



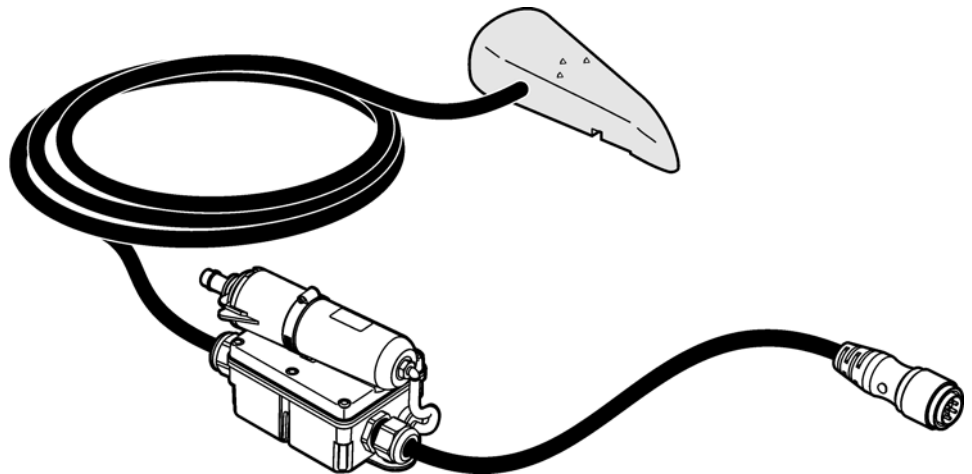
DOC026.53.00787

Flo-Tote 3 Sensor

Open Channel Flow Sensor

User Manual

July 2010, Edition 3



Section 1 Specifications	3
Section 2 General Information	5
2.1 Safety information.....	5
2.1.1 Use of hazard information.....	5
2.1.2 Precautionary labels.....	5
2.1.3 Confined space entry.....	6
2.2 Product overview.....	6
2.2.1 Flo-Tote 3 flow system features.....	6
2.2.2 Applications of a Flo-Tote 3 system.....	6
2.2.3 Advantages of a Flo-Tote 3 system.....	7
2.3 Theory of operation.....	7
2.3.1 Velocity measurement.....	7
2.3.2 Depth measurement.....	8
2.3.3 Flow calculation.....	8
Section 3 Installation	9
3.1 Component list.....	9
3.2 Site location guidelines.....	9
3.3 Sensor installation.....	12
3.3.1 Sensor installation kits.....	12
3.3.2 Connection to the Flo-Logger, FL900 Series Logger or Flo-Station.....	12
3.4 Dams for low-flow applications.....	13
3.4.1 Dam construction.....	13
3.4.2 Dam installation.....	14
Section 4 Maintenance	15
4.1 Sensor cleaning.....	15
4.2 Changing the Sensor Desiccant.....	15
4.2.1 Desiccant replacement procedure.....	15
4.3 Hydrophobic filter description.....	16
4.4 Hydrophobic filter replacement procedure.....	17
Section 5 Troubleshooting	19
Section 6 Contact Information	21
Appendix A Velocity profiling	23
A.1 About velocity profiling.....	23
A.2 Site selection.....	24
A.3 Profile guidelines.....	24
A.4 Depth of flow measurements.....	24
A.5 Velocity profile calculations.....	25
A.5.1 .9 x Vmax method.....	25
A.5.2 .2, .4, .8 method.....	26
A.5.3 .4 method.....	26
A.5.4 2D method.....	26
A.6 Auto-Cal automatic calibration.....	28
A.7 Calibrate the sensor using the Cal Wizard in the Flo-Ware software.....	28
Appendix B Flow calculations	29
B.1 Circular channels.....	29
B.2 Rectangular channels.....	32
B.3 Rivers and streams.....	33
B.4 Flow unit conversions.....	35

Section 1 Specifications

Specifications are subject to change without notice.

Table 1 Sensor specifications

General	
Material	Polyurethane
Dimensions	13.1 cm W x 4.4 cm L x 2.8 cm diameter (5.16 in. x 1.73 in. x 1.10 in.)
Weight	1.1 kg (2.4 lb) with 30 ft cable
Operating temperature	0 to 45 °C (32 to 113 °F)
Operating humidity	0-100%
Storage temperature	-20 to 52° C (-4 to 125° F)
Power requirements	10V, 100 mA. Sensor power is supplied by the portable Flo-Logger or by the Flo-Station Monitor.
Velocity measurement	Method: Electromagnetic (Faraday's law)
	Range: -1.5 to 6.1 m/s (-5 to 20 ft/s)
	Accuracy: ± 2% of reading
	Zero stability: ± 0.015 m/s (± 0.05 ft/s) at 0 to 3 m/s (0 to 10 ft/s)
	Resolution: ± 0.0003 m/s (0.01 ft/s)
Depth measurement	Method: Submerged pressure transducer
	Range: Standard 10 mm to 3.5 m (0.4 to 138 inches). Contact the factory for extended ranges
	Accuracy: ± 1% reading
	Zero stability: ± 0.009 m (± 0.03 feet), for 0 to 3 m (0 to 10 ft) Includes non-linearity, hysteresis and velocity effects.
	Resolution: 2.5 mm (0.1 in.)
	Over range protection: 2X range
Flow measurement	Method: Conversion of water level and pipe size to fluid area. Conversion of local velocity reading to mean velocity. Multiplication of fluid area by mean velocity to equal flow rate.
	Conversion accuracy: ± 5.0% of reading. Assumes appropriate site calibration coefficient, pipe flowing 10% to 90% full with a level greater than 5.08 cm (2 in.).
Temperature measurement	Method: 1 wire digital thermometer
	Range: -10 to 85 °C (14 to 185 °F)
	Accuracy: ± 2 °C (± 3.5 °F)
Sensor cable	Material: Polyurethane jacketed
	Standard length: 9.1 m (30 ft)
	Optional length: 18.2 m, 30.4 m (60,100 ft) or length as needed; maximum 304 m (1000 ft)
Warranty	
Warranty	One year from date of shipment. Does not apply to such consumable components, such as, but not limited to, desiccants and batteries.

Section 2 General Information

2.1 Safety information

Please read this entire manual before unpacking, setting up or operating this equipment. Pay attention to all danger, warning and caution statements. Failure to do so could result in serious injury to the operator or damage to the equipment.

Make sure that the protection provided by this equipment is not impaired, do not use or install this equipment in any manner other than that specified in this manual.

2.1.1 Use of hazard information



DANGER

Indicates a potentially or imminently hazardous situation which, if not avoided, will result in death or serious injury.



WARNING

Indicates a potentially or imminently hazardous situation which, if not avoided, could result in death or serious injury.



CAUTION

Indicates a potentially hazardous situation that may result in minor or moderate injury.

Notice: Indicates a situation that is not related to personal injury.

Important Note: Indicates a situation which, if not avoided, may cause damage to the instrument. Information that requires special emphasis.

Note: Information that supplements points in the main text.

2.1.2 Precautionary labels

Read all labels and tags attached to the instrument. Personal injury or damage to the instrument could occur if not observed. A symbol, if noted on the instrument, will be included with a danger or caution statement in the manual.

	This is the safety alert symbol. Obey all safety messages that follow this symbol to avoid potential injury. If on the instrument, refer to the instruction manual for operation or safety information.
	Electrical equipment marked with this symbol may not be disposed of in European public disposal systems after 12 August of 2005. In conformity with European local and national regulations (EU Directive 2002/96/EC), European electrical equipment users must now return old or end-of life equipment to the Producer for disposal at no charge to the user. Note: For return for recycling, please contact the equipment producer or supplier for instructions on how to return end-of-life equipment, producer-supplied electrical accessories, and all auxiliary items for proper disposal.
	This symbol, when noted on the product, indicates the presence of devices sensitive to Electro-static Discharge (ESD) and indicates that care must be taken to prevent damage with the equipment.

2.1.3 Confined space entry

The following information is provided to guide users of Flo-Tote 3 sensors on the dangers and risks associated with entry into confined spaces.



WARNING

Potential confined space hazards. Training in pre-entry testing, ventilation, entry procedures, evacuation/rescue procedures and safety work practices is necessary to ensure against the loss of life in confined spaces.

On April 15, 1993, OSHA's final ruling on CFR 1910.146, Permit Required Confined Spaces, became law. This standard directly affects more than 250,000 industrial sites in the United States and was created to protect the health and safety of workers in confined spaces.

Definition of Confined Space

A Confined Space is any location or enclosure that presents or has the immediate potential to present one or more of the following conditions:

- An atmosphere with less than 19.5% or greater than 23.5% oxygen and/or more than 10 ppm Hydrogen Sulfide (H₂S)
- An atmosphere that may be flammable or explosive due to gases, vapors, mists, dusts, or fibers
- Toxic materials which upon contact or inhalation, could result in injury, impairment of health, or death

Confined spaces are not designed for human occupancy. They have restricted entry and contain known or potential hazards. Examples of confined spaces include manholes, stacks, pipes, vats, switch vaults, and other similar locations.

Standard safety procedures must always be followed prior to entry into confined spaces and/or locations where hazardous gases, vapors, mists, dusts, or fibers may be present. Before entering any confined space check with your employer for procedures related to confined space entry.

2.2 Product overview

The Flo-Tote 3 sensor measures the velocity and depth of conductive liquids in open channels using electromagnetic sensor technology. The sensor connects to a data logger or to a Flo-Station to make a complete flow system.

2.2.1 Flo-Tote 3 flow system features

- Fully submersible sensor
- Debris-shedding sensor
- Measurement for extremely low velocities and reverse flow
- Operation under free flow, non-free flow or surcharge conditions
- Field replaceable sensor
- No calibration required
- Increased signal intensity for greasing applications
- Flow temperature measurement

2.2.2 Applications of a Flo-Tote 3 system

- Perform inflow & infiltration (I&I) studies
- Perform water distribution/leak isolation studies

- Evaluate existing sewer systems and storm water systems
- Monitor the flow from towns and cities
- Monitor the sewer overflow into streams and rivers
- Monitor the industrial flow from factories
- Measure the efficiency of pump stations
- Validate the accuracy of existing flow meters

2.2.3 Advantages of a Flo-Tote 3 system

Accurate: Flo-Tote 3 flow system uses the most accurate method of calculating flow, based on the continuity equation: $\text{Flow} = \text{Average Velocity} \times \text{Area}$. Verification of the Flo-Tote 3 specifications by an independent flow laboratory assures commitment to accuracy. Thousands of users worldwide have verified Flo-Tote accuracy.

Portable (FL900 Series Logger or Flo-Logger): The Flo-Logger can be moved to different sites quickly and easily. This means having the ability to accurately measure flow at all sites, without having to purchase a flow meter for each location. The Flo-Logger uses (2) standard, six-volt lantern batteries. Refer to the Flo-Logger User Manual (DOC026.53.00788). The FL900 Series Flow Logger uses (2) or (4) standard, six-volt lantern batteries and is also compatible with the long-life alkaline battery (8542900). Refer to the FL900 Series Flow Logger User Manual (DOC026.97.80015).

Permanent (Flo-Station): The four programmable 4–20 mA outputs provide a convenient way to transfer real-time flow data to SCADA and other data collection systems, control systems and display devices. Refer to the Flo-Station User Manual (DOC026.53.00790).

Reliable: The Flo-Tote 3 Flow System even operates under surcharge conditions. The Flo-Tote 3 sensor contains no moving parts, which makes it more reliable than other sensors.

Adaptable: The Flo-Tote 3 Flow System adapts to a wide range of pipe sizes and shapes, eliminating the need for costly weirs or flumes.

2.3 Theory of operation

The Flo-Tote 3 open channel sensor directly measures water velocity and depth.

2.3.1 Velocity measurement

The sensor makes use of Faraday's Law of electromagnetic induction to measure water velocity. Faraday's Law states: A conductor, moving through a magnetic field, produces a voltage.

Because water is a conductor, water moving through a magnetic field produces a voltage. The magnitude of the voltage is directly proportional to the velocity of the water. The open channel sensor generates an electromagnetic field, creating a voltage in the water. The two velocity electrodes along with the ground electrode measure this voltage (refer to [Figure 1](#)). A faster water velocity produces a higher voltage. By accurately measuring this voltage, the velocity is determined.

Non-Fouling electrodes

The sensor features non-fouling electrodes. These are raised, pointed electrodes which reduce the amount of grease and debris build-up. When the electrodes become coated, they no longer measure the water velocity accurately. The non-fouling electrodes are designed to prevent an accumulation of debris.

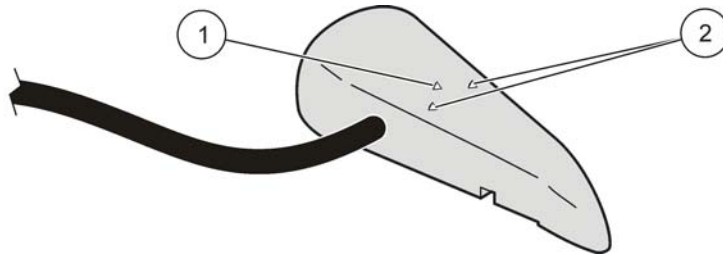


Figure 1 Electrodes on Flo-Tote sensor

1 Ground electrode	2 Velocity electrodes
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2.3.2 Depth measurement

A pressure transducer is used to measure the depth of the water. The transducer is an electronic device which uses a thin diaphragm to convert pressure to an electronic signal. The depth transducer is located inside the sensor. The cross channel (located on the bottom of the sensor) allows water pressure to reach the transducer, while at the same time protecting the fragile diaphragm from damage.

An air tube, running through the length of cable from the sensor to the desiccant junction box, enables the transducer to cancel out the atmospheric pressure in order to measure the true water pressure. The air tube (called the atmospheric pressure reference or APR tube) needs to be protected from water, which can damage the transducer.

2.3.3 Flow calculation

The velocity and depth measurements provided by the open channel sensor are used to calculate flow. Flow (also known as Q, flow rate, or throughput) is the amount of fluid moving through a channel or pipe in a period of time. For example, if 100 gallons of water move past the sensor in one minute, the flow is 100 gallons per minute (GPM). Flow calculations are performed by the flow meter (Flo-Logger, Flo-Station or other flow meters).

To calculate flow, two things are needed:

- The cross-sectional area of the channel. Cross-sectional area is found using the dimensions of the channel and the measured depth.
- The average velocity. Average velocity is found using the sensed velocity (measured by the sensor). The default calibration coefficient is often adequate. A site calibration will verify or improve accuracy. A site calibration determines the velocity profile and calculates the correct calibration coefficient for the particular application. For more information on velocity profiling, refer to [Appendix A on page 23](#).

Flow is calculated by using the continuity equation:

$$\text{Flow} = \text{AverageVelocity} \times \text{Area}$$

$$Q = V \times A$$

where

$$Q = \text{Flow}$$

$$V = \text{AverageVelocity}$$

$$A = \text{Wetted Area (calculated from depth and the channel geometry)}$$

Data is sent from the Flo-Tote 3 electromagnetic sensor to a Flo-Logger, FL900 Series Logger or a Flo-Station via a cable. Flow data is transferred from the Flo-logger to a laptop/desktop/PocketPC computer via communications cable.

Section 3 Installation



WARNING

Potential confined space hazards. Only qualified personnel should conduct the tasks described in this section of the manual.

3.1 Component list

Before going into the field, make sure that all sensor components are included in the shipment. Refer to [Figure 2](#).

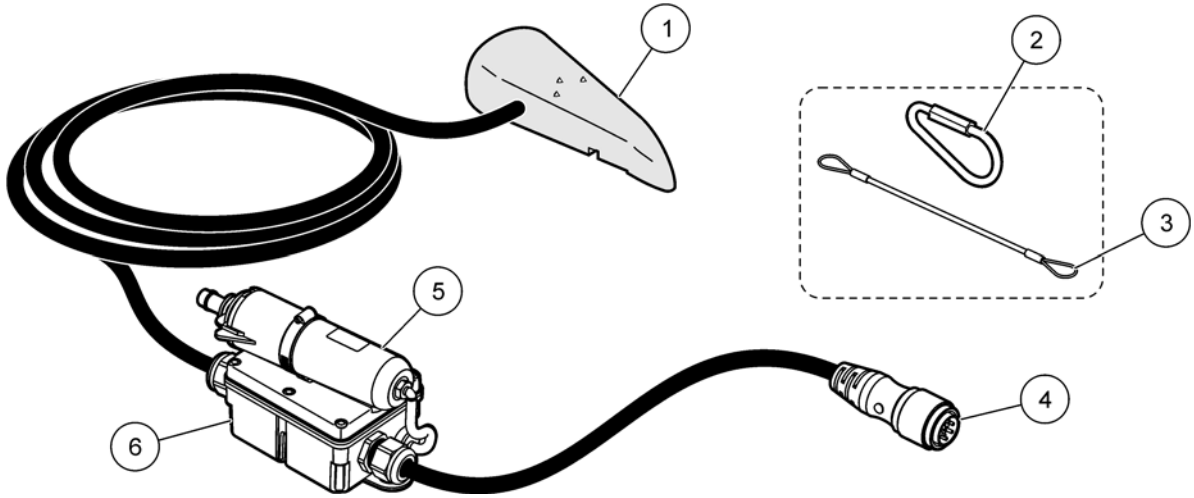


Figure 2 Instrument components

1	Flo-Tote 3 sensor	4	Cable connector or bare wires
2	Carabiner clip	5	Desiccant container
3	Hanging strap	6	Desiccant hub junction box

Determine what tools are needed for complete installation. Customer-supplied equipment:

- Sensor mounting kit
- Base
- Electrical tape to wrap the cable and band together (optional)
- Socket and ratchet wrench
- Tie wraps

3.2 Site location guidelines

The guidelines in this section are not mandatory but will help performance. Accuracy can be affected if these guidelines are not followed.

For best accuracy, install the sensor where the flow is not turbulent. An ideal location is in a manhole just downstream from a long, straight channel or pipe. Outfalls, vertical drops, baffles, curves or junctions cause the velocity profile to become distorted (refer to [Site selection on page 24](#)).

Where there are outfalls, vertical drops, baffles, curves or junctions, install the sensor upstream or downstream as shown in [Figure 3](#) and [Figure 4](#). For upstream locations, install the sensor at a distance that is at least five times the pipe diameter or maximum fluid level. For downstream locations, install the sensor at a distance that is at least ten times the pipe diameter or maximum fluid level.

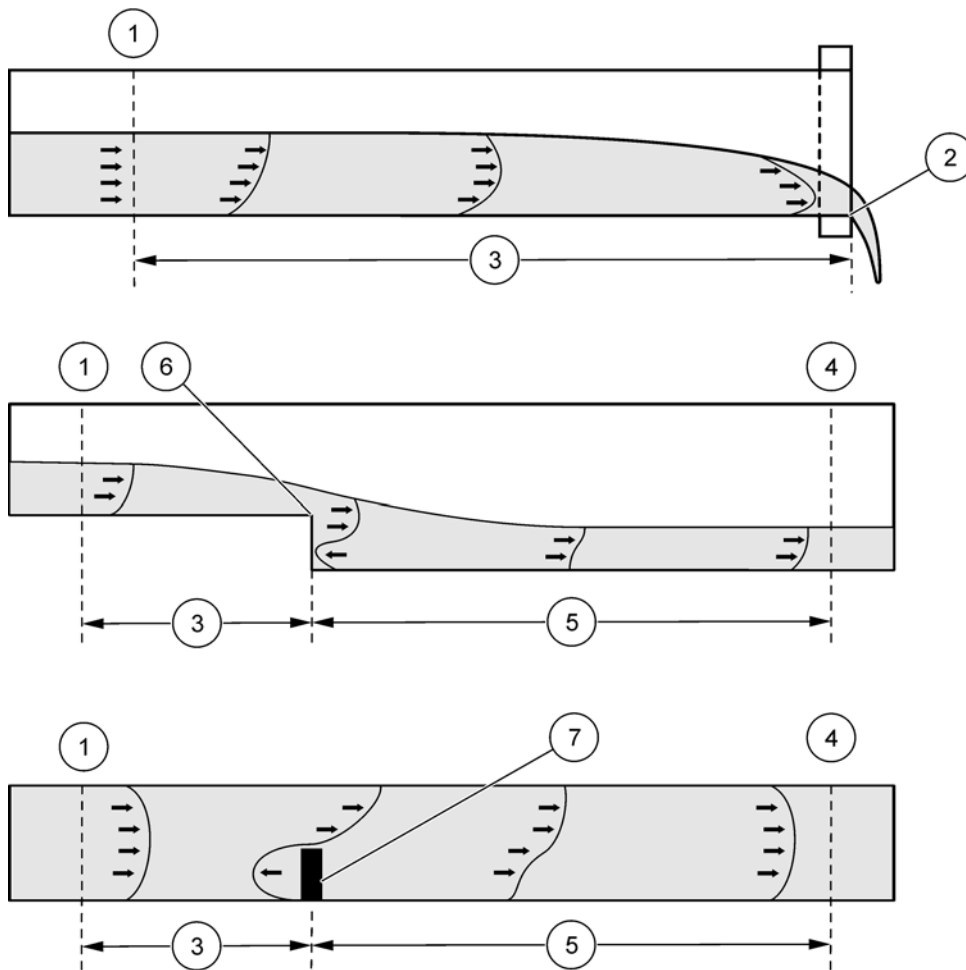


Figure 3 Sensor location near an outfall, vertical drop or baffle

1	Acceptable upstream sensor location	5	Distance downstream: 10 x pipe diameter
2	Outfall	6	Vertical drop
3	Distance upstream: 5 x pipe diameter	7	Baffle
4	Acceptable downstream sensor location		

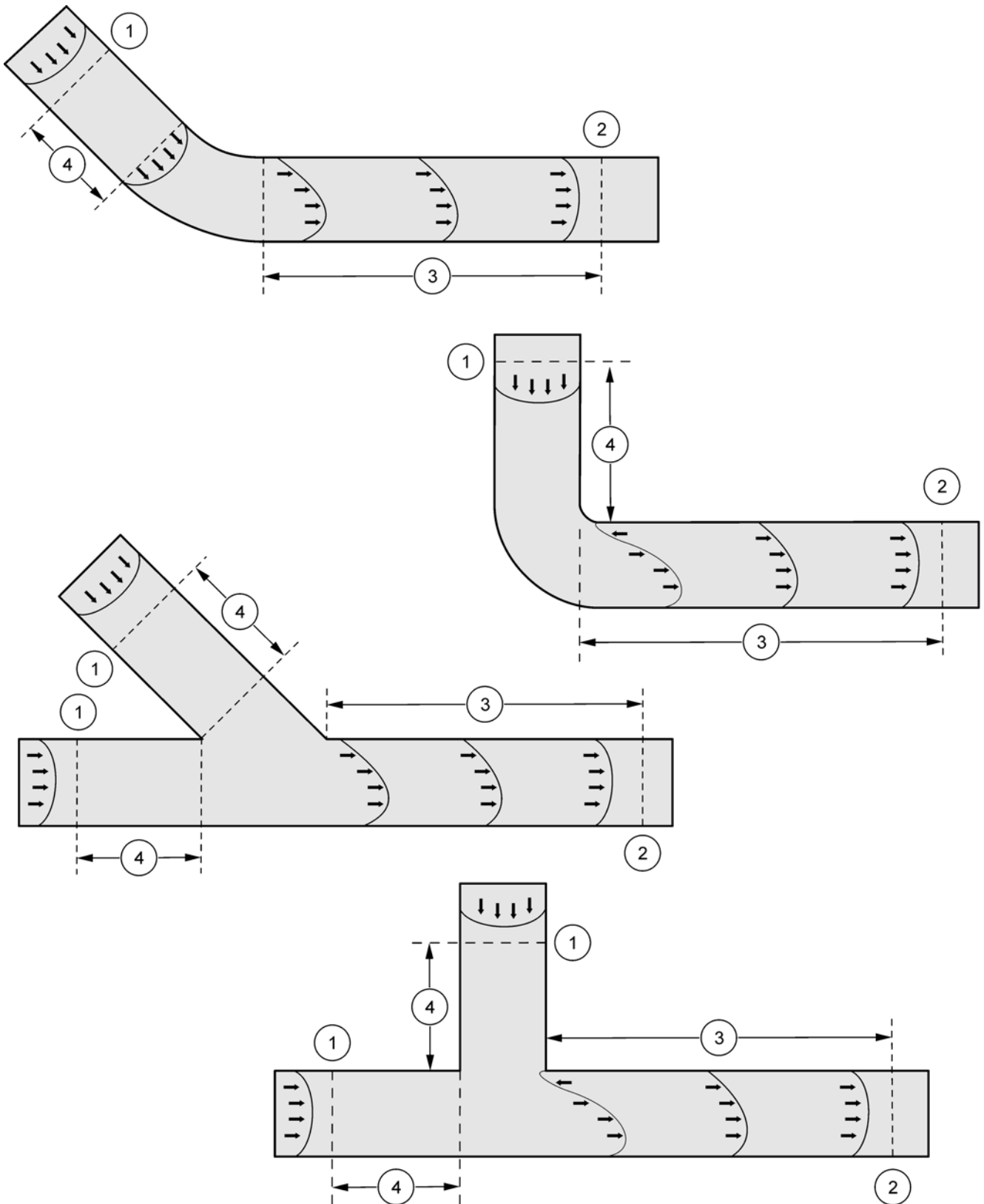


Figure 4 Sensor location near a curve, elbow or junction

1	Acceptable upstream sensor location	3	Distance downstream: 10 x pipe diameter
2	Acceptable downstream sensor location	4	Distance upstream: 5 x pipe diameter

3.3 Sensor installation

Sensor installation involves attachment of the sensor to a metal band or plate which is then installed in a pipe or channel.

3.3.1 Sensor installation kits

Several kits are available for sensor installation to accommodate various pipe sizes and shapes. Installation instructions are provided with each kit.

- **Spring band**—circular metal band that stays in place by spring action against the pipe walls. Available for pipe diameters of 6 to 19 inches. Instruction sheet: DOC273.53.80001. Optional Q-Stick for installation without manhole entry. Instruction sheet: DOC273.53.80005.
- **Scissors-jack band**—circular metal band that stays in place when a scissors jack is tightened. Available for pipe diameters of 16 to 61 inches. Instruction sheet: DOC273.53.80003.
- **Partial bands**—metal band that covers the bottom half of a channel and stays in place by attachment to the channel wall. Instruction sheet: DOC273.53.80002.
- **Rectangular channel mount**—pole with metal plates that stays in place by attachment to the channel ceiling. Instruction sheet: DOC273.53.80004.

3.3.2 Connection to the Flo-Logger, FL900 Series Logger or Flo-Station

Connect the cable from the sensor to the Flo-Logger, FL900 Series Logger or Flo-Station.

- Flo-Logger and FL900 Series Logger—connect the cable from the sensor to the Flo-Dar connector on the logger.
- Flo-Station—connect the cable from the sensor to the correct terminal in the Flo-Station.

3.4 Dams for low-flow applications

At least two inches of water is necessary for accurate velocity measurements. If the site frequently experiences low-flow conditions, use a dam to raise the water level. Locate the sensor at least one foot in front of the dam.

3.4.1 Dam construction

A low-flow dam can be made as follows:

1. Make a mold for the dam from a section of pipe with the same diameter as the dam site. Place a board at one end of the pipe, and angle the pipe to approximately 30° (refer to [Figure 5](#)).
2. Pour pre-mixed concrete into the mold. The top of the dam should be 2 inches high.
3. Allow the concrete to fully set.

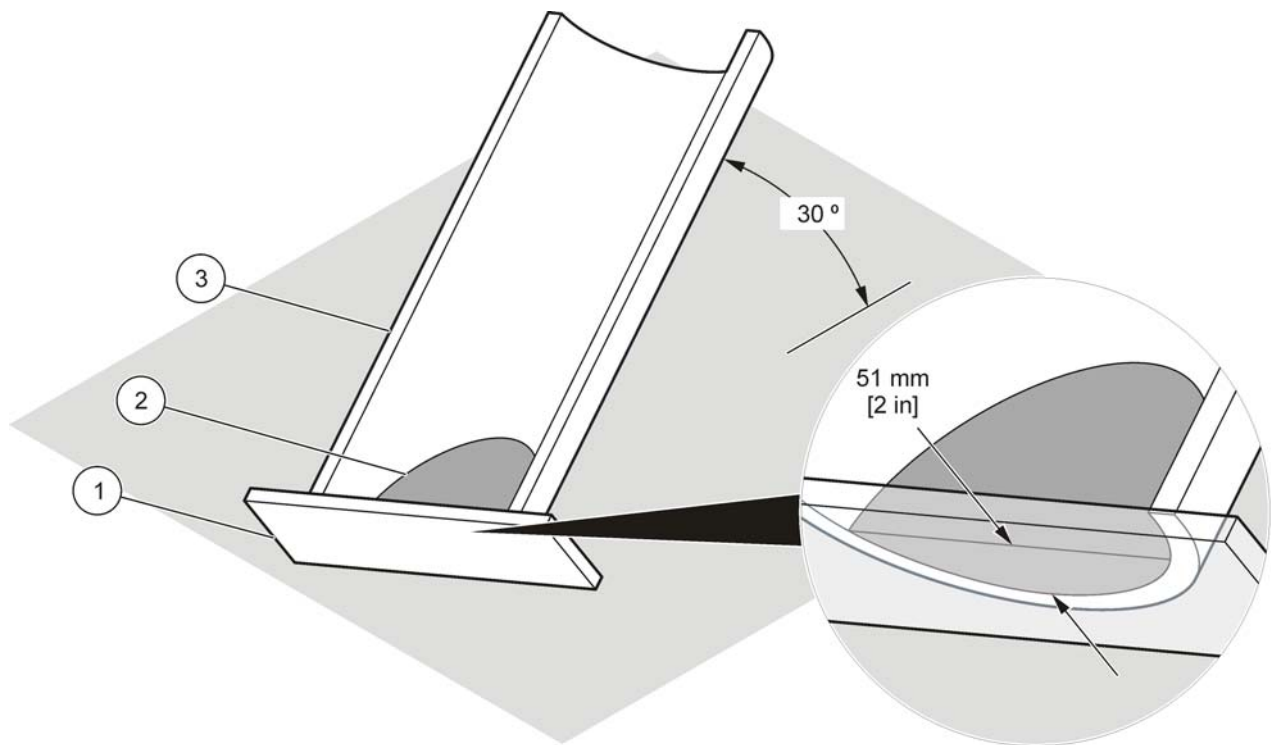


Figure 5 Low-flow dam construction

1 Board	2 Pre-mix concrete	3 Cut-pipe section
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Installation

3.4.2 Dam installation

Install the dam at the site, approximately one foot downstream from the sensor. The easiest way to attach the dam to the pipe or channel is with hydrolytic cement or waterproof caulking. The dam can also be attached with lead anchors and lag bolts. Installation options are shown in [Figure 6](#).

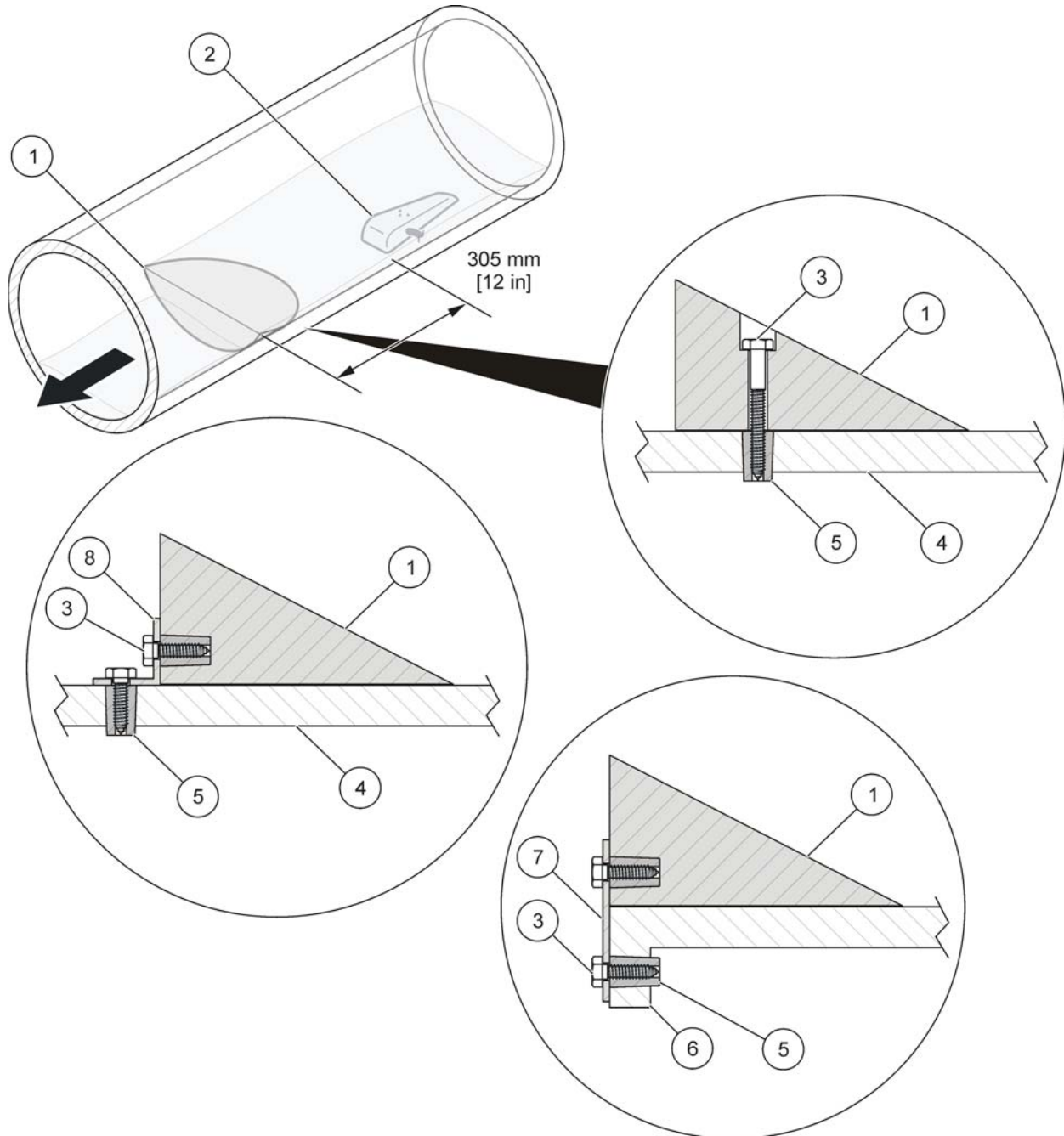


Figure 6 Installation options for low-flow dams

1 Low-flow dam	5 Lead anchor
2 Flow sensor	6 Pipe outfall
3 Lag bolt	7 Metal strap
4 Bottom of pipe	8 Metal strap

Section 4 Maintenance

WARNING

Potential confined space hazards. Only qualified personnel should conduct the tasks described in this section of the manual.

4.1 Sensor cleaning

Important Note: Do not use sandpaper to clean the non-fouling electrodes. Sandpaper can damage the electrodes.

1. To clean the sensor, pour a small amount of liquid detergent cleaner on a soft bristle brush. Use this brush to clean the electrodes on top of the sensor.
2. Rinse with clean water.

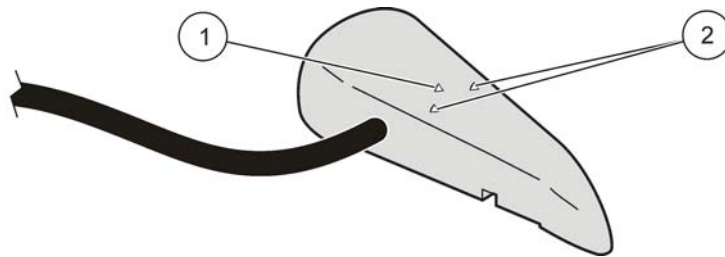


Figure 7 Electrodes on Flo-Tote sensor

1 Ground electrode	2 Velocity electrodes
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4.2 Changing the Sensor Desiccant

The desiccant canister contains beads of silica gel which ensure proper operation of the pressure transducer located in the Tote 3 sensor. When the beads are yellow, they can absorb moisture from the air. When they are green, they are saturated and cannot absorb any more moisture from the air, and they must be replaced immediately.

The cable assembly with desiccant hub is compatible with either the Flo-Logger or the FL900 Loggers. When using this cable assembly with the Flo-Logger, do not disconnect the desiccant cartridge that is attached to the Flo-Logger itself.

Important Note: When the beads begin to turn green, replace or rejuvenate the beads. Permanent damage to the sensor may occur if the desiccant is not maintained. Never operate the sensor without the proper desiccant. When rejuvenating beads, remove them from the canister and heat at 100-180 °C (212-350 °F) until the beads turn yellow. If the beads do not turn yellow, replace them with new beads. Do not heat the canister.

4.2.1 Desiccant replacement procedure

Note: Replacing the desiccant does not require that the desiccant container be removed from the desiccant box.

1. Use a slight twisting motion to twist the bottom end-cap until its slots align with the retaining clips (Figure 8).
2. Gently remove the end cap by grasping it and pulling it straight out.
3. Pour the desiccant beads out of the canister.
4. Hold the canister up to the light and inspect the hydrophobic filter.
 - If you see a small, dim light spot while looking through the hole, the filter is in good condition. If you see a bright light spot, the filter is probably torn. Replace the filter.

Maintenance

- If the desiccant beads were completely saturated with water or the filter has saturated with water or grease, replace the filter.
5. Refill the canister tube with yellow desiccant beads (Cat. No. 8755500). Inspect the O-ring (Cat. No. 5252) on the bottom cap for cracking, pits, or evidence of leakage. Replace if necessary.

Note: Applying O-ring grease to new or dry O-rings improves the ease of insertion, sealing, and life span of the O-ring.

6. Make sure that the O-ring is clean and free of dirt or debris before replacing the end cap.
7. Reinstall the end cap.

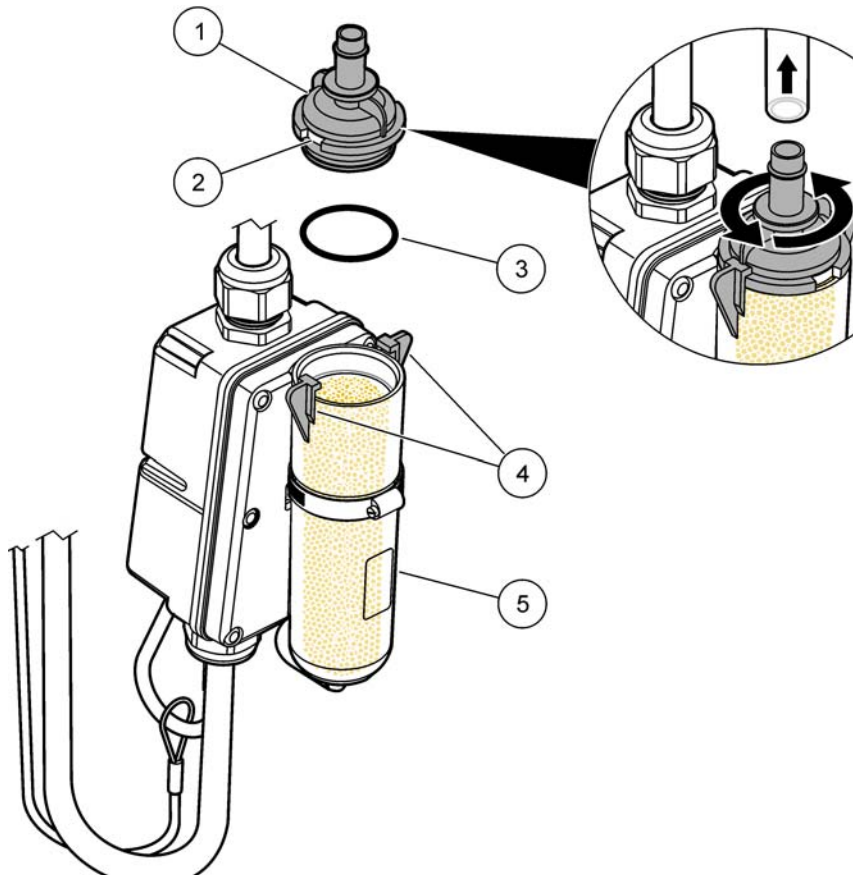


Figure 8 Remove the bottom end cap

1	End cap	4	Retaining clips
2	Slots for retaining clips	5	Desiccant container
3	O-ring		

4.3 Hydrophobic filter description

A single Teflon® hydrophobic filter (Cat. No. 3390) is installed in the top of the canister to prevent liquid from entering the vent tube.

For best performance and to avoid grease buildup on the filter during submergence or surcharge conditions, hang the canister vertically so that the end cap points downward (refer to [Figure 8](#)).

Note: The Hydrophobic Filter may need replacement at any time the cartridge is submerged or exposed to excess moisture. Refer to [section 4.4](#).

4.4 Hydrophobic filter replacement procedure

1. Disconnect the tubing from the top of the desiccant canister.
2. Unscrew the hex-head tubing nipple from the top of the canister and discard the old filter.
3. Discard any remnants of Teflon tape from the nipple threads. Apply two turns of Teflon tape (Cat. No. 10854-45) to the threads, pulling the tape into the threads until it conforms to the shape of the threads.
4. Place a new filter over the hole. Make sure that the smooth side of the filter faces the inside of the canister.
5. Place the threaded nipple on top of the filter.
6. With slight pressure, press the filter into the hole with the nipple threads and begin threading the nipple into the hole. The filter will deflect upward and feed completely into the thread until it disappears. The filter must rotate with the nipple as it is threaded into the cap. If it does not, it is torn. Start over with a new filter.
7. Inspect the installation. In the upper cap, a small, dim light spot should be visible when held up to the light. A bright spot indicates a torn filter. Start over with a new filter.

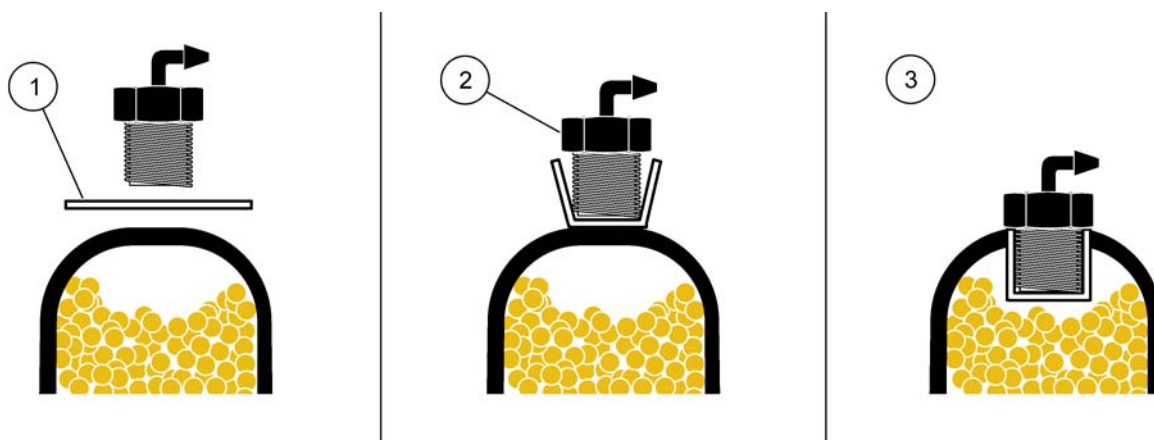


Figure 9 Replacing the hydrophobic filter

1	Filter, smooth side down	3	Finished assembly
2	Hex-head tubing nipple		

Section 5 Troubleshooting

When a problem occurs, isolate the problem to the sensor, the logger or the interconnect cable. Some typical problems and solutions are shown in [Table 2](#).

Table 2 Troubleshooting table

Problem	Cause	Solution
Sudden drops in velocity	The velocity electrodes are covered with debris.	Clean the sensor. Make sure the sensor is installed correctly.
Conductivity lost error message	The velocity electrodes are dry.	Make sure the water level is above the sensor. If the water level is low, construct a low-flow dam.
	The velocity electrodes are covered with debris or grease.	Clean the sensor.
Noisy velocity	There may be electrical noise in the pipe.	Identify and eliminate the source of the interference (if possible).
Depth measurements are incorrect or drift	Water is in the APR tube.	Replace the desiccant (or APR filter) cartridge. If possible, remove the sensor and allow it to dry.
Depth measurements are incorrect (stuck at zero or at full scale)	The internal depth transducer may be damaged.	Contact customer support.

Section 6 Contact Information

Ordering information for the U.S.A.

By Telephone:
(800) 368-2723

By Fax:
301-874-8459

By Mail:
Hach Company
4539 Metropolitan Court
Frederick, MD 21704-9452, U.S.A
Ordering information by e-mail:
hachflowsales@hach.com

Information Required

- Hach account number (if available)
- Your name and phone number
- Purchase order number
- Brief description or model number
- Billing address
- Shipping address
- Catalog number
- Quantity

European Union

Flow-Tronic
Rue J.H. Cool 19a
B-4840 Welkenraedt
Belgium
Tel: + -32-87-899799
Email: site@flow-tronic.com
www.flow-tronic.com

Outside the U.S.A. and EU

Hach Company maintains a worldwide network of dealers and distributors. To locate the representative nearest you, send E-mail to hachflowsales@hach.com or visit www.hachflow.co.

Technical Support

Technical and Customer Service Department personnel are eager to answer questions about our products and their use. In the U.S.A., call 1-800-368-2723. Outside the U.S.A. and Europe, send E-mail to hachflowservice@hach.com or call 1-301-874-5599.

Repair Service

Authorization must be obtained from Hach Company before sending any items for repair.

To send the monitor to the factory for repair:

1. Identify the serial number of the sensor.
2. Record the reason for return.
3. Call the Customer Service Department (1-800-368-2723) and get a Service Request Number (SRN) and shipping label.
4. Use the shipping label provided and ship the equipment in the original packaging if possible.

Note: Do not ship manuals, computer cables, or other parts with the unit unless they are required for repair.

Contact Information

5. Make sure the equipment is free from foreign debris and is clean and dry before shipping. Sensors returned without cleaning will be charged a fee.
6. Write the SRN number on the shipping box.
7. Make sure that all return shipments are insured.
8. Address all shipments to:

Hach Company
5600 Lindbergh Drive - North Dock
Loveland, Colorado, 80539-0389 U.S.A.
Attn: SRN#XXX

Appendix A Velocity profiling

WARNING

Potential confined space hazards. Only qualified personnel should conduct the tasks described in this section of the manual.

A.1 About velocity profiling

The sensor measures the water velocity at the bottom of the channel or pipe (called the sensed velocity). To calculate flow, the user needs to know the average velocity across the entire channel or pipe cross-section.

The average velocity is different from the sensed velocity because the water moves at different velocities at different parts of the cross section. The process of correcting the sensed velocity by measuring the average velocity is called profiling.

Profiling a site involves directly measuring the water velocity at several points across the pipe cross-section to determine the average velocity. The controller uses this profile information along with the sensed velocity and depth reported by the flow sensor to calculate the correct site calibration coefficient for the application.

The sensed velocity and depth should be obtained during or close to the time the velocity profile was done. The correct site calibration coefficient will allow the average velocity to be calculated accurately from sensed velocity at all depths.

Note: Because the exact procedure for performing a velocity profile will vary depending on the type of velocity profiling meter, the information included here is for general purposes. Refer to the user manual for the velocity profiling meter that is used for specific information.

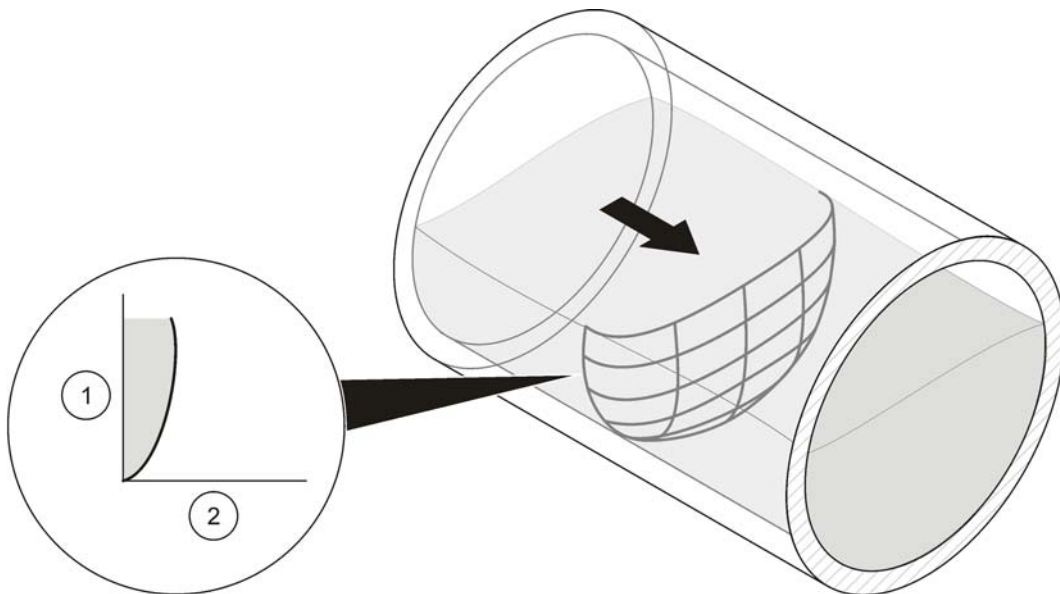


Figure 10 Typical velocity profile

1 Depth	2 Velocity
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A.2 Site selection

A site which has a typical profile shape will give the most accurate results. For most cases, sites which may be difficult to profile can be identified by a visual inspection. Use the following guidelines to select a site:

1. The channel should have as much straight run as possible. Where the length of straight run is limited, the length upstream from the profile should be twice the downstream length.
2. The channel should be free of flow disturbances. Look for protruding pipe joints, sudden changes in diameter, contributing side streams, outgoing side streams, or obstructions. Clean any rocks, sediment, or other debris that might be on the bottom of the pipe.
3. The flow should be free of swirls, eddies, vortices, backward flow, or dead zones. Avoid areas that have visible swirls on the surface.
4. Avoid areas immediately downstream from sharp bends or obstructions.
5. Avoid converging or diverging flow (approach to a flume) and vertical drops.
6. Avoid areas immediately downstream from a sluice gate or where the channel empties into a body of stationary water.

A.3 Profile guidelines

For best possible results:

1. Measure the horizontal and vertical diameter of the pipe. If there is a difference, then use the average for the inside diameter of the pipe.
2. Make sure the flow is symmetrical.
3. Measure the depth several times during the procedure.
4. Examine the pipe for rocks, sediment and other debris.

A.4 Depth of flow measurements

To perform a velocity profile, measure the depth of flow in the pipe:

1. Measure the inside diameter of the pipe.
2. Measure the distance from the top of the pipe to the top of the water ([Figure 11](#)).
3. Subtract this distance from the inside diameter of the pipe. This is the depth of flow.

Note: *The depth and velocities must be measured in the same vertical plane ([Figure 12](#)).*

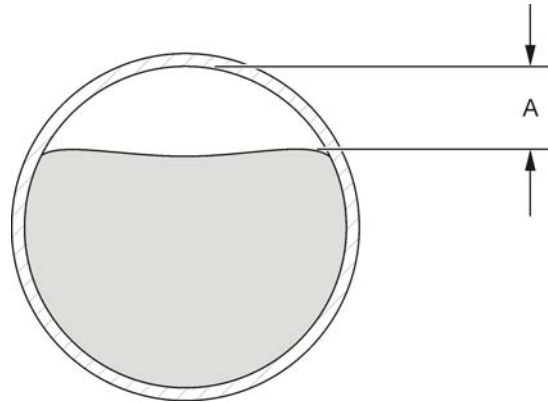


Figure 11 Depth of flow measurement

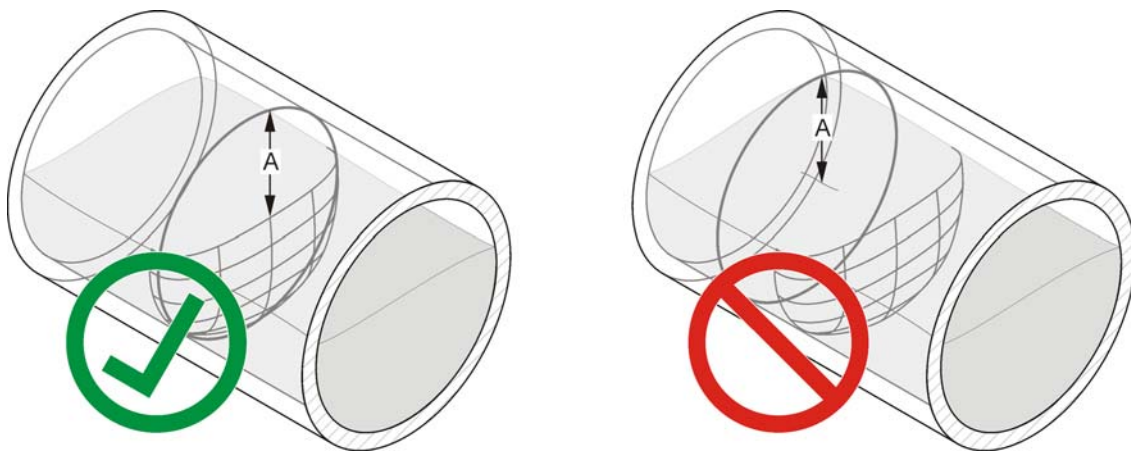


Figure 12 Depth of flow and velocity profile—single plane

A.5 Velocity profile calculations

There are four methods for profiling a site. The method chosen depends on the conditions at the site.

A.5.1 .9 x Vmax method

The .9 x Vmax method is the simplest method. Measure the velocity at different points of the cross section to determine the maximum velocity in the pipe. The average velocity is calculated by multiplying the maximum velocity by 0.9. This method should be used for:

- **Low flows**—flows of less than two inches depth.
- **Rapidly changing flows**—a flow that is changing more than 10% in three minutes or less can be classified as rapidly changing.

To profile the flow:

1. Measure the velocity at a series of points throughout the entire flow.
2. Identify the fastest velocity. In most cases, this is located in the center just beneath the surface.
3. Multiply the fastest velocity by 0.9.

Velocity profiling

A.5.2 .2, .4, .8 method

The .2, .4, .8 method is the most common method for profiling a typical flow. The velocity is measured at three points: .2, .4, and .8 times the total depth of flow. The velocity from each point is entered into the meter. This method should be used for:

- **Typical flows**—any site which does not have any disturbances, obstructions, turbulence, etc. Refer to [Site selection on page 24](#).

To profile the flow:

1. Measure the depth of flow (refer to [section A.4 on page 24](#)).
2. Calculate the measurement positions on the center line:
 - .2 position = $0.2 \times$ depth of flow
 - .4 position = $0.4 \times$ depth of flow
 - .8 position = $0.8 \times$ depth of flow
3. Measure the velocities at the .2, .4, and .8 positions ([Figure 13](#)).
4. Calculate the average of the .2 and .8 velocities.
5. Calculate the average of the .4 velocity with the .2 and .8 average from step 4.

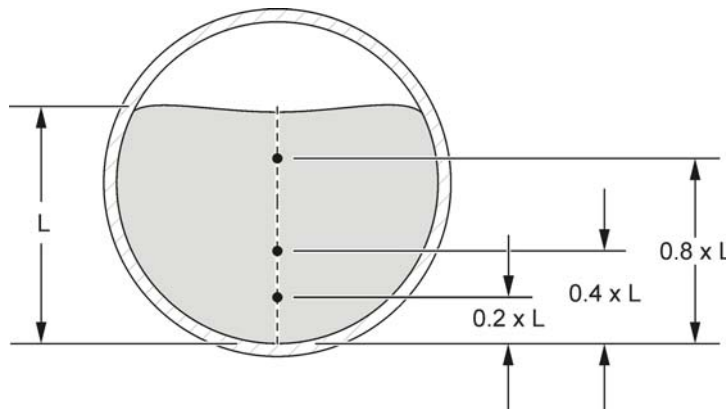


Figure 13 Measurement positions for .2, .4, and .8 method

A.5.3 .4 method

The .4 method is a simplified version of the .2, .4, .8 method. The velocity is measured at the .4 position only. Use this method for:

- **Low flows**—sites free of obstructions, etc., but without sufficient depth to measure the velocity at three points.

A.5.4 2D method

The 2D method uses the velocities from the center line, the vertical velocity lines, and corners of the flow. Use this method for:

- **Asymmetrical flows**—sites that have velocities that differ by more than 30% on either side of the pipe (for example, near a bend).
- **Vertical drops**—sites that are near an outfall or other change in depth.
- **Irregular flows**—any site thought to have an irregular or non-typical profile.

To profile the flow:

1. Find the center line of the flow.
2. Find vertical velocity lines (VVL) that are halfway between the center line and the side walls of the pipe (refer to [Figure 14](#)). Use the widest part of the flow.
3. Measure the velocity at a minimum of 7 different depths along the center line.
4. Measure the velocity along the VVL at different depths. The distance between these depths should be the same as those on the center line.
5. Measure the velocity at the right and left corners of the flow.
6. Examine the data for any outliers. An outlier will fall outside of the best fit curve region if a graph were made of the velocity profile.
7. Calculate the average velocity (except outliers) of all measurements (except outliers). Remember to include the corner measurements.

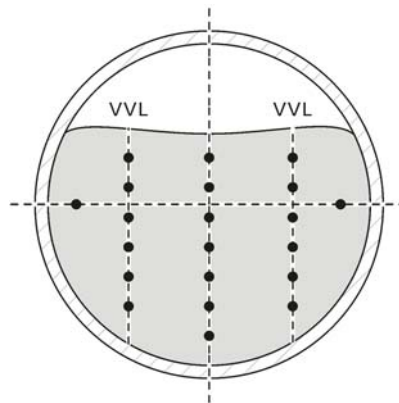


Figure 14 Velocity profiling for the 2D method

Alternate 2D method

A portable velocity sensor can be used to make a 2D profile. Move the sensor in a swirl pattern across the entire cross-section (refer to [Figure 15](#)). Set the instrument to calculate the average of these velocity measurements. Refer to the user manual for the portable velocity sensor for detailed instructions.

Typical procedure (for the Flo-Mate velocity profiling meter):

1. Set the FPA time to the appropriate number of seconds.
2. Place the sensor at the start position and wait for a few seconds.
3. Press <ON/C> and start moving the sensor.

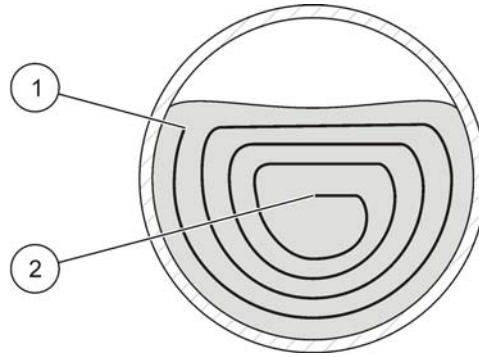


Figure 15 Velocity measured in a swirl pattern

1 Start position	2 Stop position
------------------	-----------------

A.6 Auto-Cal automatic calibration

For sites with straight-run, circular concrete pipes, an Auto-Cal automatic site calibration can be used in place of velocity profiling.

A.7 Calibrate the sensor using the Cal Wizard in the Flo-Ware software

Prerequisite:

The sensor must be installed in the process and must be online in order to perform the calibration. The sensor can be configured and calibrated with the calibration wizard as follows:

1. In the Flo-Ware software, click on the **Programming** tab in the FL900 Series Driver window.
2. Click the Sensor Port [1] (sensor name).
3. Click the **CAL WIZARD** button. The Calibration Wizard window opens.
4. Select the options on each screen. When the Calibration Complete screen appears, click **FINISH**.
5. Click **WRITE TO LOGGER** to save the settings.

Appendix B Flow calculations

WARNING

Potential confined space hazards. Only qualified personnel should conduct the tasks described in this section of the manual.

For most applications, the flow in a channel is calculated and recorded by a flow meter. This appendix is included to calculate the flow manually, or to understand how flow is calculated.

Flow calculations are provided for:

- Circular channels ([section B.1](#))
- Rectangular channels ([section B.2 on page 32](#))
- Rivers and streams ([section B.3 on page 33](#))

B.1 Circular channels

The following values are necessary before the flow can be calculated:

- The average velocity in ft/sec ([Appendix A on page 23](#))
 - The depth of flow in inches (in.) at the time of the velocity profile ([section A.4 on page 24](#))
 - The inside diameter of the channel in inches (in.)
1. Calculate the depth to diameter ratio (L/D) where:
 - L is the depth of flow in inches at the time of the profile.
 - D is the inside diameter in inches.
 2. Find the flow unit multiplier (K) from [Table 3 on page 30](#):
 - a. In the left column, find the L/D ratio from step 1.
 - b. Move to the right (to the desired units column) to get the flow unit multiplier (K).

Note: [Table 3](#) is for circular conduits only, measured in feet. The multiplier was derived using a one foot per second flow in a one foot diameter conduit as the model.

3. Convert the diameter to square feet:
 - $D^2 = (\text{channel diameter in inches} \div 12) \times (\text{channel diameter in inches} \div 12)$.
4. Calculate the flow:
 - $\text{Flow} = K \times D^2 \times \text{average velocity}$.

Example: What is the flow in millions of gallons per day (MGD) in a 10-inch diameter channel with a 6-inch depth? The average velocity was found to be 1.5 ft/sec.

$$L/D = 6 \text{ inches}/10 \text{ inches} = 0.6$$

$$K = 0.3180$$

$$D^2 = (10 \text{ in} \div 12)^2 = (0.833 \text{ ft})^2 = 0.694 \text{ ft}^2$$

$$\text{Flow} = K \times D^2 \times \text{average velocity} = 0.3180 \times 0.694 \text{ ft}^2 \times 1.5 \text{ ft/sec} = \mathbf{0.331 \text{ MGD}}$$

Flow calculations

Table 3 Flow unit multiplier

L/D	MGD	GPM	CFS	CMM	CMD	LPM
.01	.0009	.5966	.0013	.0023	3.2522	2.2585
.02	.0024	1.6824	.0037	.0063	9.1709	6.3687
.03	.0044	3.0814	.0069	.0117	16.7986	11.6644
.04	.0068	4.7296	.0105	.0179	25.7811	17.9036
.05	.0095	6.5894	.0147	.0249	35.9190	24.9438
.06	.0124	8.6351	.0192	.0327	47.0701	32.6876
.07	.0156	10.8475	.0242	.0411	59.1295	41.0621
.08	.0190	13.2113	.0294	.0500	72.0148	50.0103
.09	.0226	15.7143	.0350	.0595	85.6585	59.4851
.10	.0264	18.3460	.0409	.0694	100.0039	69.4471
.11	.0304	21.0975	.0470	.0799	115.0022	79.8627
.12	.0345	23.9609	.0534	.0907	130.6108	90.7020
.13	.0388	26.9294	.0600	.1019	146.7919	101.9388
.14	.0432	29.9967	.0668	.1135	163.5116	113.5497
.15	.0477	33.1571	.0739	.1255	180.7393	125.5134
.16	.0524	36.4056	.0811	.1378	198.4467	137.8102
.17	.0572	39.7374	.0885	.1504	216.6081	150.4223
.18	.0621	43.1480	.0961	.1633	235.1995	163.3330
.19	.0672	46.6334	.1039	.1765	254.1985	176.5267
.20	.0723	50.1898	.1118	.1900	273.5844	189.9892
.21	.0775	53.8135	.1199	.2037	293.3373	203.7064
.22	.0828	57.5012	.1281	.2177	313.4387	217.6657
.23	.0882	61.2496	.1365	.2319	333.8710	231.8548
.24	.0937	65.0555	.1449	.2463	354.6172	246.2619
.25	.0992	68.9161	.1535	.2609	375.6613	260.8759
.26	.1049	72.8286	.1623	.2757	396.9880	275.6861
.27	.1106	76.7901	.1711	.2907	418.5825	290.9823
.28	.1163	80.7982	.1800	.3059	440.4305	305.8545
.29	.1222	84.8503	.1890	.3212	462.5182	321.1932
.30	.1281	88.9439	.1982	.3367	484.8325	336.3892
.31	.1340	93.0767	.2074	.3523	507.3605	352.3337
.32	.1400	97.2464	.2167	.3681	530.0894	368.1176
.33	.1461	101.4507	.2260	.3840	553.0071	384.0327
.34	.1522	105.6875	.2355	.4001	576.1017	400.0706
.35	.1583	109.9546	.2450	.4162	599.3618	416.2234
.36	.1645	114.2500	.2545	.4325	622.7757	432.4831
.37	.1707	118.5715	.2642	.4488	646.3325	448.8419
.38	.1770	122.9172	.2739	.4653	670.0208	465.2922
.39	.1833	127.2851	.2836	.4818	693.8301	481.8265
.40	.1896	131.6733	.2934	.4984	717.7501	498.4375
.41	.1960	136.0797	.3032	.5151	741.7607	515.1178
.42	.2023	140.5026	.3130	.5319	765.8788	531.8603
.43	.2087	144.9400	.3229	.5487	790.0673	548.6578

Table 3 Flow unit multiplier (continued)

L/D	MGD	GPM	CFS	CMM	CMD	LPM
.44	.2151	149.3902	.3328	.5655	814.3250	565.5034
.45	.2215	153.8512	.3428	.5824	838.6420	582.3902
.46	.2280	158.3212	.3527	.5993	863.0080	599.3111
.47	.2344	162.7985	.3627	.6163	887.4133	616.2592
.48	.2409	167.2811	.3727	.6332	911.8480	633.2277
.49	.2473	171.7673	.3827	.6502	936.3024	650.2100
.50	.2538	176.2553	.3927	.6672	960.7664	667.1989
.51	.2603	180.7433	.4027	.6842	985.2306	684.1879
.52	.2667	185.2295	.4127	.7012	1009.6850	701.1701
.53	.2732	189.7121	.4227	.7181	1043.1200	718.1385
.54	.2796	194.1894	.4327	.7351	1058.5250	735.0869
.55	.2861	198.6594	.4426	.7520	1082.8910	752.0076
.56	.2925	203.1204	.4526	.7689	1107.1080	768.8945
.57	.2989	207.5706	.4635	.7857	1131.4660	785.7401
.58	.3053	212.0080	.4724	.8025	1155.6540	802.5377
.59	.3117	216.4309	.4822	.8193	1179.7630	819.2801
.60	.3180	220.8374	.4920	.8360	1203.7830	835.9605
.61	.3243	225.2255	.5018	.8526	1227.7030	852.5715
.62	.3306	229.5934	.5115	.8691	1251.5120	869.1057
.63	.3369	233.9392	.5212	.8856	1275.2010	885.5560
.64	.3431	238.2607	.5308	.9019	1298.7580	901.9149
.65	.3493	242.5560	.5404	.9182	1322.1710	918.1745
.66	.3554	246.8232	.5499	.9343	1345.4320	934.3275
.67	.3615	251.0600	.5594	.9504	1368.5260	950.3654
.68	.3676	255.2643	.5687	.9663	1391.4440	966.2805
.69	.3736	259.4340	.5780	.9821	1414.1730	982.0645
.70	.3795	263.5668	.5872	.9977	1436.7010	997.7090
.71	.3854	267.6604	.5963	1.0132	1459.0150	1013.2050
.72	.3913	271.7125	.6054	1.0285	1481.1030	1028.5440
.73	.3970	275.7206	.6143	1.0437	1502.9510	1043.7160
.74	.4027	279.6822	.6231	1.0579	1524.5460	1058.7120
.75	.4084	283.5946	.6319	1.0735	1545.8720	1073.5220
.76	.4139	287.4553	.6405	1.0881	1566.9170	1088.1370
.77	.4194	291.2612	.6489	1.1025	1587.6630	1102.5440
.78	.4248	295.0096	.6573	1.1167	1608.0950	1116.7330
.79	.4301	298.6972	.6655	1.1307	1628.1970	1130.6920
.80	.4353	302.3210	.6736	1.1444	1647.9500	1144.4090
.81	.4405	305.8774	.6815	1.1579	1667.3360	1157.8720
.82	.4455	309.3629	.6893	1.1711	1686.3350	1171.0660
.83	.4505	312.7735	.6969	1.1840	1704.9260	1183.9760
.84	.4552	316.1053	.7043	1.1966	1723.0880	1196.5890
.85	.4599	319.3538	.7115	1.2089	1740.7950	1208.8860
.86	.4644	322.5143	.7186	1.2208	1758.0230	1220.8490
.87	.4688	325.5815	.7254	1.2325	1774.7430	1232.4600

Table 3 Flow unit multiplier (continued)

L/D	MGD	GPM	CFS	CMM	CMD	LPM
.88	.4731	328.5500	.7320	1.2437	1790.9240	1243.6970
.89	.4772	331.4135	.7384	1.2545	1806.5330	1254.5360
.90	.4812	334.1650	.7445	1.2650	1821.5310	1264.9520
.91	.4850	336.7967	.7504	1.2749	1835.8760	1274.9140
.92	.4886	339.2997	.7560	1.2844	1849.5200	1284.3890
.93	.4920	341.6636	.7612	1.2933	1862.4060	1293.3370
.94	.4952	343.8759	.7662	1.3017	1874.4650	1301.7120
.95	.4981	345.9216	.7707	1.3095	1885.6160	1309.4560
.96	.5008	347.7815	.7749	1.3165	1895.7540	1316.4960
.97	.5032	349.4297	.7785	1.3277	1904.7390	1322.7350
.98	.5052	350.8287	.7816	1.3280	1912.3650	1328.0310
.99	.5068	351.9145	.7841	1.3321	1918.2840	1332.1410
1.00	.5076	352.5112	.7854	1.3344	1921.5360	1334.4000

B.2 Rectangular channels

Flow in rectangular channels is calculated as follows:

1. Find the average velocity with the 0.2, 0.4, 0.8 method (refer to [section A.5.2 on page 26](#)).

Note: For channel widths that are six feet or more, use the .2, .6, .8 method as described for rivers and streams ([section B.3 on page 33](#)). Velocity units must be in ft/sec.

2. Calculate the cross-sectional area in square feet (ft²):
 - Area = [(depth of flow) in. ÷ 12] x [(channel width) in. ÷ 12]
3. Calculate the flow:
 - Average velocity x cross-sectional area

The result will be a flow rate in ft³/sec (CFS). For conversion to other flow units, refer to [section B.4 on page 35](#).

Example: What is the flow in millions of gallons per day (MGD) in a rectangular channel that is 24 inches wide and has a 10-inch deep flow?

Average velocity:

Velocity at .2 x depth (2 inches) = 1.5 ft/sec
 Velocity at .4 x depth (4 inches) = 1.7 ft/sec
 Velocity at .8 x depth (8 inches) = 1.8 ft/sec
 $(1.5 + 1.8) \div 2 = 1.65$ ft/sec
 Average velocity = $(1.65 + 1.7) \div 2 = 1.67$ ft/sec

Cross-sectional area:

Convert inches to feet: $10 \text{ in} \div 12 = 0.83 \text{ ft}$
 Area = $0.83 \text{ ft} \times 2 \text{ ft} = 1.66 \text{ ft}^2$

Flow = $1.67 \text{ ft}^2/\text{sec} \times 1.66 \text{ ft} = 2.77 \text{ ft}^3/\text{sec}$
 From [Table 4 on page 35](#), $2.77 \text{ ft}^3/\text{sec} \times 0.64632 = 1.7903 \text{ MGD}$

B.3 Rivers and streams

1. Find the depth of each segment of the channel:
 - a. Divide the width of the channel into segments of equal length (d). Refer to [Figure 16 on page 34](#).
 - b. Locate the center line of each segment ($\frac{1}{2} \times d$).
 - c. Measure the depth of each segment on the segment center line.

Note: The .2, .6, and .8 positions for rivers and streams are measured from the surface. All depth and velocity measurements must be on the same plane.

Note: Smaller segments will give better results. If the difference in mean velocity between two adjacent segments is greater than 10%, make the segments smaller.

2. Use a velocity profile to calculate the flow for each segment:
 - a. Calculate the .2, .6, .8 velocity positions on the center line of each segment.
 - b. Measure the velocity at the .2, .6, and .8 positions.
 - c. Calculate the average of the .2 and .8 velocities.
 - d. Calculate the average of the .6 velocity and the average of the .2 and .8 velocities. This is the average velocity.
 - e. Calculate the cross-sectional area of each segment. Refer to [Figure 17 on page 34](#).
 - f. Calculate the flow of each segment:

$$\text{Flow} = \text{segment area} \times \text{average velocity}$$

3. Add the flows of all of the segments. The total flow for the river or stream is the sum of the segment flows.

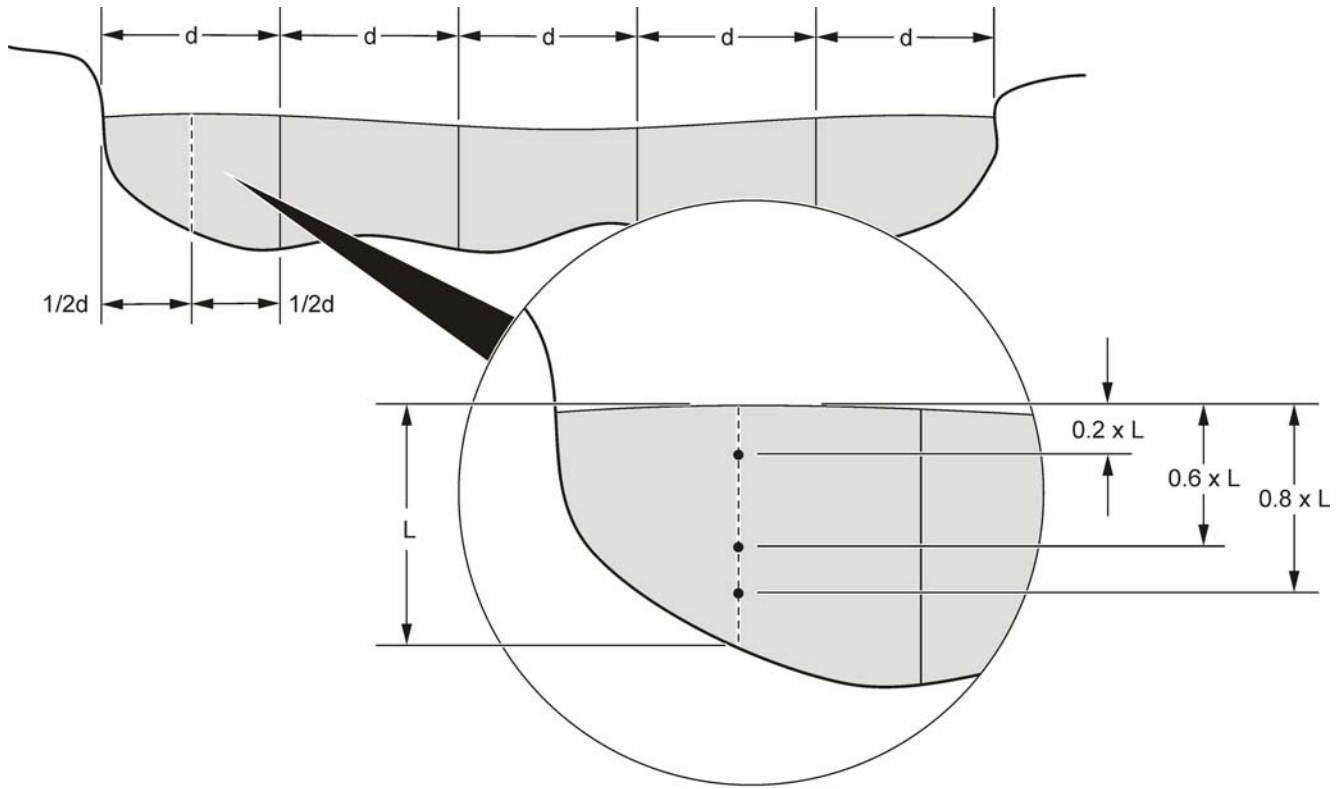


Figure 16 Segments for a river or stream

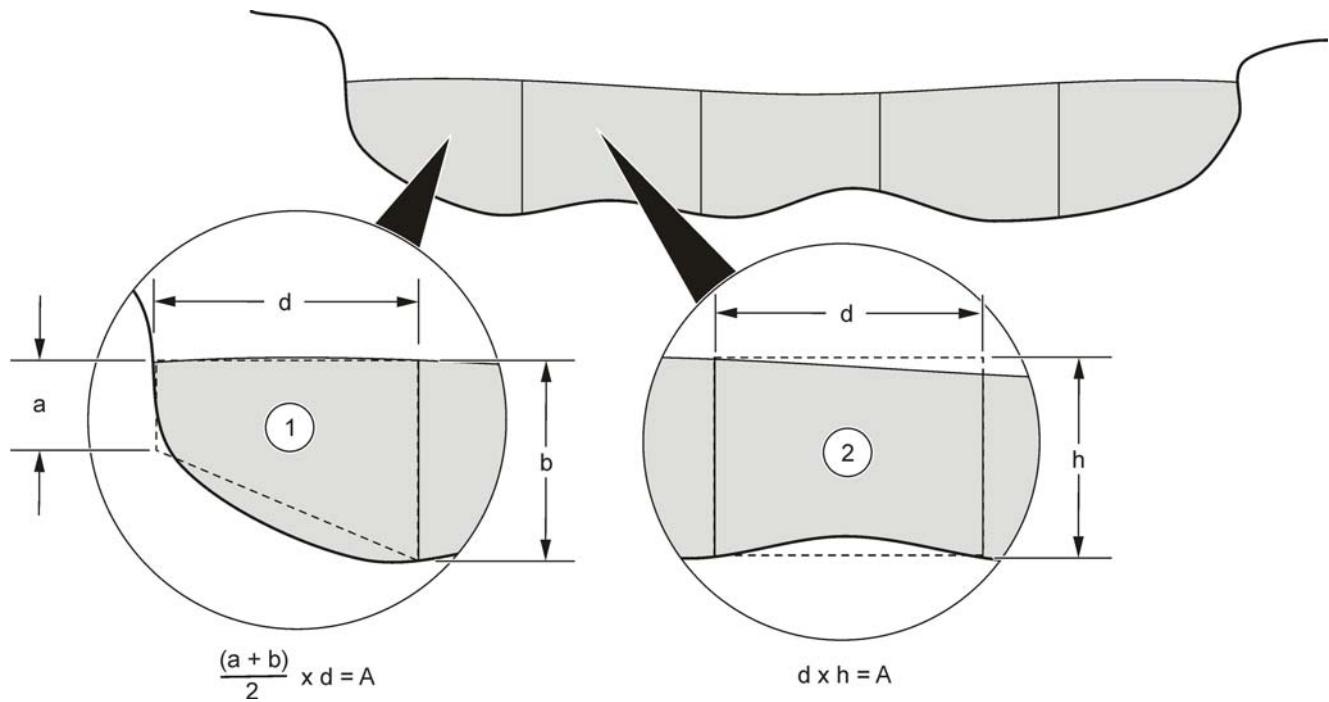


Figure 17 Segment area calculations

1 Trapezoid	2 Rectangle
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B.4 Flow unit conversions

1. Find the original unit in the left column of [Table 4](#).
2. Find the new unit in the top row of [Table 4](#).
3. Find the table cell where the units intersect. This is the conversion factor.
4. Multiply the original value by the conversion factor to get the value in terms of the new unit.

Example: convert 20 ft³/sec (CFS) to million gallons per day (MGD).
 From [Table 4](#), the conversion factor from CFS to MGD is 0.64632.
 20 ft³/sec x 0.64632 = 12.9 MGD

Table 4 Flow unit conversion factors

From (original units)	To (new units)				
	CFS	MGD	GPM	CMD	CMM
CFS	1	0.64632	448.831	2446.576	1.69901
MGD	1.54723	1	694.44	3785.412	2.62876
GPM	0.002228	0.00144	1	5.45099	0.0037854
CMD	0.000408	0.0002642	0.18345	1	0.0006944
CMM	0.5885	0.380408	264.172	1440	1

Flow units:

Unit	Definition
MGD	= million gallons per day
GPM	= gallons per minute
CFS	= cubic feet per second
CMM	= cubic meters per minute
CMD	= cubic meters per day
LPM	= liters per minute

A	
accuracy problems	19
APR tube	8
area, cross-sectional	32
C	
cleaning	15
concrete mold for dams	13
confined space entry	6
conversion factors	35
D	
dam construction for low flow	13
depth measurement	8
depth of flow measurement	24
E	
electrodes	7
errors	19
F	
Faraday's law	7
flow rate calculation	8
circular channels	29
rectangular channel	32
rivers and streams	33
flow unit multipliers	30
I	
installation	9
installation kits	12
K	
K, flow unit multiplier	30
L	
L/D ratio	29
location guidelines	9
low-flow applications	13
M	
measurement	
depth	8
velocity	7
P	
parts	9
S	
safety information	5
sensor locations	9
specifications	3
T	
theory of operation	7
troubleshooting	19
U	
units, flow	35
V	
velocity measurement	7
velocity profile	
0.4 method	26
0.9 Vmax method	25
2D method	26
about	23
methods	25

