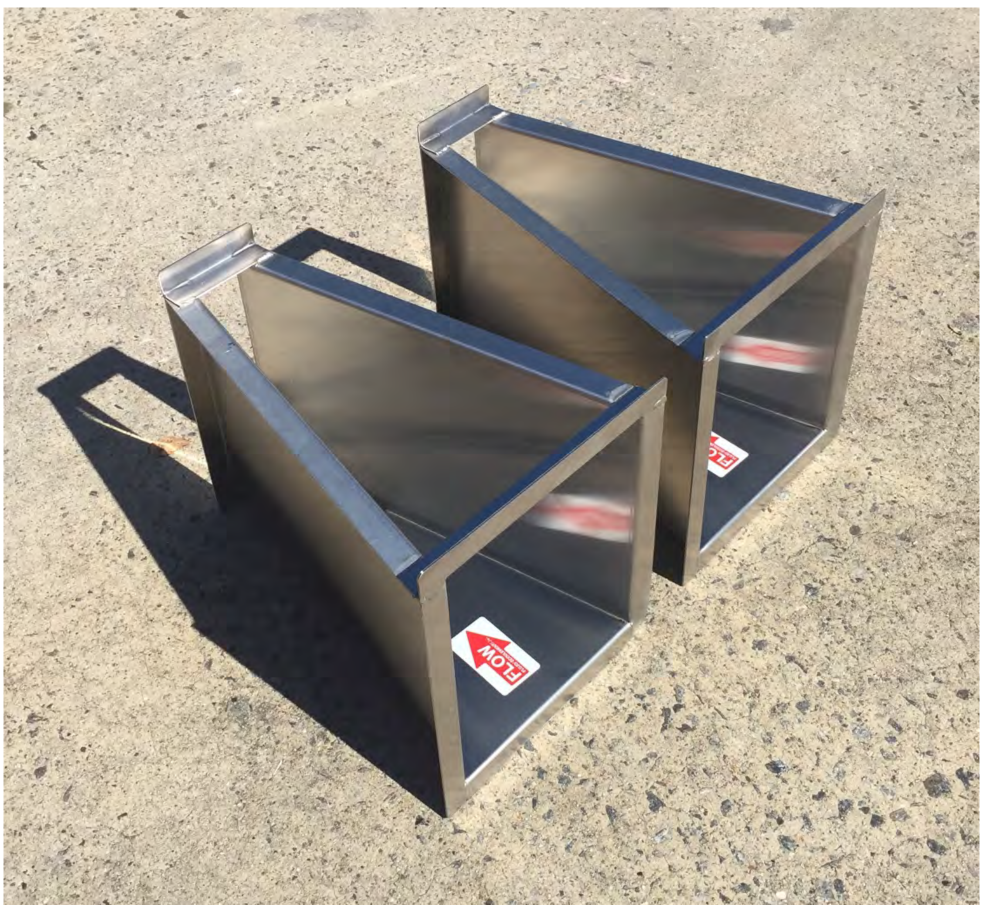
MONTANA FLUME

User's Manual



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INTRODUCTION TO THE MONTANA FLUME

The Montana flume is a modification to the popular Parshall flume – where the extended throat and discharge sections have been removed to save cost and increase portability.

The flume is a fixed hydraulic structure used to measure the flow of sub-critical waters in open channels. Although originally developed to measure irrigation / water rights flow, the use of the flume has been expanded and now includes:

- *Cooling water discharge*
- *Dam seepage*
- *Industrial effluent*
- *Irrigation / water rights*
- *Landfill leachate*
- *Mine discharge / dewatering*
- *Sanitary sewage (piped and treatment plant)*
- *Storm water*

FUNCTION

Sub-critical flumes like the Montana flume operate by accelerating slow, sub-critical flow ($Fr<1$) to a supercritical state ($Fr>1$) by restricting the flow as it passes through the flume. The Montana flume accomplishes this restriction by contracting the side walls and free-spilling discharge off the end of the flume.

DESIGN

When viewed from above, the Montana flume has a truncated, triangular shape, with the truncated apex serving as the discharge of the flume.

As flow enters the flume it is accelerated in the flat-bottomed, uniformly converging inlet. Having been accelerated to a supercritical state, the flow spills off the end of the flume.

Unlike the Parshall flume, the Montana flume has a flat floor, with no drop to accelerate the flow.

STANDARDS

The design and discharge characteristics of the Parshall flume – from which the Montana flume is derived - have been standardized in:

- *ASTM D1941 – 91 (2013) Standard Test Method for Open Channel Flow Measurement of Water with the Parshall Flume*
- *ISO 9826:1992 Measurement of Liquid Flow in Open Channels – Parshall and SANIIRI Flumes*
- *JIS B7553 Parshall Flume Type Flowmeters*

The Montana flume itself is defined in:

- *MT 9127 (AG) Montana (Short Parshall) Flume (Part 1), Montana State University*
- *MT 9128 (AG) Montana (Short Parshall) Flume (Part 2), Montana State University*
- *Water Measurement Manual, 3rd Edition, US Department of the Interior, Bureau of Reclamation*

Montana / Parshall flumes of non-standard (commonly 21-inch, 30-inch, and 42-inch) sizes or those not conforming to the published standard dimensions should be considered to be non-conforming and should be replaced or field rated.

ACCURACY

Based upon test performed on Parshall flumes, Montana flumes can be accurate to within +/-2% under controlled, laboratory conditions.

In practice, however, the free-flow accuracy of a Montana flume installation is usually within +/- 5% - once practical considerations such as approach flow, installation, and dimensional tolerance accounted for.

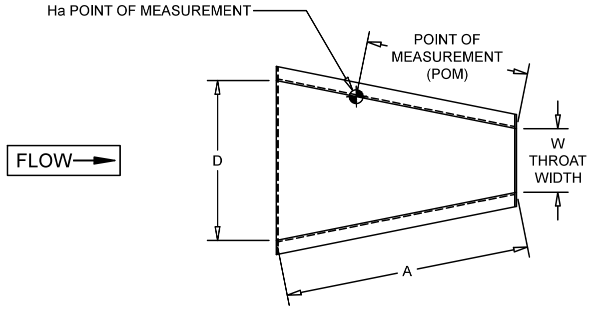
DIMENSIONS

The master dimensions for Montana flumes with throat widths from 1-inch to 144-inches are found in Figure 1.

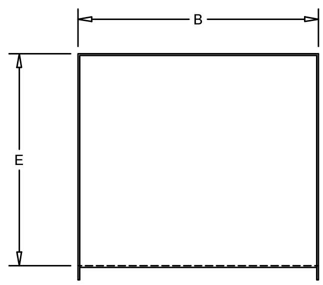
DIMENSIONAL TOLERANCES

ASTM D1941 requires that Parshall flume dimensions be within 2% of nominal, while JIS B7553 requires tolerance of +/- 1 to 1.5%, depending upon flume size. Montana flumes should be expected to adhere to these tolerances.

Montana flumes with dimensions outside of these ranges should be considered to be non-conforming and should be either replaced or field rated.



PLAN VIEW



ELEVATION VIEW

W (SIZE)	A	POM	B	D	E
1" [2.54 CM]	1'-2 9/32" [36.27 CM]	9 17/32" [24.21 CM]	1'-2" [35.56 CM]	6 19/32" [16.75 CM]	9" [22.86 CM]
2" [5.08 CM]	1'-4 5/16" [41.43 CM]	10 7/8" [27.62 CM]	1'-4" [40.64 CM]	8 13/32" [21.35 CM]	10" [25.4 CM]
3" [7.62 CM]	1'-6 3/8" [46.67 CM]	1'-0 1/4" [31.12 CM]	1'-6" [45.72 CM]	10 3/16" [47.23 CM]	2' [60.96 CM]
6" [15.24 CM]	2'-0 7/16" [62.07 CM]	1'-4 5/16" [41.44 CM]	2' [60.96 CM]	1'-3 5/8" [39.69 CM]	2' [60.96 CM]
9" [22.86 CM]	2'-10 5/8" [87.95 CM]	1'-11 1/8" [58.74 CM]	2'-10" [86.36 CM]	1'-10 5/8" [57.47 CM]	2'-6" [76.2 CM]
12" [30.48 CM]	4'-6" [137.2 CM]	3' [91.44 CM]	4'-4 7/8" [134.3 CM]	2'-9 1/4" [84.46 CM]	3' [91.44 CM]
18" [45.72 CM]	4'-9" [144.8 CM]	3'-2" [96.52 CM]	4'-7 7/8" [141.9 CM]	3'-4 3/8" [102.6 CM]	3' [91.44 CM]
24" [60.96 CM]	5' [152.4 CM]	3'-4" [101.6 CM]	4'-10 7/8" [149.5 CM]	3'-11 1/2" [120.7 CM]	3' [91.44 CM]
36" [91.44 CM]	5'-6" [167.6 CM]	3'-8" [111.8 CM]	5'-4 3/4" [164.5 CM]	5'-1 7/8" [157.2 CM]	3' [91.44 CM]
48" [121.9 CM]	6' [182.9 CM]	4' [121.9 CM]	5'-10 5/8" [179.4 CM]	6'-4 1/4" [193.7 CM]	3' [91.44 CM]
60" [22.86 CM]	6'-6" [198.1 CM]	4'-4" [132.1 CM]	6'-4 1/2" [194.3 CM]	7'-6 5/8" [230.2 CM]	3' [91.44 CM]
72" [182.9 CM]	7' [213.4 CM]	4'-8" [142.2 CM]	6'-10 3/8" [209.2 CM]	8'-9" [266.7 CM]	3' [91.44 CM]
84" [213.4 CM]	7'-6" [228.6 CM]	5' [152.4 CM]	7'-4 1/4" [224.2 CM]	9'-11 3/8" [303.2 CM]	3' [91.44 CM]
96" [243.8 CM]	8' [243.8 CM]	5'-4" [162.6 CM]	7'-10 1/8" [239.1 CM]	11'-1 3/4" [339.7 CM]	3' [91.44 CM]
120" [304.8 CM]	14'-3 21/64" [435.2 CM]	6' [182.9 CM]	14' [426.7 CM]	15'-7 1/4" [475.6 CM]	4' [121.9 CM]
144" [365.8 CM]	16'-3 51/64" [497.3 CM]	6'-8" [203.2 CM]	16' [487.7 CM]	18'-4 3/4" [560.7 CM]	5' [152.4 CM]

Figure 1 – Montana Flume Master Dimensions

POINTS OF MEASUREMENT

The primary, free-flow, point of measurement, Ha, is located in the converging section of the flume at the location indicated in Figure 1. For all but the largest Montana flumes this location is 2/3 length of the converging section wall "A" *upstream* of the throat. For large Montana flumes, Ha is located closer to the throat.

Lacking a throat, the secondary point of measurement, Hb, used to determine the submergence of a Montana flume is located in the channel downstream of the flume.

FLOW EQUATIONS

For free-flow conditions, the level-to-flow equation for the Montana flume can be expressed as:

$$Q = KH_a{}^{n}$$

Q = free flow rate (cfs / m3/s)
K = flume discharge constant (varies by flume size / units)
H_a = depth at the point of measurement (feet / meters)
n = discharge exponent (depends upon flume size)

Equation 1 – Montana Flume Free-Flow Equation

Throat Width	K (cfs)	K (m3/s)	N
1-inch	0.338	0.0479	1.55
2-inches	0.676	0.0959	1.55
3-inches	0.992	0.141	1.55
6-inches	2.06	0.264	1.58
9-inches	3.07	0.393	1.53
1-foot	4	0.624	1.522
1.5-feet	6	0.887	1.538
2-feet	8	1.135	1.55
3-feet	12	1.612	1.566
4-feet	16	2.062	1.578
5-feet	20	2.5	1.587
6-feet	24	2.919	1.595
7-feet	28	3.337	1.601
8-feet	32	3.736	1.607
10-feet	39.28	4.709	1.6
12-feet	46.75	5.590	1.6
15-feet	57.81	6.912	1.6
20-feet	76.25	9.117	1.6
25-feet	94.69	11.32	1.6
30-feet	113.13	13.53	1.6
40-feet	150	17.94	1.6
50-feet	186.88	22.35	1.6

Table 1 – Montana Flume Free-Flow Discharge Values

SUBMERGED FLOW

Lacking the throat and discharge sections of the standard Parshall flume design, the Montana flume is not intended for use in applications where submergence could be present. If submergence is a possibility, a full length Parshall flume should be used.

WHERE TO INSTALL A MONTANA FLUME

When selecting a site in which to install a Montana flume, there are several points to consider:

UPSTREAM OF THE FLUME

- *Flow entering the Montana flume MUST be sub-critical.*
- *The Froude number (Fr) for flow entering a flume should not exceed 0.5 and should never exceed 0.99.*
    - *Surface turbulence may be encountered for Froude numbers above 0.5.*
    - *For a flume to accurately measure flow, that flow must be sub-critical (Fr<0.99).*
- *If the approaching flow is critical (Fr = 1.0) or supercritical (Fr > 1.0), then a hydraulic jump must be formed at least 30 times the maximum anticipated head upstream of the entrance to the flume.*
- *The flow entering the flume should be smooth, tranquil, and well distributed across the channel.*
- *If the flow is super-critical approaching the flume a hydraulic jump must be formed well upstream of the flume or upstream energy absorbers and tranquilizing racks must be used).*
- *Should a hydraulic jump need to be formed to slow the flow, it should be forced to occur at least 30 Ha upstream of the flume.*
- *The approaching channel should be straight so that the velocity profile is uniform. Surging, turbulent, or unbalanced flows must be conditioned before the flow enters the flume.*
- *Any bends, dips, elbows, or flow junctions upstream of the flume must be sufficiently far upstream so that the flow has is well distributed and non-turbulent.*
- *EPA recommendations for upstream channel runs are conservatively the same as for long throated flume – 25 throat widths. While ASTM D1941 indicates that 10 to 20 times the throat with usually will meet the necessary inlet conditions.*

- *While corrections can be made for improper installations or flume settlement, they should be avoided where at all possible.*
- *Montana flumes have been successfully used in applications where the flow rises up a uniform vertical column and then enters the flume.*
- *Where the channel is wider than the inlet of the Montana flume, wing walls should be formed to smoothly direct the flow into the flume. The inlet wing walls should be of a constant radius and should end tangent to the inlet walls of the flume.*
- *When connecting to inlet piping, observations have shown that the pipe should be straight and without bends for at least 15 pipe diameters.*
- *The upstream channel should be clear of vegetative growth.*
- *Open channel (non-full pipe) flow must be present under all flow conditions.*

FLUME LOCATION

- *The flume must be able to be set so that the floor is level from front-to-back and from side-to-side.*
- *When Montana flumes are installed in earthen channels and furrows, care should be taken to ensure a that a stable bottom elevation is present and that the elevation does not change during dry / wet seasons or low-flow periods.*
- *The flume must be centered in the flow stream.*
- *Where a Montana flume must be set above the floor of a channel, a 1:4 (rise:run) slope should be formed into the flume. Slopes greater than this should be avoided as they can cause turbulence as the flow separates as the junction of the ramp and the inlet of the flume.*
- *All of the flow must go through the flume – there should be no bypass.*

DOWNSTREAM OF THE FLUME

- *Lacking the throat and discharge sections of the Parshall flume, the Montana flume must have free-flowing (free-spilling) discharge under all flow conditions.*
- *The discharge off the end of a Montana flume is turbulent and energetic. The downstream channel should be reinforced to minimized downstream scour.*
- *The downstream channel must be clear of vegetative growth or the collection of debris so that flow does not back up into the flume.*

HOW TO INSTALL A MONTANA FLUME

Once a site has been selected, the flume must then be installed correctly:

- *The flume should be set so that it is centered in the flow stream.*
- *The narrow opening of the flume must be set downstream.*
- *The outlet of the flume must be set high enough above the downstream water level so that submergence does not occur.*
- *The floor must be level from front-to-back and from side-to-side (using a level on the floor - not the top - of the flume)*
- *The flume must be braced internally (plywood and lumber are typically used) during installation to ensure that distortion does not occur.*
- *The flume must not float out of its intended final position during installation.*

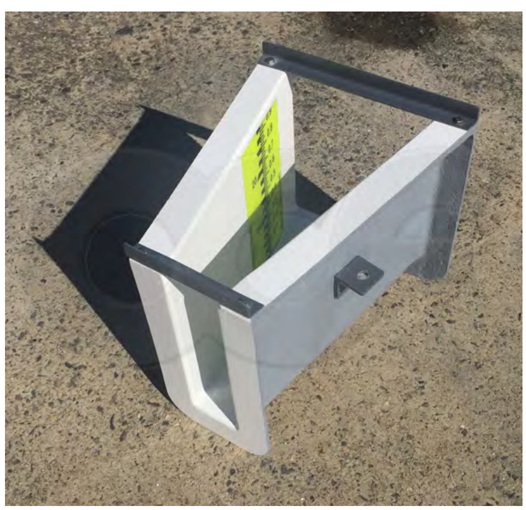
BRACING THE FLUME

Most Montana flumes ship with dimensional bracing (angle or tube) at the top of the flume. The bracing should be left on the flume until the installation has been completed.

If the flume is set in concrete, the bracing may be removed once the installation has been completed.

For installations where the flume is free-standing or otherwise not set in concrete, the bracing should be left in place.

If the bracing is removed, verify the dimensional accuracy of the flume after the removal.



CONNECTION JOINTS

Montana flumes supplied with bulkheads, or transition sections must remain sealed between the joints.

While these joints may be sealed initially at the factory, a final visual inspection of all joints should be done before installation. Where required, apply one or two continuous beads of silicone on all seating surfaces before proceeding with the installation.

HOW TO MAINTAIN A MONTANA FLUME

For a Montana flume to accurately measure flow, it must be periodically inspected and maintained. This inspection should be done six (6) months after installation and each following year.

The inspection should include the channel in which the flume is installed, the flow entering / exiting the flume, and the flume itself.

CHANNEL INSPECTION

- The upstream channel banks should be clear of vegetation or debris that could affect the flow profile entering the flume (upstream) or restrict flow out of the flume (downstream).
- Inspect the upstream channel to make sure that flow is not bypassing the flume.
- Inspect the downstream channel to make sure that scouring is not occurring.
- Any hydraulic jump should be at least 30 times the maximum head (Hmax) upstream of the flume.

FLOW INSPECTION

- *Flow entering the flume should be tranquil and well distributed.*
- *Turbulence, poor velocity profile, or surging should not be present.*
- *The Froude (Fr) number should, ideally, be 0.5.*
- *As the Froude number increases so does surface turbulence.*
- *Flumes accelerate sub-critical flow (Fr < 1) to a supercritical state (Fr 1>) .*
- *Flumes experiencing flows greater than unit (Fr = 1) will not accurately measure flow.*

FLUME INSPECTION

- *Flumes must be level from front-to-back and from side-to-side.*
- *Earthen installations are particularly susceptible to settling due to wet / dry and freeze / thaw cycles.*
- *Flow surfaces are to be kept clean of surface buildup or algal growth. Scrubbing or a mild detergent can be used.*
- *Galvanized flumes should be checked for corrosion.*
- *Any corrosion should be removed and then cold galvanization applied to the area.*