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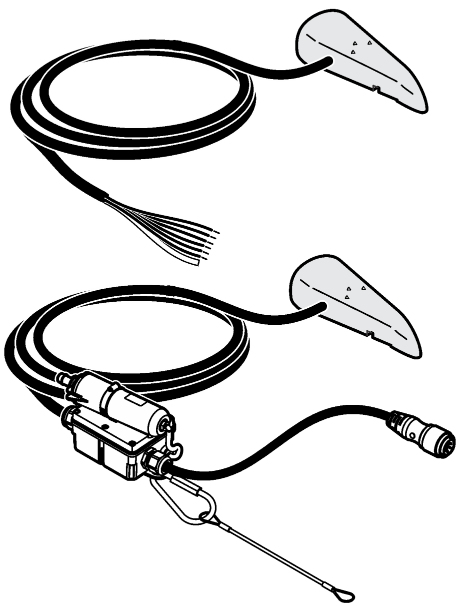
Flo-Tote 3

08/2017, Edition 1

User Manual



Specifications

Specifications are subject to change without notice.

Specification	Details
Dimensions (W x L x D)	131 x 44 x 28 mm (5.16 x 1.73 x 1.10 in.)
Enclosure	Polyurethane
Sensor cable	Polyurethane jacket. Standard length: 9 m (30 ft); maximum length: 305 m (1000 ft)[1]
Weight	1.1 kg (2.4 lb) with 9.1 m (30 ft) cable
Pollution degree	3
Protection class	III
Installation category	I
Operating temperature	0 to 45 °C (32 to 113 °F), 0 to 100% humidity
Storage temperature	–20 to 52° C (–4 to 125° F)
Power requirements	10 V, 100 mA supplied by the flow logger
Velocity measurement[2]	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 in.). 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), maximum length: 305 m (1000 ft)

1 Keep cable lengths as short as possible to prevent electromagnetic interferences.
2 Refer to Site location guidelines on page 8 for other measurement related information.

Specification	Details
Compatible instruments	FL series flow loggers
Warranty	1 year (EU: 2 years)

General information

In no event will the manufacturer be liable for direct, indirect, special, incidental or consequential damages resulting from any defect or omission in this manual. The manufacturer reserves the right to make changes in this manual and the products it describes at any time, without notice or obligation. Revised editions are found on the manufacturer's website.

Safety information

NOTICE

The manufacturer is not responsible for any damages due to misapplication or misuse of this product including, without limitation, direct, incidental and consequential damages, and disclaims such damages to the full extent permitted under applicable law. The user is solely responsible to identify critical application risks and install appropriate mechanisms to protect processes during a possible equipment malfunction.

Please read this entire manual before unpacking, setting up or operating this equipment. Pay attention to all danger 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.

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 which, if not avoided, may cause damage to the instrument. Information that requires special emphasis.

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 on the instrument is referenced in the manual with a precautionary statement.

	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.
	This symbol indicates the presence of devices sensitive to Electro-static Discharge (ESD) and indicates that care must be taken to prevent damage with the equipment.
	Electrical equipment marked with this symbol may not be disposed of in European domestic or public disposal systems. Return old or end-of-life equipment to the manufacturer for disposal at no charge to the user.

Confined space precautions

⚠ DANGER	
	Explosion hazard. Training in pre-entry testing, ventilation, entry procedures, evacuation/rescue procedures and safety work practices is necessary before entering confined spaces.

The information that follows is supplied to help users understand the dangers and risks that are associated with entry into 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 a confined space:

A confined space is any location or enclosure that has (or has the immediate potential for) one or more of the following conditions:

- An atmosphere with an oxygen concentration that is less than 19.5% or more than 23.5% and/or a hydrogen sulfide (H_2S) concentration that is more than 10 ppm.
- An atmosphere that can be flammable or explosive due to gases, vapors, mists, dusts or fibers.
- Toxic materials which upon contact or inhalation can cause injury, impairment of health or death.

Confined spaces are not designed for human occupancy. Confined spaces have a 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 obeyed before entry into confined spaces and/or locations where hazardous gases, vapors, mists, dusts or fibers can be present. Before entry into a confined space, find and read all procedures that are related to confined space entry.

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 FL series flow logger to make a complete flow system.

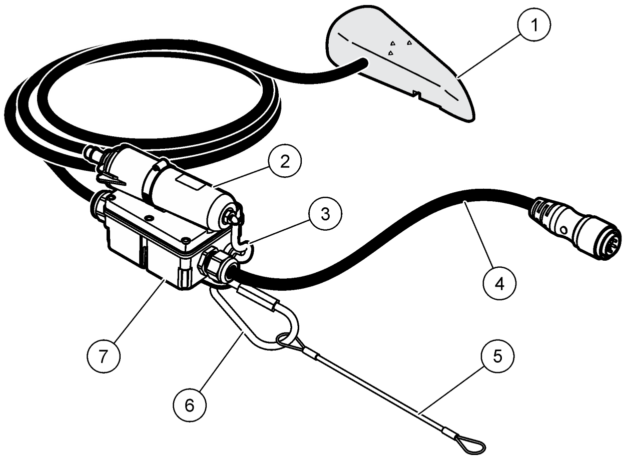
The Flo-Tote 3 sensor is available with a connector or bare-wire. Refer to Figure 1 and Figure 2.

The Flo-Tote 3 system features follow:

- Fully submersible sensor
- Debris-shedding sensor

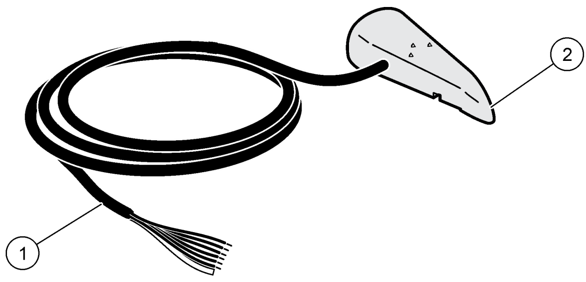
- Measurement for extremely low velocities and reverse flow
- Operation under free flow, non-free flow or surcharge conditions
- Field replaceable sensor
- No calibration required
- Increased signal intensity for greasing applications
- Flow temperature measurement

Figure 1 Product overview—Flo-Tote 3 sensor with connector



1 Flo-Tote 3 sensor	**5** Lanyard
2 Desiccant container	**6** Carabiner clip
3 Air reference tube	**7** Desiccant hub
4 Sensor cable with connector	

Figure 2 Product overview—Flo-Tote 3 sensor with bare-wire



1 Sensor cable with bare-wire	**2** Flo-Tote 3 sensor

Theory of operation

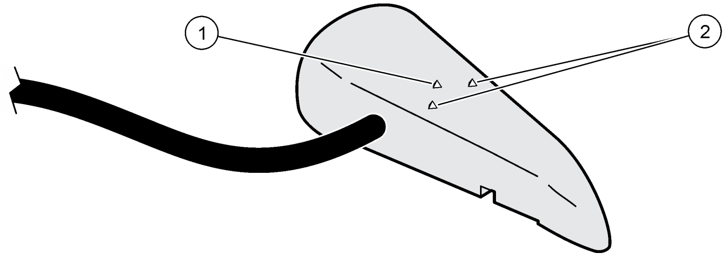
The Flo-Tote 3 open channel sensor directly measures water velocity and depth.

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 3. A faster water velocity produces a higher voltage. By accurately measuring this voltage, the velocity is determined.

Figure 3 Sensor electrodes



1 Ground electrode	**2** Velocity electrodes

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.

Flow calculations

The velocity and depth measurements are used with the channel dimensions to identify the flow rate. The flow rate is calculated from the continuity equation (1):

(1) Flow rate = Average velocity × Area

where

Flow rate = volume of liquid passing the sensor per unit of time (e.g., 200 gallons per minute)

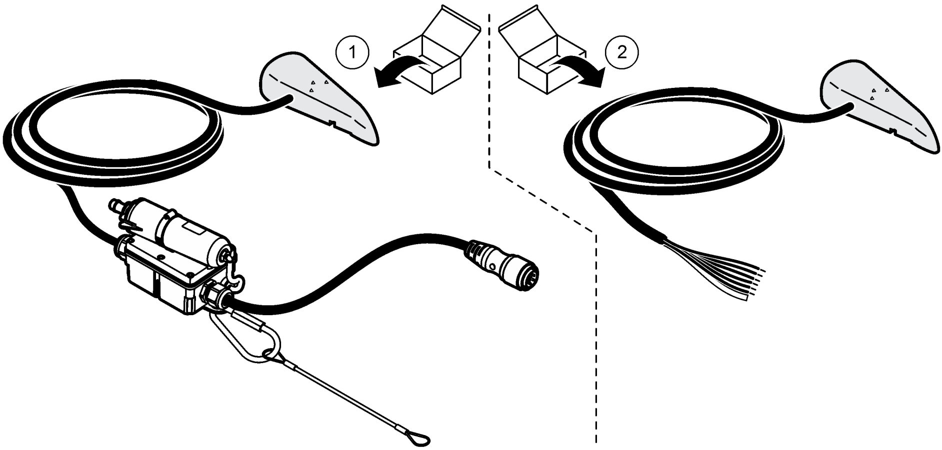
Average velocity = average velocity of the liquid, calculated with point velocity measurements and algorithms

Area = cross-sectional area of the liquid in the channel, calculated with the channel dimensions and depth measurement

Product components

Make sure that all components have been received. Refer to Figure 4. If any items are missing or damaged, contact the manufacturer or a sales representative immediately.

Figure 4 Product components



1 Flo-Tote 3 sensor with connector	**2** Flo-Tote 3 sensor with bare-wire[3]

Installation

⚠ DANGER	
	Explosion hazard. The instrument is not approved for installation in hazardous locations.

⚠ CAUTION	
	Multiple hazards. Only qualified personnel must conduct the tasks described in this section of the document.

NOTICE
Usually, the typical Flo-Tote 3 installations do not receive electromagnetic interferences. But, because of the velocity measuring method used in the AV probe, electrical machinery or radio transmitters near to the installation can cause measurement errors. Keep cable lengths as short as possible to prevent electromagnetic interferences. Also, be careful in the routing or collection of cables to keep this effect to a minimum level.

Items to collect

Collect the items that follow to install the sensor. The items that follow are supplied by the user.

- Sensor installation hardware[4]
- Socket and ratchet wrench
- Tie wraps
- Electrical tape to wrap the cable and installation hardware together (optional)

Site location guidelines

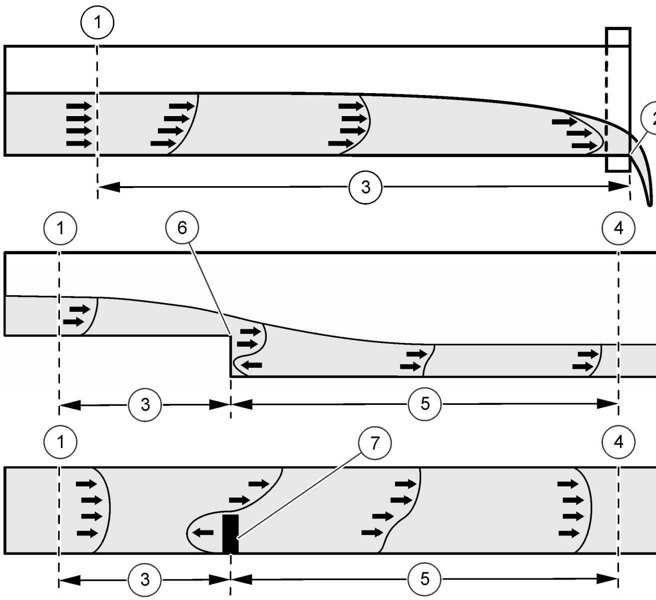
For the best accuracy, install the sensor where the flow is not turbulent. The ideal location is in a long, straight channel or pipe. Outfalls, vertical drops, baffles, curves or junctions cause the velocity profile to become distorted.

[3] Bare-wire is an alternative to the connector.
[4] Refer to Sensor installation hardware on page 12.

Where there are outfalls, vertical drops, baffles, curves or junctions, install the sensor upstream or downstream as shown in Figure 5–Figure 7. For upstream locations, install the sensor at a distance that is at least five times the pipe diameter or the maximum fluid level. For downstream locations, install the sensor at a distance that is at least ten times the pipe diameter or the maximum fluid level.

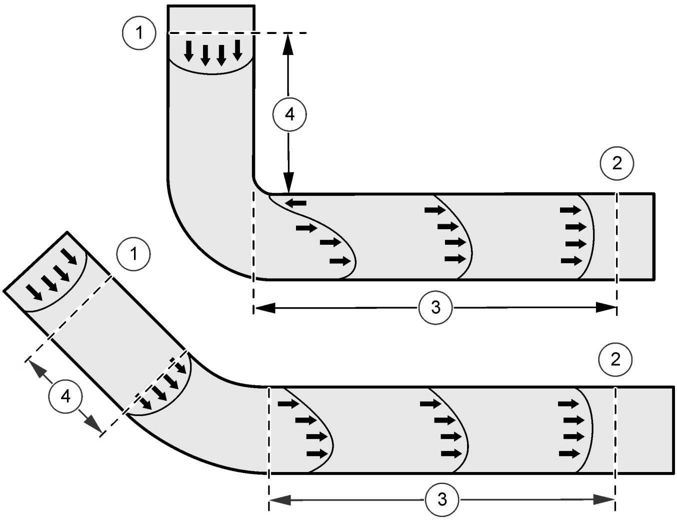
If the location contains a junction and the flow in one pipe is much higher, install the sensor on the wall near the lower flow pipe.

Figure 5 Sensor location near an outfall, vertical drop or baffle



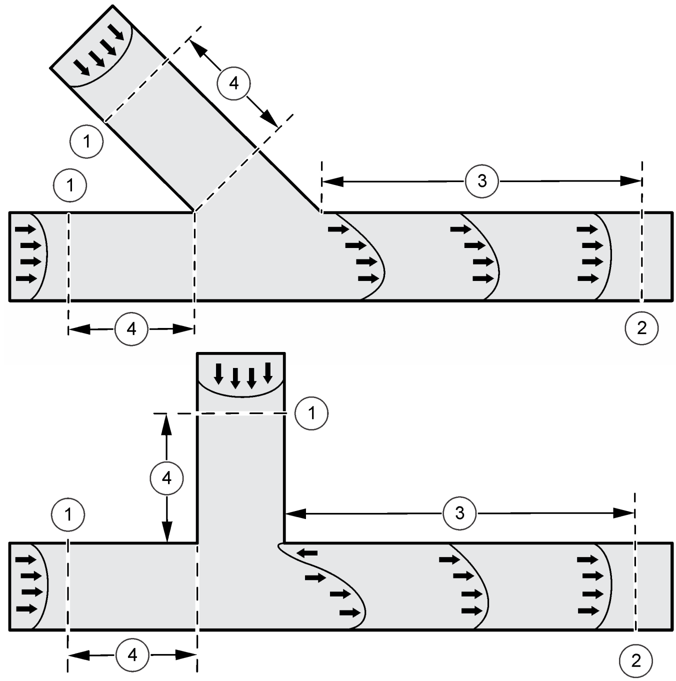
1	Acceptable upstream sensor location	**5**	Distance downstream: 10 × pipe diameter
2	Outfall	**6**	Vertical drop
3	Distance upstream: 5 × maximum level	**7**	Baffle
4	Acceptable downstream sensor location		

Figure 6 Sensor location near a curve or elbow



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

Figure 7 Sensor location near a junction



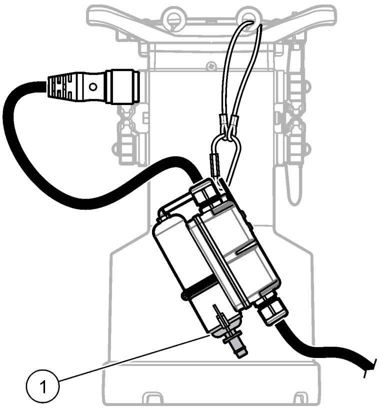
1 Acceptable upstream sensor location	**3** Distance downstream: 10 × pipe diameter
2 Acceptable downstream sensor location	**4** Distance upstream: 5 × pipe diameter

Attach the desiccant hub (FL900)

Attach the desiccant hub to the FL900 flow logger to give strain relief to the sensor cable and the connector. Refer to Figure 8.

For the best performance, make sure to install the desiccant container vertically with the end cap pointed down. Refer to Figure 8.

Figure 8 Attach the desiccant hub



1	End cap

Connect to a flow logger

Connect the sensor cable to a FL series flow logger. Refer to the flow logger documentation for instructions.

Sensor installation hardware

Attach the sensor to the installation hardware. Then install the installation hardware in a pipe or channel. Different installation hardware is available for sensor installation in different pipe sizes and shapes. Refer to Replacement parts and accessories on page 28 for ordering information. Refer to the documentation supplied with the installation hardware for installation instructions.

The installation hardware options follow:

- **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.
- **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.
- **Partial bands**—Metal band that covers the bottom half of a channel and stays in place by attachment to the channel wall.
- **Rectangular channel mount**—Metal plate that stays in place by attachment to the channel.

Operation

For sensors connected to an FL900 flow logger, connect a computer with FSDATA Desktop software to the flow logger to configure, calibrate and collect data from the sensors. Refer to the FSDATA Desktop documentation to configure, calibrate and collect data from the sensor.

For sensors connected to an FL1500 flow logger, refer to the FL1500 flow logger documentation to configure, calibrate and collect data from the sensors. As an alternative, connect a computer with FSDATA Desktop software to the flow logger to configure, calibrate and collect data from the sensors. Refer to the FSDATA Desktop documentation to configure, calibrate and collect data from the sensor.

Install the software

Make sure that the latest version of the FSDATA Desktop software is installed on the computer. Download the software from http://www.hachflow.com. Click Support, then select Software Downloads>Hach FL Series Flow Logger.

Maintenance

⚠ CAUTION	
⚠	Multiple hazards. Only qualified personnel must conduct the tasks described in this section of the document.

NOTICE
Do not disassemble the instrument for maintenance. If the internal components must be cleaned or repaired, contact the manufacturer.

Clean the sensor electrodes

NOTICE
Do not use sandpaper to clean the sensor electrodes. Sandpaper can damage the electrodes.

Refer to Troubleshooting on page 16 for when to clean the sensor electrodes.

1. Put a small amount of liquid detergent cleaner on a soft bristle brush.
2. Clean the sensor electrodes with the soft bristle brush. Refer to Figure 3 on page 7 to identify the electrodes.
3. Rinse the sensor electrodes with clean water.

Replace the desiccant

NOTICE
Do not operate the sensor without desiccant beads or with green desiccant beads. Permanent damage to the sensor can occur.

Immediately replace the desiccant when it changes to green. Refer to Figure 9.

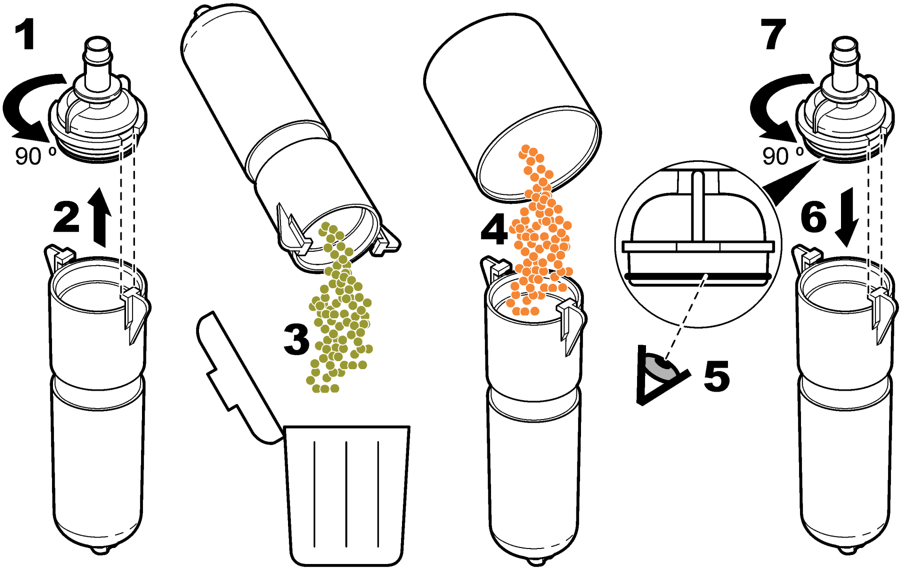
***Note:** It is not necessary to remove the desiccant container from the desiccant hub to install new desiccant.*

At step 5 of Figure 9, make sure that the O-ring is clean and has no dirt or debris. Examine the O-ring for cracking, pits or sign of damage. Replace the O-ring if it has damage. Apply grease to dry or new O-rings to make installation easier, to get a better seal and to increase the life of the O-ring.

For the best performance, make sure to install the desiccant container vertically with the end cap pointed down. Refer to Attach the desiccant hub (FL900) on page 11.

***Note:** When the beads just begin to turn green, it may be possible to rejuvenate them by heating. Remove the beads from the canister and heat them at 100-180 °C (212-350 °F) until they turn orange. Do not heat the canister. If the beads do not turn orange, they must be replaced with new desiccant.*

Figure 9 Replace the desiccant



Replace the hydrophobic membrane

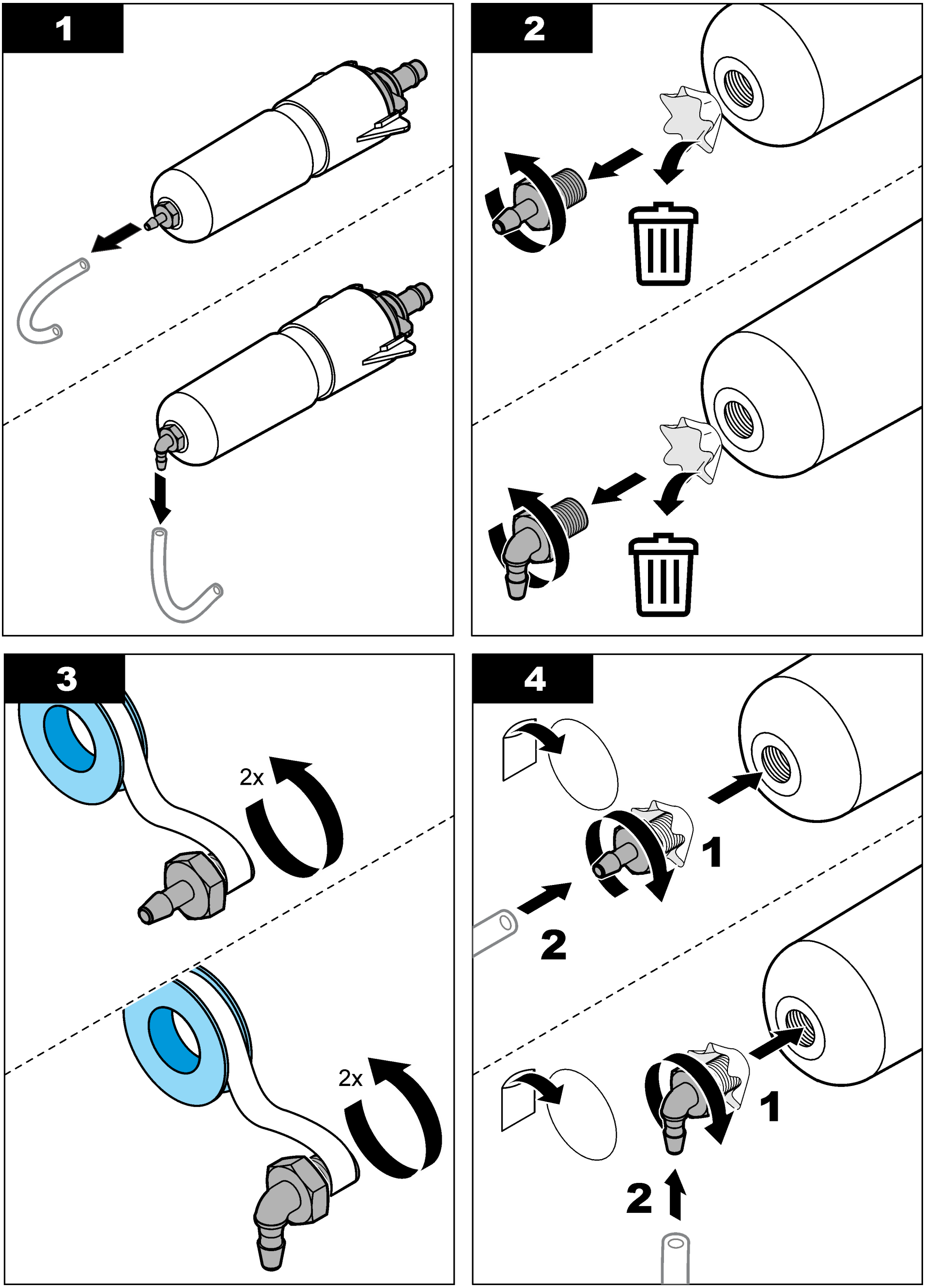
Replace the hydrophobic membrane when:

- Unexpected increases or decreases in level trends occur.
- Level data is missing or incorrect, but the velocity data is valid.
- The membrane is torn or has become saturated with water or grease.

Refer to the illustrated steps that follow to replace the membrane. At step 4, make sure that the following occurs:

- The smooth side of the hydrophobic membrane is against the inner surface of the desiccant container.
- The hydrophobic membrane bends up and goes fully into the thread until it is not seen.
- The hydrophobic membrane turns with the nipple when the nipple in the desiccant container turns. If the membrane does not turn, it has damage. Start the procedure again with a new membrane.

For the best performance, make sure to install the desiccant container vertically with the end cap pointed down. Refer to Attach the desiccant hub (FL900) on page 11.


1
2
3
2x
2x
4
1
2
1
2

Troubleshooting

When a problem occurs, isolate the problem to the sensor, the logger or the interconnect cable.

Problem	Possible cause	Solution
Sudden drops in velocity	The velocity electrodes are covered with debris.	Clean the sensor. Refer to Clean the sensor electrodes on page 13. 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. Refer to Clean the sensor electrodes on page 13.
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. Refer to Replace the desiccant on page 13. 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 technical support.

Appendix A: Velocity profiling

WARNING

Multiple hazards. Only qualified personnel must conduct the tasks described in this section of the document.

Read the confined space precautions before this procedure is started. Refer to Confined space precautions on page 5.

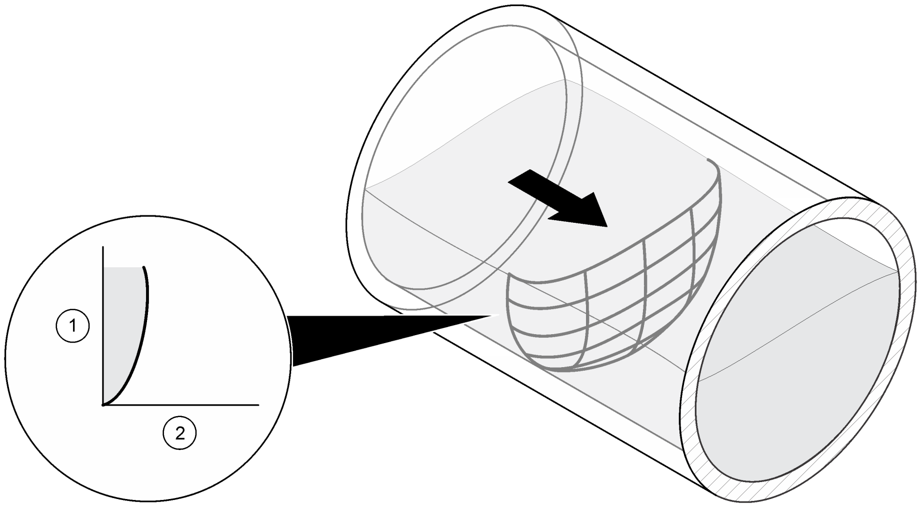
Profiling a site involves directly measuring the water velocity at several points across the pipe cross-section to determine the average velocity. The flow logger uses this profile information along with the sensed velocity and depth reported by the flow sensor to calculate the correct site calibration coefficient for the application. Refer to Figure 10.

***Note:** Profiling verifies or improves accuracy. However, the default site calibration coefficient is often adequate.*

The sensor measures the water velocity at the bottom of the channel or pipe (called the sensed velocity). The average velocity is different from the sensed velocity because the water moves at different velocities at different parts of the cross section. 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

Site selection

A site with the typical profile shape gives the most accurate results. Visual inspection is typically sufficient to identify problem sites. Use the information in these guidelines to help select the best site.

These guidelines apply to conduit and stream profiles.

- The channel should have as much straight run as possible. If the length of the straight run is limited, the length upstream from the profile should be two times the downstream length.
- The channel should be free of flow disturbances. The site must not have protruding pipe joints, sudden changes in diameter, contributing side-streams, outgoing side-streams or obstructions. Remove all rocks, sediment or other debris from the bottom of the pipe.
- The flow should not have visible swirls, eddies, vortices, back-flow or dead zones.
- Do not select areas immediately downstream from sharp bends or obstructions.
- Do not select areas with converging or diverging flow (approaches to a flume) or vertical drops.
- Do not select areas immediately downstream from sluice gates or places where the channel spills into a body of stationary water.

Profile guidelines

For best possible results:

- 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.
- Make sure the flow is symmetrical.
- Measure the depth several times during the procedure.
- Examine the pipe for rocks, sediment and other debris.

Measure the depth of flow

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. Refer to 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. Refer to Figure 12.*

Figure 11 Depth of flow measurement

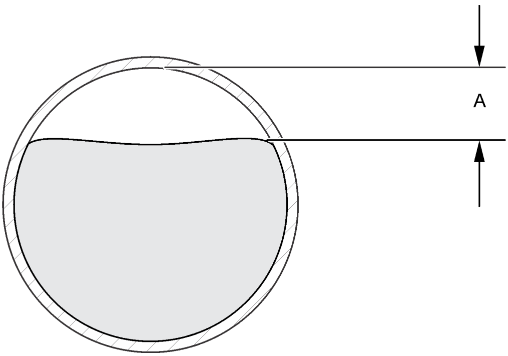
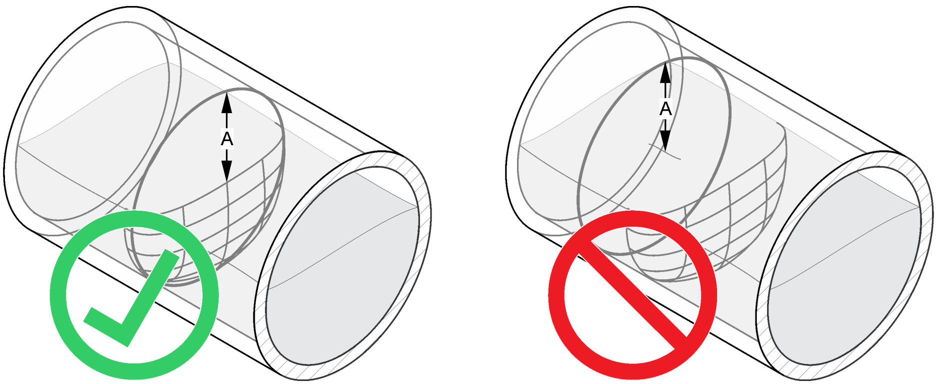


Figure 12 Depth of flow and velocity profile—single plane



Velocity profile calculations

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

0.9 x Vmax method measurement

The 0.9 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.

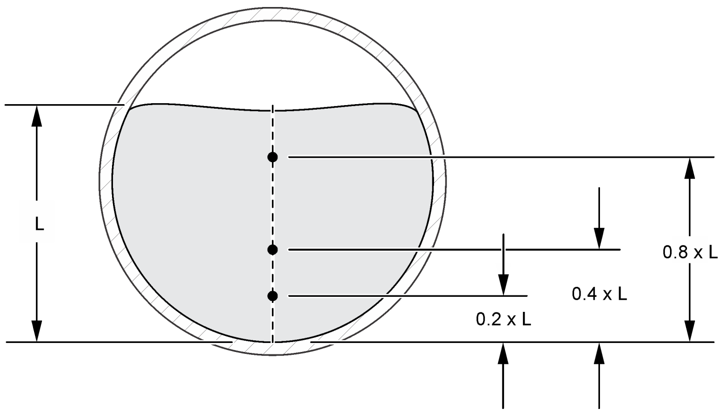
0.2, 0.4, 0.8 method

The 0.2, 0.4, 0.8 method is the most common method for profiling a typical flow. The velocity is measured at three points: 0.2, 0.4, and 0.8 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 17.

1. Measure the depth of flow. Refer to Measure the depth of flow on page 18.
2. Calculate the measurement positions on the center line:
   - 0.2 position = 0.2 x depth of flow
   - 0.4 position = 0.4 x depth of flow
   - 0.8 position = 0.8 x depth of flow
3. Measure the velocities at the 0.2, 0.4, and 0.8 positions. Refer to Figure 13.
4. Calculate the average of the 0.2 and 0.8 velocities.
5. Calculate the average of the 0.4 velocity with the 0.2 and 0.8 average from step 4.

Figure 13 Measurement positions for 0.2, 0.4, and 0.8 method



0.4 method

The 0.4 method is a simplified version of the 0.2, 0.4, 0.8 method. The velocity is measured at the 0.4 position only. Use this method for:

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

2D method

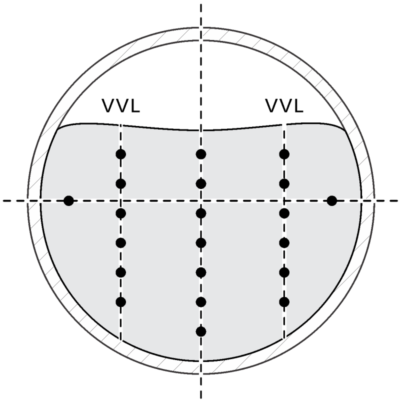
The 2D method uses the velocities from the center line, the vertical velocity lines, and corners of the flow. Use this method for:

- **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 (V V L) 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 V V L 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



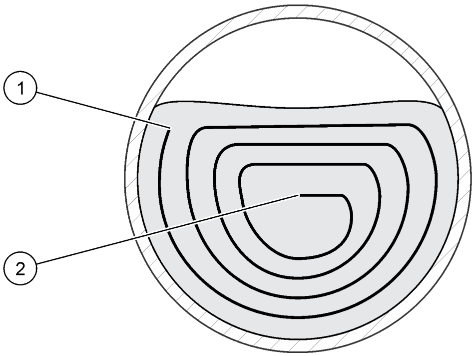
Alternate 2D method

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

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. The sensor must be installed in the process and must be online in order to perform the calibration. Refer to the FSDATA Desktop documentation to calibrate the sensor.

Appendix B: Flow calculations

⚠ WARNING	
⚠	Multiple hazards. Only qualified personnel must conduct the tasks described in this section of the document.

Read the confined space precautions before this procedure is started. Refer to Confined space precautions on page 5.

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
- Rectangular channels
- Rivers and streams

Calculate the flow—circular channels

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

- The average velocity in ft/s ()
- The depth of flow in inches at the time of the velocity profile (Measure the depth of flow on page 18)
- The inside diameter of the channel in inches

1. Calculate the depth to diameter ratio (L/D) where:
    - L= the depth of flow in inches at the time of the profile
    - D = the inside diameter in inches
2. Find the flow unit multiplier (K) from Table 1:
    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 1 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 = (channel diameter in inches ÷ 12) x (channel diameter in inches ÷ 12)

4. Calculate the flow:

Flow = K x D^2 x 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/s.

L/D = 6 inches ÷ 10 inches = 0.6 K = 0.3180

D^2 = (10 inches ÷ 12)^2 = (0.833 ft)^2 = 0.694 ft^2

Flow = K x D^2 x average velocity = 0.3180 x 0.694 ft^2 x 1.5 ft/s = 0.331 MGD

Table 1 Flow unit multiplier

L/D	MGD	GPM	CFS	CMM	CMD	LPM
.01	0.0009	0.5966	0.0013	0.0023	3.2522	2.2585
.02	0.0024	1.6824	0.0037	0.0063	9.1709	6.3687
.03	0.0044	3.0814	0.0069	0.0117	16.7986	11.6644
.04	0.0068	4.7296	0.0105	0.0179	25.7811	17.9036
.05	0.0095	6.5894	0.0147	0.0249	35.919	24.9438
.06	0.0124	8.6351	0.0192	0.0327	47.0701	32.6876
.07	0.0156	10.8475	0.0242	0.0411	59.1295	41.0621
.08	0.019	13.2113	0.0294	0.05	72.0148	50.0103
.09	0.0226	15.7143	0.035	0.0595	85.6585	59.4851
.10	0.0264	18.346	0.0409	0.0694	100.0039	69.4471
.11	0.0304	21.0975	0.047	0.0799	115.0022	79.8627
.12	0.0345	23.9609	0.0534	0.0907	130.6108	90.702
.13	0.0388	26.9294	0.06	0.1019	146.7919	101.9388
.14	0.0432	29.9967	0.0668	0.1135	163.5116	113.5497
.15	0.0477	33.1571	0.0739	0.1255	180.7393	125.5134
.16	0.0524	36.4056	0.0811	0.1378	198.4467	137.8102
.17	0.0572	39.7374	0.0885	0.1504	216.6081	150.4223
.18	0.0621	43.148	0.0961	0.1633	235.1995	163.333
.19	0.0672	46.6334	0.1039	0.1765	254.1985	176.5267
.20	0.0723	50.1898	0.1118	0.19	273.5844	189.9892
.21	0.0775	53.8135	0.1199	0.2037	293.3373	203.7064
.22	0.0828	57.5012	0.1281	0.2177	313.4387	217.6657
.23	0.0882	61.2496	0.1365	0.2319	333.871	231.8548
.24	0.0937	65.0555	0.1449	0.2463	354.6172	246.2619
.25	0.0992	68.9161	0.1535	0.2609	375.6613	260.8759
.26	0.1049	72.8286	0.1623	0.2757	396.988	275.6861

Table 1 Flow unit multiplier (continued)

L/D	MGD	GPM	CFS	CMM	CMD	LPM
.27	0.1106	76.7901	0.1711	0.2907	418.5825	290.9823
.28	0.1163	80.7982	0.18	0.3059	440.4305	305.8545
.29	0.1222	84.8503	0.189	0.3212	462.5182	321.1932
.30	0.1281	88.9439	0.1982	0.3367	484.8325	336.3892
.31	0.134	93.0767	0.2074	0.3523	507.3605	352.3337
.32	0.14	97.2464	0.2167	0.3681	530.0894	368.1176
.33	0.1461	101.4507	0.226	0.384	553.0071	384.0327
.34	0.1522	105.6875	0.2355	0.4001	576.1017	400.0706
.35	0.1583	109.9546	0.245	0.4162	599.3618	416.2234
.36	0.1645	114.25	0.2545	0.4325	622.7757	432.4831
.37	0.1707	118.5715	0.2642	0.4488	646.3325	448.8419
.38	0.177	122.9172	0.2739	0.4653	670.0208	465.2922
.39	0.1833	127.2851	0.2836	0.4818	693.8301	481.8265
.40	0.1896	131.6733	0.2934	0.4984	717.7501	498.4375
.41	0.196	136.0797	0.3032	0.5151	741.7607	515.1178
.42	0.2023	140.5026	0.313	0.5319	765.8788	531.8603
.43	0.2087	144.94	0.3229	0.5487	790.0673	548.6578
.44	0.2151	149.3902	0.3328	0.5655	814.325	565.5034
.45	0.2215	153.8512	0.3428	0.5824	838.642	582.3902
.46	0.228	158.3212	0.3527	0.5993	863.008	599.3111
.47	0.2344	162.7985	0.3627	0.6163	887.4133	616.2592
.48	0.2409	167.2811	0.3727	0.6332	911.848	633.2277
.49	0.2473	171.7673	0.3827	0.6502	936.3024	650.21
.50	0.2538	176.2553	0.3927	0.6672	960.7664	667.1989
.51	0.2603	180.7433	0.4027	0.6842	985.2306	684.1879
.52	0.2667	185.2295	0.4127	0.7012	1009.685	701.1701
.53	0.2732	189.7121	0.4227	0.7181	1043.12	718.1385
.54	0.2796	194.1894	0.4327	0.7351	1058.525	735.0869
.55	0.2861	198.6594	0.4426	0.752	1082.891	752.0076
.56	0.2925	203.1204	0.4526	0.7689	1107.108	768.8945
.57	0.2989	207.5706	0.4635	0.7857	1131.466	785.7401
.58	0.3053	212.008	0.4724	0.8025	1155.654	802.5377
.59	0.3117	216.4309	0.4822	0.8193	1179.763	819.2801
.60	0.318	220.8374	0.492	0.836	1203.783	835.9605
.61	0.3243	225.2255	0.5018	0.8526	1227.703	852.5715

Table 1 Flow unit multiplier (continued)

L/D	MGD	GPM	CFS	CMM	CMD	LPM
.62	0.3306	229.5934	0.5115	0.8691	1251.512	869.1057
.63	0.3369	233.9392	0.5212	0.8856	1275.201	885.556
.64	0.3431	238.2607	0.5308	0.9019	1298.758	901.9149
.65	0.3493	242.556	0.5404	0.9182	1322.171	918.1745
.66	0.3554	246.8232	0.5499	0.9343	1345.432	934.3275
.67	0.3615	251.06	0.5594	0.9504	1368.526	950.3654
.68	0.3676	255.2643	0.5687	0.9663	1391.444	966.2805
.69	0.3736	259.434	0.578	0.9821	1414.173	982.0645
.70	0.3795	263.5668	0.5872	0.9977	1436.701	997.709
.71	0.3854	267.6604	0.5963	1.0132	1459.015	1013.205
.72	0.3913	271.7125	0.6054	1.0285	1481.103	1028.544
.73	0.397	275.7206	0.6143	1.0437	1502.951	1043.716
.74	0.4027	279.6822	0.6231	1.0579	1524.546	1058.712
.75	0.4084	283.5946	0.6319	1.0735	1545.872	1073.522
.76	0.4139	287.4553	0.6405	1.0881	1566.917	1088.137
.77	0.4194	291.2612	0.6489	1.1025	1587.663	1102.544
.78	0.4248	295.0096	0.6573	1.1167	1608.095	1116.733
.79	0.4301	298.6972	0.6655	1.1307	1628.197	1130.692
.80	0.4353	302.321	0.6736	1.1444	1647.95	1144.409
.81	0.4405	305.8774	0.6815	1.1579	1667.336	1157.872
.82	0.4455	309.3629	0.6893	1.1711	1686.335	1171.066
.83	0.4505	312.7735	0.6969	1.184	1704.926	1183.976
.84	0.4552	316.1053	0.7043	1.1966	1723.088	1196.589
.85	0.4599	319.3538	0.7115	1.2089	1740.795	1208.886
.86	0.4644	322.5143	0.7186	1.2208	1758.023	1220.849
.87	0.4688	325.5815	0.7254	1.2325	1774.743	1232.46
.88	0.4731	328.55	0.732	1.2437	1790.924	1243.697
.89	0.4772	331.4135	0.7384	1.2545	1806.533	1254.536
.90	0.4812	334.165	0.7445	1.265	1821.531	1264.952
.91	0.485	336.7967	0.7504	1.2749	1835.876	1274.914
.92	0.4886	339.2997	0.756	1.2844	1849.52	1284.389
.93	0.492	341.6636	0.7612	1.2933	1862.406	1293.337
.94	0.4952	343.8759	0.7662	1.3017	1874.465	1301.712
.95	0.4981	345.9216	0.7707	1.3095	1885.616	1309.456
.96	0.5008	347.7815	0.7749	1.3165	1895.754	1316.496

Table 1 Flow unit multiplier (continued)

L/D	MGD	GPM	CFS	CMM	CMD	LPM
.97	0.5032	349.4297	0.7785	1.3277	1904.739	1322.735
.98	0.5052	350.8287	0.7816	1.328	1912.365	1328.031
.99	0.5068	351.9145	0.7841	1.3321	1918.284	1332.141
1.00	0.5076	352.5112	0.7854	1.3344	1921.536	1334.4

Calculate the flow—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 0.2, 0.4, 0.8 method on page 19.

   Note: *For channel widths that are 1.8 m (6 ft) or more, use the 0.2, 0.6, 0.8 method as described for rivers and streams. Refer to* Calculate the flow—rivers and streams *on page 25. Velocity units must be in ft/s.*
2. Calculate the cross-sectional area in square feet (ft^2):

   Area = (depth of flow in inches ÷ 12) x (channel width in inches ÷ 12)
3. Calculate the flow:

   Flow = average velocity x cross-sectional area

   The result will be a flow rate in ft^3/s (CFS). For conversion to other flow units, refer to Convert the flow units on page 27.

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 0.2 x depth (2 inches) = 1.5 ft/s

Velocity at 0.4 x depth (4 inches) = 1.7 ft/s

Velocity at 0.8 x depth (8 inches) = 1.8 ft/s

(1.5 + 1.8) ÷ 2 = 1.65 ft/s

Average velocity = (1.65 + 1.7) ÷ 2 = 1.67 ft/s

Cross-sectional area:

Convert inches to feet: 10 inches ÷ 12 = 0.83 ft

Area = 0.83 ft x 2 ft = 1.66 ft^2

Flow:

Flow = 1.67 ft^2/s x 1.66 ft = 2.77 ft^3/s

From Convert the flow units on page 27, 2.77 ft^3/s x 0.64632 = 1.7903 MGD

Calculate the flow—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.
   b. Locate the center line of each segment (½ x d).
   c. Measure the depth of each segment on the segment center line.

   Note: *The 0.2, 0.6, and 0.8 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 0.2, 0.6, 0.8 velocity positions on the center line of each segment.

b. Measure the velocity at the 0.2, 0.6, and 0.8 positions.
c. Calculate the average of the 0.2 and 0.8 velocities.
d. Calculate the average of the 0.6 velocity and the average of the 0.2 and 0.8 velocities. This is the average velocity.
e. Calculate the cross-sectional area of each segment. Refer to Figure 17.
f. Calculate the flow of each segment:

   Flow = segment area x 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

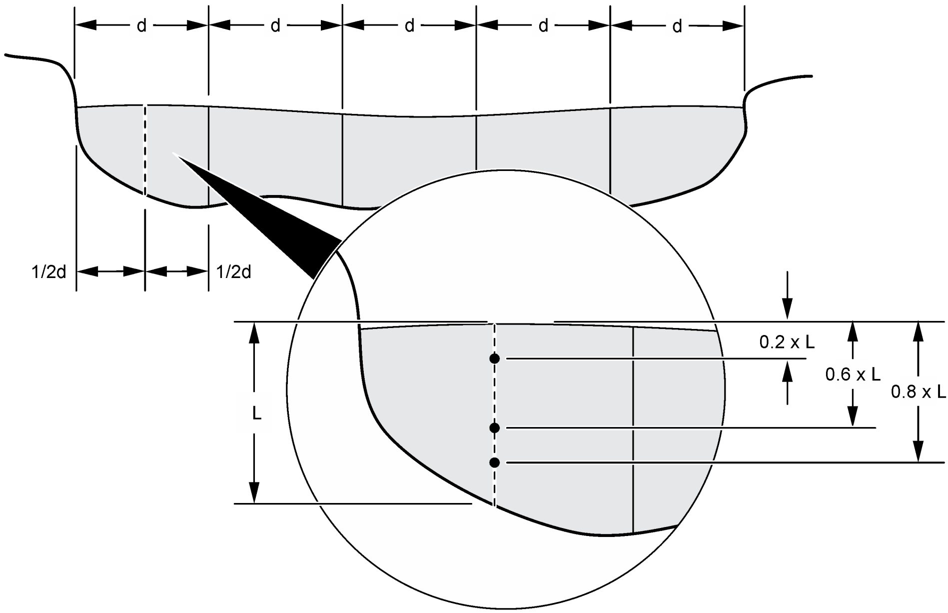
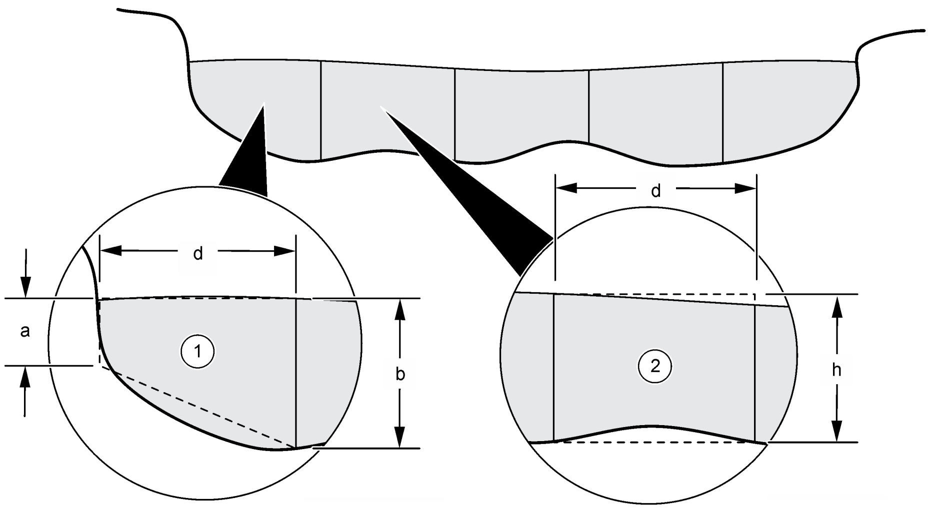


Figure 17 Segment area calculations



$$\frac{(a + b)}{2} \times d = A$$

$$d \times h = A$$

1 Trapezoid	**2** Rectangle

Convert the flow units

1. Find the original unit in the left column of Table 2.
2. Find the new unit in the top row of Table 2.
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 the new unit.

   Example: Convert 20 ft^3/s (CFS) to million gallons per day (MGD). The conversion factor from CFS to MGD is 0.64632.

   20 ft^3/s x 0.64632 = 12.9 MGD

Table 2 Flow unit conversion factors

Original unit	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

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

Replacement parts and accessories

⚠ WARNING

Personal injury hazard. Use of non-approved parts may cause personal injury, damage to the instrument or equipment malfunction. The replacement parts in this section are approved by the manufacturer.

***Note:** Product and Article numbers may vary for some selling regions. Contact the appropriate distributor or refer to the company website for contact information.*

Replacement parts

Description	Item no.
Desiccant beads, bulk, 1.5 pound canister	8755500
Desiccant container	8542000
Hydrophobic membrane	3390
O-ring, dessicant container end cap, 1.176 ID x 0.070 OD	5252

Accessories

Description	Item no.
Scissor band for ∅ 15.24 cm (6 in.) pipe	800008105
Scissor band for ∅ 20.32 cm (8 in.) pipe	800008106
Scissor band for ∅ 25.40 cm (10 in.) pipe	800008107
Scissor band for ∅ 30.48 cm (12 in.) pipe	800008108
Scissor band for ∅ 38.10 cm (15 in.) pipe	800008109
Scissor band for ∅ 45.72 cm (18 in.) pipe	800008110
Scissors-jack band, 10 in. wide x 18 in. base	800008101
Scissors-jack band, 10 in. wide x 36 in. base	800008102
Scissors-jack band, 10 in. wide x 18 in. base with 10 in. extension assemblies	800008103
Scissors-jack band	800008104
Spring band, Q-Stick[5]	750000201
Partial bands	800010101
Rectangular channel mount	75012-xx

[5] Tool for installation of a spring band without confined space entry.

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