# South Florida Water Management District Water Use Flow Monitoring and Calibration Guidelines

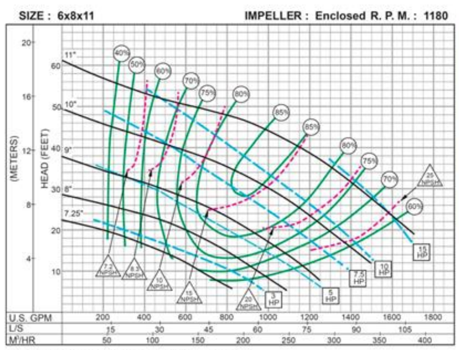

Figure 1: Manufacturer's Published Curve

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# 1.0 - Introduction

For over more than 30 years, the South Florida Water Management SFWMD (SFWMD) has developed water use rules and criteria designed to preserve, protect, and ensure an adequate supply of water resources within its jurisdiction. In order to fulfill this mission, the SFWMD requires certain holders of a water use permit to record the quantity of water they use each month and report the values every six months (unless otherwise stated in the limiting conditions of their water use permit). Section 4.1.1 of the Applicant's Handbook for Water Use Permit Applications requires all permittees with an average daily allocation of greater than 100,000 gallons, or irrigation water users located within the South Dade County Water Use Basin (as designated in Figure 21-11, Chapter 40E-21, Florida Administrative Code [FAC]) with an average daily allocation of greater than 300,000 gallons, to monitor and report withdrawal quantities from each withdrawal facility or point of diversion. The rule specifies that a permittee must install and maintain a reliable, repeatable water use accounting system on all of its active withdrawal facilities. The SFWMD considers a reliable water use accounting method to be accurate within +/- 10 percent (%) of the actual flow. Applicants seeking a water use permit must document the water use accounting method they plan to use and submit calibration certification as a part of the permit application. Prior to the use of any authorized facility, the approved water use accounting method must be operating and a current calibration certification submitted to the SFWMD. Under SFWMD guidelines, the water use accounting method for each active facility requires calibration every five years to ensure that the accuracy of the flow measurements is within +/- 10 % of the actual flow.

## 1.1 - Intent of the Guidelines

These guidelines provide an overview of the flow measurement and calibration methods currently accepted by the SFWMD. This guidebook lists the acceptable methods for flow measurement and calibration, information on method selection, and standard forms for recording water use and calibration data. Water use permit holders and/or their contractors are not required to use the enclosed forms. If a proposed water use accounting or calibration method does not appear in this guidebook, an individual/entity can submit documentation of their method to the SFWMD for review and approval.

## 1.2 - Selection of Flow Measurement and Calibration Method

When selecting a flow measurement and/or calibration method there are several factors to consider. The overall objective is that the recorded water use values, as required by the water use permit, are accurate to within +/- 10%.

- Facility Type: What types of water use facilities are included in the water use permit (well, pump, open channel flow [with or without structures])? The selected water use accounting method should be appropriate for the facility type.
- Flow Range: What are the expected ranges of flow at the site? The selected water use accounting system should cover the expected flow ranges for the permitted water use.
- Cost: What are the costs of the available water use accounting methods? Individuals/entities should base cost on the appropriateness of the water use accounting system for the on-site facilities. When considering the cost of a water use accounting system, one should also consider the maintenance and calibration costs, not just the price associated with the purchase and installation of the system.
- Adaptability: What are the flow conditions at the site? Will water flow only downstream or will it be pumped upstream as well? How much influence will the water use accounting system have on the water flow?
- Type of Measurements Needed: Does the water use flow continuously or periodically? Periodic and continuous flows may require different water use accounting methods.

All flow measurement devices presented in this document are suitable for achieving the desired accuracy required by the SFWMD's regulatory program. All instruments and structures will yield sufficient accuracy as long as their installation is according to manufacturers' specifications and are appropriate for the field situation.

All calibration methods' accuracies are tightly clustered and rarely exceed +/-2 to 5% (laboratory rating) and +/-5 to 10% in field use. Calibration methods should be recognized as having the same vulnerabilities when used in non-uniform field situations. Hence, simply selecting a device/method that performs better in a laboratory situation does not mean it will meet expectations/requirements when used under field conditions. Flow measurement in large water bodies and non-uniform open channel field conditions is not an exact science and will never result in an exact volume determination. It is an exercise in achieving the best estimates possible. Measurements in pipe flow under pressure are more exact and much less dependent on field non-uniformities.

## 1.3 – Maintenance and Calibration Considerations

Regardless of what system an individual/entity selects for water use accounting, they should consider the ease and cost of system maintenance. Routing maintenance should be part of the system operations and should include regular checks to ensure that the system(s) are clean and undamaged. The individual/entity should maintain logs documenting these checks. Culverts, gates, weirs, and flumes should be checked for geometric integrity on a regular basis since changes in form (bent cutouts, partially crushed culverts, gate restraints) may lose the ability to produce a repeatable opening. Additionally, clearing sediment buildup at inlets or outlets may be required periodically, as should any debris.

Each water use accounting system requires calibration every five years under SFWMD rules. However, if changes to the water use accounting system occur during the five year period between calibration(s), then recalibration of the new system is required. For example, if repairs or changes are made to the motor, pump or configuration for a pump station, then recalibration is required to make sure the water use accounting is accurate, especially if the individual/entity is using a pump curve determine flow. Also, if changes to the dimensions of a weir system are noticed, recalculation of the weir equation is necessary to determine accurate flow over the structure. One must be cautioned that in the case of hydraulic structures, changes in the rating curve are generally caused by a change in the primary measuring structure geometry. Hence, simply developing a new rating curve may not suffice until the appropriate repairs are made. Any repairs must be made consistent with the design requirements of the structure.

# 2.0 – Water Use Accounting and Calibration Methods

This section provides an overview of the current water use accounting and calibration methods accepted by the SFWMD. For a comprehensive explanation of different water use accounting methods and calculating flow, refer to the Water Measurement Manual prepared by the Bureau of Reclamation. The link below leads to the Bureau's web site where readers can obtain a copy of the manual.

Water Measurement Manual, A Water Resources Technical Publication, United States Department of the Interior, Bureau of Reclamation, Third Edition, Revised and Reprinted 2001, 317p.

Additionally, if an individual/entity is using a pump curve or flow meter to account for their water use, the SFWMD recommends following the manufacturer's directions to ensure accurate readings.

## 2.1 – Approved Water Use Accounting and Calibration Methods

The following sections list the water use accounting and calibration methods currently accepted by the SFWMD. The sections cover closed systems, such as pumps, pipes, and wells, and open channel systems. The open channel section is further divided into channels with structures and those without. As previously mentioned, if a water use accounting method is not presented in this document, individuals/entities can submit alternative methods with supporting data and references for the SFWMD to consider. Typically one of the systems described below is used for the primary water use accounting system for a water use permit and another of the methods is used to verify/calibrate the flow, when required. Some of the methods discussed are expected to be used in continuous flow monitoring applications while others are more suited for point-in-time measurements to verify rated pump system performance. While the latter seems to be less accurate than installing a continuous flow meter, this may not be the case. The user should check with the District prior to installation and use of the unmentioned methods.

### *2.1.1 - Understanding Flow Measurement Accuracy/Errors*

The determination of accuracy/error of a flow measurement technique requires the ability to know the actual or true flow of the water conveyance system. The accuracy/error of the primary flow measuring method is typically measured with a secondary flow measurement technique of a known accuracy. For example, to evaluate an inline flowmeter for accuracy, a second flow measurement device with known measurement accuracy, such as another flow meter or a manometer will be temporarily installed downstream of the flowmeter being tested. By comparing the flows of the two devices, the accuracy of the primary flow measuring system can be determined. The estimated error of the tested flowmeter is the difference between the two measurements divided by the flow measured by the second device plus its known error, mathematically expressed as

Error = (Tested Device’s Flow – Second Device’s Flow)/Second Device’s Flow

+ Error of Secondary Device

For example, if the measured flow of the primary measuring device is 105 cubic feet per second (cfs) and the true flow (as measured by the secondary device) is 100 cfs, then the error would be 5% (105 minus 100 divided by 100 then converted to %), while your accuracy would be 95% (100% - error as a %).

The level of accuracy of flow monitoring desired will directly influence the measurement technique that should be used and the overall cost of monitoring. This guidebook is intended to assist in the selection of the most appropriate flow measurement method for the typical situations encountered in South Florida, as well as procedures, proper operation, and determination and minimization of error.

This section summarizes choices for flow measurement configurations that would typically be applicable to South Florida water conveyance systems. It is only intended as a quick reference guide for the user to identify applicable flow monitoring alternatives for their system. Once identified, the user will need to obtain their own manufacturer specific information to complete the set up in conjunction with the general information provided in the following sections.

## 2.2 – Pumps

Pumps are typically used to move water from a surface water system, such as a lake or a canal, or groundwater from a well. Flow from a pump can be measured either directly from the pump or through the intake or discharge line running from the pump. The following subsections describe flow measurement methods related directly to the pump. Flow meters are discussed in the next section under pipe flow since these devices are generally attached to an intake or discharge pipe.

### *2.2.1 – Pumps and Head Discharge Curves*

Flow rating curves or “pump curves” are commonly used to determine flow through a pump. Pump manufactures provide these curves, but as the pump wears, they must be updated by recalibrating the pump. Pump curves provide the flow through the pump as a function of total dynamic head and the pump’s revolutions per minute. Total dynamic head is the height that the pump lifts the water from its source and it takes into account the outflow head and the frictional head loss in the pipes. Therefore, to determine flow by this method you must record both the total dynamic head and revolutions per minute of the pump. Pump curves consist of graphical charts (head versus discharge) for different pump revolutions per minute. It is possible to describe pump curves mathematically in the form of an equation so that one can calculate flows directly using a computer with data logging instruments.

### *2.2.2 - Pumps as Siphon Devices*

Siphoning is an alternative pump operation mode where a pump is used to fill a pipe and then turned off. The pump bore then backflows, or siphons, by gravity from the higher stage side of the pump to the lower stage side. This type of use is rare and typically limited to low head axial flow pump systems. Back siphoning can be damaging to most other systems and may require backflow prevention. Users must develop a flow rating curve when measuring flow this way with a pump.

## 2.3 – Pipes

Pipes convey water from either a pump fed or gravity fed system. The source of the water could be surface water from a lake or canal or groundwater from a well. Measurement methods for pipe flow can be simple, such as the trajectory method, or more complex using various types of flow meters or dye tracers. All methods discussed below meet the SFWMD accuracy standards and can be used for both flow measurements and calibration of a primary flow measurement device.

### *2.3.1 - Flow Meters*

For pumped systems, flow meters are easier to use than pump curves because they provide a direct reading of flow in the discharge line. However, they can be expensive, particularly for larger diameter pipes with higher quantities of water flow. Several types of approved flow meters are described below.

#### *2.3.1.1 - Inline Mechanical Flow meters*

These meters have propellers, impellers, turbines, vanes, or paddles to measure flow in a pipe and are installed along the discharge line. The installation distance from a pump, a pipe junction, or a bend must be at least 10 times the diameter of the pipe and uniform full pipe flow must be occurring. These types of meters are simple to use and can provide cumulative flow directly, eliminating the need for data loggers or frequent readings. Essentially, they are calibrated such that given the proper flow conditions and appropriate sizing, each turn of the device shaft represents a flow volume passing through that pipe section. An appropriately sized meter, based on the diameter of the discharge pipe, must be selected. Frequent maintenance may be required for these meters as debris in the pipe can disrupt the meter impeller. Installation and calibration according to manufacturers' specifications are an important factor in ensuring reliable readings. If all installation specifications are adhered to, accuracies are generally within +/- 2%.

*2.3.1.2 - Differential Pressure Flow meters*

These flow meters measure a pressure drop through a flow restriction (reduced cross-sectional area) in a pipe. Since this type of flow meter has no mechanical parts, measured flow rates are very reliable, as they do not trap debris like and impeller flow meter. Common types of these meters include venturis, orifices, and nozzles, with the venturi meter being the most common. The accuracy of this method is dependent on the accuracy of the pressure drop measurement and the measurement of the cross-sectional area of flow. The meters require the pipe to be flowing full and under pressure. The meter must be located a sufficient distance from the pump, a pipe bend, or joint (at least 10 pipe diameters) such that turbulent flow is minimized. These meters require head measurements to be taken upstream and at the throat of the constriction in the meter section (subtract to find the head difference). These meters can be very accurate compared to other devices used to measure pipe flow (+/-1% for venturi meters, +/- 1 to 2% for nozzles, and +/- 2 to 4% for orifices). Maintenance on these flow meters is minimal as there are no moving parts. The manufacturer supplies a coefficient of discharge, a ratio of throat to inlet diameter, and the area of the throat section with these flow meters. This information, along with the measured difference in head, are required to calculate flow. There are various ways of measuring and logging the head differences over time including physical recording of manometer readings and pressure transducers with data loggers. Recalibration of these flow meters should be conducted according to manufacturers' specifications. These flow meters lose accuracy when used in systems that flow at lower pressure than the manufacturers' recommended range of operation.

*2.3.1.3 - Ultrasonic/Acoustic Flowmeters*

Ultrasonic flowmeters are useful for continuous monitoring and recording during a pumping event as well as for calibrating pumping systems. Full pipe flow is required for these flowmeters to work properly. These flow meters include Doppler meters and time-of-travel (transit- time) meters. Doppler flow meter uses ultrasonic sound to measure fluid velocity by measuring the Doppler, or frequency shift, between the source signal and the reflected return signal bouncing off moving particles or bubbles in the flow stream. The frequency shift between the transmitted and detected signals is directly proportional to the flow velocity. The meter sensors can be mounted inside or strapped around the outside of the discharge pipe. Doppler meters are convenient to use because they can be attached to the outside of existing pipes, minimizing installation problems or errors. However, these meters require the presence of particles or bubbles in the water to function and do not work well in systems without suspended particulate matter or under laminar flow conditions. The meters are also sensitive to changes in fluid density and temperature. Hence, while not viewed as being extremely accurate under many conditions, accuracies meet the requirements of the SFWMD.

Time-of-travel or transit-time acoustic/ultrasonic flowmeters are more expensive and robust than the Doppler meters. Their main advantage is that they do not require particles in the fluid to work effectively. These meters can also be attached to the outside of existing pipes. The principle of operation is that a sonic signal travel time in the direction of flow to a receiving transducer will depend on flow velocity. A transmitter and receivers are placed on opposite sides of a pipe at about a 45-degree angle to the direction of flow. Travel times in the upstream direction are slower than those sent downstream. Using the difference in signal travel time, average velocity can be calculated.

*2.3.1.4 - Electromagnetic Flowmeters*

Electromagnetic flow meters consist of a non-magnetic and non-electrical conducting pipe section with two magnetic coils placed on opposite sides of the pipe section. Two electrodes are mounted on opposite sides of the pipe in a plane perpendicular to the magnetic coils. As flow passes through the meter, the electrodes pick up a voltage that is directly proportional to the flow velocity. The signal is amplified and translated into flow and volume measurements. These meters are accurate to +/-1% of the rated operating range when installed and used in accordance with manufacturers' specifications.

### *2.3.2 – Trajectory and Vertical Flow into Open Air Methods In Pipes*

The measurement of flow in a pipe can be done with or without the installation of a measurement device. Each method has its pros and cons and can be used as either a primary device or a device for verifying another flow measurement method. Although these methods are looked upon as simple and inaccurate, they have been calibrated and tested enough to ensure they meet the SFWMD's accuracy standards. Whether water is leaving a pipe in a horizontal trajectory (horizontal) or in a fountain pattern (vertical), the characteristics of the outflow stream are dependent on the fluid properties, the pipe properties, gravity, and the force that the water leaves the pipe. These parameters are generally stable, repeatable, or constant, making flow approximations quite accurate.

*2.3.2.1 – Horizontal Flow*

The horizontal pipe trajectory method is appropriate for both full and partially filled pipes. Calculating the flow rate is done by measuring the distance in inches that the stream of water travels in the horizontal direction from the end of the pipe as it drops 12 inches (Bureau of Reclamation, 2001. Water Measurement Manual). The diameter of the discharge pipe also must be known, or measured, to calculate the inside area of the pipe. The same measurements are required if the discharge pipe is slightly sloped. For full flow conditions, this method is often referred to as the Purdue Method. For partial flow from a pipe, in addition to collecting the aforementioned data, the ratio of the depth to the water inside the pipe to the inside pipe diameter needs calculation.

*2.3.2.2 – California Pipe Method*

This method calculates flow from the end of a partially filled horizontal pipe. The pipe needs to be level and the discharge point needs to be at least six times the pipe diameter away from the last elbow or junction (Bureau of Reclamation, 2001. Water Measurement Manual). The only measurements needed are the pipe inside diameter and the vertical distance between the inside of the pipe and the water surface measured from the inside of the top of the pipe. The measurements are input into a standard formula to calculate the discharge rate.

*2.3.2.3 – Vertical Flow*

The discharge rate from a vertical pipe, such as flow from an artesian well, is determined by measuring the maximum height at which the water rises above the top of the pipe. Look-up tables provide flow rates for different pipe diameters for the measured maximum height of the flowing water.

### *2.3.3 - Pitot Tubes*

A pitot tube can calculate the rate of flow in pipelines under pressure from the conduit cross sectional area and velocity measurements. This device consists of a tube bent at a right-angle which, when immersed with the bent open ended part pointed into the flow, will provide a direct measure of total head (velocity plus static head). For flow in open channels, the velocity head will simply be the distance that water rises in the vertical stem of the pitot tube above the water surface. However, when flowing under pressure, the user must also account for the static pressure within the pipe that will be included in the pitot tube reading. In this case, the static pressure head within the pipe is measured by using a static probe. A static probe is a simple tube with its opening(s) facing perpendicular to the flow so that it will not measure any velocity head associated with the flowing water. Some probes will couple the tubes with the static pressure tube concentric around the velocity tube, with holes drilled in the static tube. The pitot-static pressure probe essentially consists of two separate, essentially parallel parts, one for indicating the sum pitot-static pressure and velocity heads (total head) and the other for indicating the pressure head. Subtracting the static pressure head from the total head yields the velocity head.

Since the pitot tube can only measure the fluid velocity at one point in the flow profile, care is needed to account for varying velocities across the flow cross-section. In practicality, the pitot tube is not the best instrument to measure continuous flow because of velocity variability, clogging issues, and difficulty of accurately measuring continuous low heads. It is typically used to calibrate a primary flow measuring device. Using a pitot tube for continuous or event flow monitoring could be possible under explicit conditions. Those conditions are: 1) Pipe flow is extremely uniform and two readings are taken during an event to demonstrate uniformity; 2) A representative average flow velocity point within the pipe can be identified and substantiated under the range of flow conditions enabling more frequent or continuous monitoring; 3) A recording manometer is part of the monitoring system; 4) water is fairly clean such that blocking or clogging of the pitot tube is not an issue; and 5) the District preapproves the procedure.

### *2.3.4 - Dye Fluorometry*

There are two types of dye fluorometry methods that will yield pipe flow measurements. They are the tracer dilution and tracer velocity methods. Basically, tracer velocity is limited to use in high velocity pipe sections with definite mixing while tracer dilution can be used in both high and low velocity situations such as flow through culverts.

The tracer dilution method is based on the principles of mass balance. A tracer is introduced upstream at a measured rate and concentration. Downstream concentrations are then measured with a fluorometer for a period of time at a point where complete mixing is ensured. Measurements continue until the tracer concentration becomes constant. The amount that the tracer is diluted in the flowing water is determined and can be related directly to flow rate.

The tracer velocity method is simply a measure of time that it takes a tracer to pass through a pipe. Again, the tracer is introduced upstream and downstream concentrations are recorded with a fluorometer over time. Flows are then mathematically calculated from estimated velocity and cross-sectional area.

Dye fluorometry flow methods are generally accepted to be accurate to +/-2% using a dye such as Rhodamine WT and a suitable fluorometer. While the methods are cumbersome for continuous flow monitoring, it is an excellent flow measuring choice for calibrating pipe flow systems.

### *2.3.5 - Other Methods for Pipe Flow Measurement*

There are many other meters and methods for measuring or estimating pipe flow velocities and volumes. These methods will generally fall under one of the above discussed categories. Their exclusion in this discussion does not indicate that they cannot accurately estimate water flow in pipes. Rather, the methods or meters are generally less popular, more cumbersome, more expensive, closely related to, and/or more complicated than the methods described in this handbook.

## 2.4 - Open Channel Flow

This section is broken down into open channel flow systems that are categorized based on the presence or absence of designed flow management/monitoring structures (weirs, culverts, gates, etc.). Instrumentation, monitoring procedures, and verification (calibration) exercises are virtually the same for both conditions, with the presence of structures simply providing a higher level of accuracy because of a clearer definition of a channel cross-section. Some structures may not require any calibration because reliable flow measurement values can be directly calculated based on heads and the physical parameters of the structures.

### *2.4.1 - Absence of Hydraulic Structures*

Flow through an open channel or stream with no hydraulic structures present can be calculated by use of the Manning formula, a stream rating curve, stream gaging, or dye fluorometry. The Manning formula is very challenging to use because certain parameters cannot be easily determined. Therefore, for routine flow monitoring, the Manning formula and its related derivatives are probably not the most appropriate method.

The stream rating curve method requires that a relationship between flow and stage be developed through a detailed stream gaging process. For the low gradient systems, such as those found in South Florida, the stream rating curve method is not very reliable and is not recommended.

Velocity meters can also be used in association with stage for cross-sectional area relationships to estimate stream flow. Either magnetic, mechanical, transit-time, or Doppler type meters can be used, but these are fairly expensive alternatives for continuous measurements because of high installation costs and maintenance requirements. However, these meters are excellent for short-term measurements associated with calibration of other measurement techniques. This short-term approach is referred to as area-velocity/stream gaging and is discussed in greater detail below.

Dye fluorometry is also only appropriate for calibration purposes, but can be very useful for situations when stream geometries cannot be handled by other techniques. This and other alternative methods are also discussed in greater detail below.

*2.4.1.1 - Float Method*

The float method, while not simple, provides an inexpensive method for approximating flows. If used in situations where flows are generally uniform and within relatively narrow upper and lower bounds, the method can produce excellent results.

The float method measures the cross-sectional area of flow along a channel section where the channel geometry does not change greatly or involve flow from side channels. Given the measured cross-sectional area of the channel, the user then measures the flow rate in the channel section using floating objects spread out on the water surface. The time it takes the floating objects to travel a certain distance is the average water surface velocity. It is recommended that the average velocity be multiplied by a 0.8 correction factor to account for the shape of the velocity profile from the surface to the channel bottom. This method should not be used in channels with turbulent flow, in channels with greatly varying cross-sections over the test length, or on windy days when the water surface velocity can be skewed forward, backward, or sideways by wind velocity.

*2.4.1.2 - Area-Velocity/Stream-Gaging*

In the absence of a hydraulic structure in an open channel, the channel bottom shape defines the cross-sectional area of flow in the flow equation. Accurate determination of the cross-sectional area of flow can be a cumbersome procedure. After defining the area, adequate readings are needed to measure the average velocity of flow through the cross- sectional area in order to calculate the flow rate in the channel. This activity is also referred to as stream gaging.

For routine monitoring of flow, this method is cumbersome and simply not applicable. However, if time is spent to gage the stream enough times and locate an approximate point of average flow velocity, under different depths and flow conditions, a cross-sectional area of flow versus depth relation can be developed. Then, mounting a meter at a point in the channel that has been determined to be representative of the average flow velocity, channel stage and single point velocity readings can be taken and automatically recorded during flow events to yield an accurate discharge rate and volume. However, due to cost considerations, the sensitivity of the equipment and instrument mounting requirements, this method is not recommended. Measuring flows in this manner should be limited to pump and hydraulic structure calibration exercises.

In addition to the constraints listed above, stream gaging is only recommended and accepted as a calibration data collection method in situations where 100% of the flow to the pump is measured through the single channel. Situations with low flow velocities, non-uniform channels, interference from side channels, and fluctuating water levels during data collection will interfere with accurate discharge measurements in the measured channel. While it is advised that upstream channel sections be monitored, at times it may be necessary to measure a channel section downstream of the pump station to avoid side channel interference and backflow through leaky pump stations. backflow is common in box pump configurations where the primary purpose of the pump station is to move water laterally (as opposed to vertically) on or off a property. In this case, one must demonstrate that the channel stage between the pump station and the cross-section selected for measurement is not accumulating storage (constant stage; a pressure transducer mounted in the channel can provide a continuous record of stage during measurements).

*2.4.1.3 - Current/Velocity Meters for Stream-Gaging*

Vertical axis or vane type current meters and electromagnetic meters are two of the most often used current/velocity meters. A vertical axis meter consists of a wheel that rotates when immersed in flowing water and a device for determining the number of revolutions of the wheel. Water velocity is determined by counting the number of revolutions of the wheel over a given period of time. The relation between the velocity of the water and the number of revolutions of the wheel per unit of time is determined for each instrument by United States Bureau of Standards and are supplied in the form of an equation from which a rating table is compiled.

An electromagnetic meter operates on the principle that a voltage is induced in an electrical conductor moving through a magnetic field. For a given field strength, the magnitude of the induced voltage is proportional to the velocity of the conductor (flowing water). The sensor is equipped with an electromagnetic coil that produces the magnetic field and a pair of electrodes that measure the voltage produced by the flowing water. The measured voltage is then digitally converted as a linear measurement of velocity.

There are other types of current meters for measuring water velocity. These include the Acoustic Doppler Current Profiler (ADCP), the Point Acoustic Doppler Velocity Meter (PADVM), and the Smart Acoustic Current Meter (SACM).

The ADCP and PADVM operate on the principle of the Doppler effect of sound moving in water. The meters send a series of phase-encoded acoustic pulses at fixed frequency along each of the narrow acoustic beams and measure the frequency shift of the return echo. The ADCP is suspended in a fixed position within the water column and continuously measures velocities at user-prescribed intervals from near the channel bottom to near the water surface as the meter is moved across the channel. The PADVM measures a discrete velocity near the transducer heads and must be moved laterally and vertically within the measurement section to determine mean channel velocity. Velocities as low as 0.03 feet per second (ft/s) can be measured using these meters.

The SACM is a vector averaging current meter. The SACM is based on the time of travel of acoustic signals sent between two pairs of transducers oriented diagonally across the flow path. A small reflector located about one inch below the acoustic transducers reflects an acoustic pulse from one transducer to the opposite transducer. Components of the velocity vector are resolved using the velocities measured along the two acoustic paths and an internal, magnetic compass. The SACM can measure point velocities as low as 0.03 ft/s.

Factors to be aware of when using current meters are:

- Metering equipment must be used within the manufacturer’s guidelines.
- Eighty percent (80%) of the point velocities measured must be above the manufacturer’s minimum velocity.
- The two-point method and six-tenths-depth method of determining mean velocity in vertical line should be used. Meter measurements should be taken at two (2) and eight (8) tenths depths if the depth of flow equals or exceeds two (2) feet, otherwise at the six (6) tenths depth.
- No velocity measurement section shall carry more than 10% of the flow.
- The United States Geological Survey standard 40 second minimum observation time should be used

- Approach velocity measurement sections must be taken near the pump but no closer than a main canal width form the pump station and at least a main canal width downstream from side canals in a reach characterized by uniform flow and no turbulence. Artificial and/or temporary blocking of side or tributary canals is not representative of actual field operating conditions thus is not recommended.
- The meter shall be uniformly calibrated according to manufacturer's criteria.
- The meter must be visually inspected often to ensure physical integrity.

*2.4.1.4 - Dye Fluorometry*

There are two general dye fluorometry techniques used in open channel flow: 1) the velocity-area method; and 2) the tracer dilution method.

For the velocity-area method, the average cross-sectional area of the reach length, the distance between detection stations, and the time required for the tracer to travel between the detection stations have to be measured and/or known.

For the tracer dilution technique the tracer-dilution method does not require channel geometry or time measurements. Rather, the method depends on dilution concentrations and fully mixed conditions to occur downstream. The injection flow rate provides the volume per time dimensions for Q.

The accuracy of tracer methods depends on several parameters holding their accuracy. The primary factors for accurate measurements are the use of a calibrated fluorometer with a high accuracy rating and complete dye mixing in the stream segment being monitored. Another consideration is that the chemical tracer used must be stable in the environment in which it is used (i.e. it cannot fade in sunlight or be adsorbed by bottom sediments or biological growths). Backflows and eddies in the channel will delay the dye movement and impede the necessary mixing. Therefore, upstream dye injection must continue until the downstream concentration stabilizes at a constant value at all points across the flow path.

As with the stream gaging methods, dye fluorometry techniques are not readily suited for continuous monitoring during flow events. The methods are more suited for pump station calibration exercises or to check the accuracies of other methods used.

Tracer dilution method considerations:

- Determine whether slug or continuous injection of a tracer should be used and develop appropriate tracer measurement plan.
- Ensure the tracer is uniformly mixed within the sampling section. Injection manifolds may be needed to help achieve mixing.
- Instrumentation must be maintained and calibrated according to manufacturer's recommendations. Care must be taken to ensure that dye-water samples are within the linear range of a fluorometer and that background fluorescence is taken into account.

#### *2.4.1.5 - Other Flow Measurement Methods*

The use of any other data collection method not identified in this document will require prior approval from the SFWMD. Some manufacturers have designed instrument systems combining depth measurement with a point-velocity sensor. The velocity in the flow stream is measured at one point, typically the bottom of the channel, and the point velocity is converted into an average stream velocity based on stored calibration data. The average velocity is then used with the measured depth to determine the flow rate in the stream. Because of the complexity, expense of these devices, and the short history of in-field testing for reliability and accuracy, these devices are not widely used.

### ***2.4.2 - Presence of Hydraulic Structures***

For the purposes herein, hydraulic structures are defined as any structure that can be used to divert, restrict, stop or otherwise manage the flow of water. They can be made from a variety of materials including concrete, steel, rock, asphalt, wood, and earth. Water control structures include pump stations, weirs, flumes, gates and culverts. When a hydraulic structure is present, flow monitoring and calculation is often simplified and more accurate since the structure provides a definite and measurable cross-sectional area of flow. Further, many structures are designed to enable the monitoring of flow by forcing unique flow conditions to occur in a cross- section, requiring that only relatively simple head measurements be taken on a regular basis to estimate flow. In other words, the function of some hydraulic structures is to produce a flow that is characterized by a known relationship (usually nonlinear) between a water level measurement (head) at a particular location(s) and the flow rate through the structure. This relationship or head-flow rate curve for the particular structure or device is called the structure rating curve. A hydraulic structure designed to monitor flows is referred to as the primary device while the change in water level is measured by a secondary device. Many electronic data loggers associated with the secondary device can also automatically convert the water level readings to a flow rate using preprogrammed equations. Weirs and flumes are intentionally installed to enable flow monitoring while culverts and gates are flow control structures that yield known flow geometries and can be adapted to flow monitoring.

*2.4.2.1 - Weirs*

A weir is an overflow structure built across an open channel to raise the upstream water level so that water flows over the weir's top edge (a well-defined cutout section). The lowest point of structure surface or edge over which water flows is called the weir crest and the stream of water that exits over the weir is called the nappe. The depth of the flow over the crest is called the head and can be directly related to the flow going over the weir.

A properly installed weir has a shape and orientation that provides a unique depth of water in the upstream pool for a given discharge. Hence, they can be flow rated using the upstream head relative to the crest height. The shape of the cutout determines the crest overflow shape, which in turn governs how the discharge varies with head. Head-discharge equations are then used to calculate flows. Weir equations and crest coefficients for common weir geometries are available in most hydraulic books.

Weirs can be characterized in a number of ways, each resulting in the need to adjust the weir equation. Contracted weirs are characterized by notch sides that are narrower than the channel and crest heights sufficiently above the channel bottom. This configuration results in flow paths that converge through the cutout from all directions. A suppressed weir is one in which no side contraction of the flow stream exists. Partially contracted weirs result when specified distances of the cutout sides or bottom from the channel sides and bottom are not met.

In addition to contracted and suppressed weirs, weirs can be identified as either sharp-crested weirs or broad-crested weirs. Sharp-crested (or thin plate) weirs are thin plastic or metal plates set vertically across a channel and perpendicular to the flow. They have sharp upstream edges formed so that nappe flows clear of the crest. Sharp-crested weirs are partially named by the shape of the blade overflow opening, such as rectangular, triangular (V-notch) and trapezoidal (Cipolletti). A broad crested weir is a structure that supports the nappe for an appreciable distance in the direction of flow.

Each type of weir has a specific discharge equation for determining the flow rate through the weir. The equation is based on the depth of the water in the pool formed upstream from the weir. A weir discharge measurement consists of measuring depth or head (height of the water above the crest) relative to the crest at the proper upstream location in the weir pool, and then using a table or equation for the specific kind and size of weir to determine discharge.

Flow over weirs can be classified as free flow (unsubmerged) or submerged. In free flow, air has free access under the falling jet or sheet of water (nappe) exiting the (weir crest) cutout. When downstream water levels rise above the weir crest elevation, submerged conditions exist. This condition requires a correction to be made to the weir equation. When submerged conditions exist, flow measurements, even with submerged condition calibrations, should only be viewed as flow approximations since accuracy falls off dramatically.

Flows estimated from weir relationships can have accuracies up to +/-1.5% to 2.5% if care is taken to follow proper protocols and manufacturers'/design specifications. However, it must be noted that the range of error in the accuracy of head measurements will introduce further error. Plus, any clogging of or structural damage to the weir can also introduce significant error. For standard weir geometries without submergence problems, calibration is only required for the water depth measurement instrument selected. However, for non-standard geometries, calibration of the weir using stream gaging techniques is recommended.

Weir Considerations

- construction must be precise and according to specifications
- installation must be normal to flow path and crest must be level (centerline of V vertical for V-notch configurations)
- adjust weir crest coefficient based on the crest width in the flow path
- the most accurate condition is a sharp crested weir whose crest thickness is between 0.03 and 0.08 in and uniform over the entire overflow edge
- upstream edges of the weir opening must be straight and sharp but not knife-edged
- downstream water surface should always be at least 0.2 foot below the crest
- measurement of head on the weir is the vertical distance between the crest and the water surface upstream a distance of at least four times the maximum expected head on the crest
- approach to weir must be kept free of sediment deposits and surface debris build-up

*2.4.2.2 - Flumes*

Flumes are artificial channels with clearly specified shape and dimensions that constrict and accelerate water flow through them. They are primarily designed for measuring flows that vary widely, such as seasonal runoff, but can also be used for continuous monitoring. The area or slope (or both) of the flume is intentionally different from that of the channel, causing an increase in water velocity to “critical,” which creates an associated drop in water level that is proportional to the rate of water flowing through the flume. This “critical” flow condition is created by gradually reducing the width of the flume at its midpoint while the flume bottom is either raised or lowered in such a way that critical flow occurs. Note that when only the bottom is raised with no side contractions, the flume will function as a broad-crested weir. Because critical flow is attained, measuring the upstream water level allows discharge to be accurately computed.

The most common types of flumes are the Parshall flume, and the trapezoidal flume. The Parshall flume is the most widely known and used flume. It consists of a converging upstream section, a throat, and a diverging downstream section. Parshall flumes constrict horizontally and are designed for rectangular or trapezoidal channels. As water enters the flume, it converges in a restricted section called a throat. At the same time, a drop in the floor at the throat causes a change in the flow depth.

A Trapezoidal flume consists of a wide approach section, a gradual transition section, and a throat section. The flow through a trapezoidal flume is computed by estimating the discharge through the critical depth at the throat.

Special considerations for flumes

- standard flumes require no calibration whereas non-standard shapes will
- should not be located near turbulent flow, tranquil flow is best
- 65 to 85% submergence is currently recommended as a maximum
- sufficient head loss through the flume is necessary to enable accurate head measurements
- head can be measured in the flume or in a stilling well set off to the side

## 2.5 - Culverts

A culvert is a closed conduit for conveyance of water. This type of water control structure provides a means for water to pass underground from one location to another. The traditional use of culverts is to convey storm water flow under access roads without causing excessive backwater buildup or overtopping, while minimizing downstream velocity.

Culverts are commonly made of metal (aluminum or steel), reinforced concrete, or polyvinyl chloride (PVC). Concrete culverts may be either circular or rectangular in cross section. When rectangular, the culvert is usually referred to as a box culvert. The major components of a culvert are its inlet, the culvert pipe barrel itself, and its outlet. The metal and PVC culverts are typically corrugated for additional strength.

There can be four states of flow through an open culvert, which depend on the up and downstream heads, culvert dimensions, and its bottom slope. These flow states are: 1) inlet orifice controlled (requires high upstream head and low downstream head); 2) inlet weir controlled (upstream head below top of culvert, low downstream head, and significant bottom slope); 3) pipe controlled (up and downstream heads above culvert); and finally 4) open channel controlled (partially filled culvert with downstream backwater where the Manning's Equation controls). The low head drops (by design) through a culvert and these different states of flow that can occur sometimes make it difficult to use culverts for flow measurement. Often culverts are associated with other structures such are weir or gates and in these cases the structures would typically provide a better flow measurement location and are discussed separately in this guidebook. However, two common structures that are attached to culverts are briefly discussed below.

Gated culverts provide control of culvert flow using slide gates. The design maximum discharge for the culvert assumes the gate(s) are completely open or do not restrict flow. The configuration of the inlet may be flush against a headwall, projected into the approach channel, or angled to a wingwall. Provisions are sometimes made for reverse flow.

Flashboard risers are more common than gated culverts. This moveable board system allows upstream water levels to be controlled by the number of boards placed in the riser. With flashboard risers, water is forced to flow over the top of the board(s). Raising the water level can create a low flow area just upstream of the riser that facilitates deposition of sediments and their accompanying nutrients or pesticides. Flow through culverts with flashboard structures are typically controlled by the weir that is formed by the boards. However, at high up-and/or downstream heads, there is a possibility that the flow could still be controlled by pipe flow through the culvert.

### *2.5.1 - Flow Computations for Culverts*

As previously indicated, using flow through a culvert as a primary monitoring device can be difficult and is typically not recommended unless it is the only available structure in the flow system. If it is known that the culvert will be under full-conduit flow (pipe flow) or open channel for most conditions (typical case for south Florida) then use of the open channel flow measurement options all apply to culverts where the cross-sectional areas are well defined.

In many cases, pipe and open channel flow will occur through a culvert interchangeably. In these cases, the head reading must be used to switch between computational methods or an integrated computational method can be developed.

#### *2.5.2 - Gates*

Various types of gates are used to control flow. Virtually any gate structure can be used as a primary flow measuring device if the structure is of a standard geometry or is properly calibrated. Flow through gate openings is typically controlled by orifice flow conditions. This means the flow through the opening is proportional to the head difference between the two sides of the gate. For non-standard gate structures, an in-field calibration will be needed. This calibration requires upstream and downstream heads across the gate and corresponding flow measurements (see stream gaging). The range of head conditions and gate openings expected should be covered by the calibration exercises, yielding a family of curves that should then yield a single C coefficient. In some cases, the C coefficient can vary as a function of gate opening, so care is needed. Also, the orifice flow assumption is invalid if the upstream water surface is not above the top of the gate opening. In this case the gate opening will act as a weir.

### 2.6 - Secondary Measuring Devices for Water Levels

As discussed above, the rate or discharge through a primary measuring device such as a weir, flume, culvert, or gate, or in an open channel, is a function of the water level in or near the primary measuring device. The secondary measuring device provides the water level(s) or head(s) that are required to calculate flow from the primary measuring device's rating curve or flow. Pressure transducers can record water level measurements and store the readings on a data loggers which can be used to perform calculations to determine flow velocity, flow rate, and totalized flow volume.

The following are some more commonly used methods to measure water level elevations.

#### *2.6.1 - Staff Gage*

Every installation should include a staff gage from which the height of the open water may be determined. The datum, or reference elevation, for the staff gage should be determined prior to installation by a licensed surveyor. Typically, the datum is set to either National Geodetic Vertical Datum of 1929 (NGVD) or the stream or structure bottom.  Staff gages provide an easy, visual indication of the water level.  The user should choose a staff gage that is environmentally rugged.  Typically they are made of porcelain enamel covered steel.  Staff gages are not appropriate in cases where continuous monitoring is required.  However, installation and use is recommended for all situations because they are a convenient way to verify the proper functioning of other continuous recording devices.  They are useful when flow rates are large and flows are considered to be constant and consistent requiring few head measurements to achieve suitably accurate flow volume estimates.  Applications are common for large axial flow pump stations and for open channel structures.

### *2.6.2 - Float-Pulley Stage Recorders*

The float gage is a simple, inexpensive, yet practical means of automatically measuring water levels in canals, rivers, flumes and other uncovered conduits.  The operating principle is simple in that a graduated tape or beaded cable, with a counterweight on one end and a float on the other, is hung over a pulley.  The float moves the tape or cable up or down as the water fluctuates, thus rotating the pulley.  Many of the instruments available have basic strip chart recorders.  Some float pulley systems use potentiometric devices to eliminate strip charts and enable electronic data logging.  These units have been used for many years and are very reliable.  The most common installation practice requires a stilling well or basin to limit unnecessary float movement that yields “noise” or false readings.  Float-pulley systems are common for flumes and weirs, but can be used effectively for any of the open channel flow methods.

#### *2.6.2.1 – Electrical Systems*

This type of level measurement system uses some sort of change in electrical current caused by a changing water level to indicate the head.  Most designs use a capacitive or resistance type probe or strip.  The resistive tapes have become very reliable and extremely useful for tight applications such as wells.  These methods require data loggers and power supplies to store the collected data.

#### *2.6.2.2 – Ultrasonic Systems*

The liquid level is measured by determining the time required for an acoustic pulse to travel from a transmitter to the liquid surface (where it is reflected) and returned to a receiver.  These can be designed for above water surface or subsurface applications. A data logger is required to store the collected data.

#### *2.6.2.3 – Bubbler Systems*

A bubbler tube is anchored in the flow stream at a fixed depth, and the tube supplies a constant bubble rate of pressurized air or other gas.  The pressure required to maintain the bubble rate is measured. This measured pressure is proportional to the water level.

*2.6.2.4 - Pressure Transducer Systems*

A pressure transducer contains a strain gage that converts water pressure changes to changes in electrical resistance under a constant voltage. The pressure transducer is mounted below the lowest water level expected and referenced to a point that enables the appropriate head measurement to be made. The pressure transducer requires a power supply and may or may not require a data logger to store the collected data. Measurements are accurate and continuous monitoring is possible. Pressure transducer sensor longevity is excellent as the units are made of rugged materials, but their costs are relatively high compared to some of the aforementioned methods.

# 3.0 - FLOW VERIFICATION (CALIBRATION) METHODS

## 3.1 - Introduction

This section is intended to assist all water users with practical flow monitoring calibration procedures that can provide calibration results within the expected +/-10% accuracy level required by the SFWMD. Its content is based on the draft "Methods for Calibrating, Measuring and Reporting Agricultural Water Use in South Florida," developed by the Agricultural Coalition of South Florida, Clewiston, Florida 2005. That document lists various methods that are applicable to water use flow verification (calibration), for different withdrawal facilities.

If needed, the user is directed to Appendix A of this handbook for forms that can be used to report data for the various flow measurement/verification methods mentioned in this document. It is recognized that there are other methods discussed in this documents and elsewhere. Although some of those methods may be more accurate than the ones discussed in this section, they may or may not be practical to use in South Florida.

## 3.2 - Choosing the Correct Flow Verification (Calibration) Method

Any chosen flow verification method should be suitable for the specific facility type and flow conditions under which they will be used. For example, "California open pipe discharge method" can be used specifically for open pipes but should not be used for open ditches, while the "volumetric flow meter" method should be used only for small flows.

Suggested flow verification (calibration) methods are shown below in the following subsections to help users select an appropriate flow verification method.

### *3.2.1 - Calibration of Pipe Systems*

*3.2.1.1 - Appropriate Methods when Pipe Flow is Full:*

- Propeller Meter
- Ultrasonic Totalizing Meter (External)
- Electromagnetic Insertion Meter
- Flow Probe Meter
- Doppler Meter (External)

- Orifice Manometer Method
- Pitot Tube Manometer Method
- Trajectory Method
- Volumetric Flow Method
- Vertical Pipe Method
- Dye Tracer or Color Method
- Dye Fluorometry or Chemical Gauging Method

*3.2.1.2 - Appropriate Methods When Pipe Flow is Partially Full:*

- Electromagnetic Insertion Meter
- Flow Probe Meter
- Pitot Tube Manometer Method
- California Method
- Volumetric Flow Method
- Dye Tracer or Color Method
- Dye Fluorometry or Chemical Gauging Method

#### ***3.2.2 - Calibration of Open Ditches or Channels***

- Electromagnetic Meter
- Flow Probe Meter
- Dye Tracer or Color Method
- Dye Fluorometry or Chemical Gauging Method
- Weir
- Float Velocity Method

## 3.3 – Training and Requirements

Any person can perform the flow verification methods presented in this handbook provided they have the necessary level of training or expertise. Some of the methods in this handbook may require complex flow verification devices or methods. A Florida registered Professional Engineer may need to perform these methods.

## 3.4 - Documention of Flow Verification

Each flow verification method in this section has a "required conditions" and "test procedure" for that method. The conditions for the chosen flow verification method should be satisfied prior to conducting the flow verification. A detailed record of these conditions and any other conditions affecting the flow test should be documented and submitted to the SFWMD, along with the flow verification method form. Field notes, pictures, scaled drawings, and/or diagrams are good ways to document all such conditions.

## 3.5 - Performing the Flow Verification During the Dry Season

Greater supplemental water use generally occurs during the dry season, therefore, the SFWMD prefers that flow verification should be done during this period. The dry season in South Florida occurs between January 1st and May 31st of any year with normal rainfall.

The procedures described above are for a typical dry season condition in a "normal" rainfall calendar year. If the date(s) for calibration/recalibration occur during year with a water shortage then the SFWMD may request the user to perform additional flow verifications that more closely represent these extreme conditions, or the user may elect to do so on his/her own.

It is also recognized that some of the flow measurement methods described in this handbook may require modification for specific withdrawal locations and user practices to operate correctly. Further, procedures, calculations, and tabulated flow calculation aids can vary since researchers often publish minor adjustments to standard practices and equations. Any modifications to the procedures discussed in this handbook, that include proper references, should be approved by the SFWMD staff. Other modifications must be justified by the user and reviewed for approval by the SFWMD staff prior to implementation.

# Appendix A
# Flow Measurement/Verification Forms

# South Florida Water Management District
# Flow Meter Accuracy Calibration Report Form

Online reporting is available at www.sfwmd.gov/ePermitting

**PERMIT INFORMATION**

WATER USE PERMIT NUMBER: _____________ PERMITTEE NAME: ______________________________

PROJECT NAME: ______________________COMPLIANCE CONTACT:_____________________________

**WELL/PUMP/STATION INFORMATION**

DISTRICT ID: __________________________ NAME: ______________________________________

METER MANUFACTURER: ________________ SERIAL NUMBER: ___________________________

**ACCURACY TESTING**

DATE OF TEST: _______________

| STATION METER | | TESTING METER | |
|---|---|---|---|
| Initial meter reading @ start of test: | ____________ | Initial meter reading @ start of test: | ____________ |
| Final meter reading @ end of test: | ____________ | Final meter reading @ end of test: | ____________ |
| Total gallons: | ____________ | Total gallons: | ____________ |

DURATION OF TEST*: ____________

*Should be at least 5 minutes.

PERCENT ACCURACY [(total gallons station meter/total gallons test meter)*100]: ____________

PERCENT ERROR (percent accuracy-100): ______________________________

**TEST METER INFORMATION**

METER MANUFACTURER: ___________________ SERIAL NUMBER: __________________________

DATE OF LAST CALIBRATION (test meter): __________________________________________________

ATTACH DIAGRAM OR PHOTO OF TEST METER INSTALLATION POSITION (optional)

*Reference the SFWMD Calibration Handbook located online at www.sfwmd.gov – Select: Permits / Consumptive Water Use Permits / Compliance / Calibration Handbook.*

**TESTER INFORMATION**

NAME OF PERSON PERFORMING TEST: ______________________________________________

PHONE NUMBER:________________ EMAIL ADDRESS: _________________________________

I certify that to the best of my knowledge and belief that all of the information on this form is correct. I understand that any permit issued shall be subject to review and modification, enforcement action, or revocation, in whole or in part, for any material false statement in an application to continue, initiate, or modify a use, or for any material false statement in any report or statement of fact required of the permittee [Section 373.243(1), Florida Statutes].

Please mail form to:
Regulatory Support/Regulation Division
South Water Management District
P.O. Box 24680
West Palm Beach, Florida 33416-4680

For assistance, please contact: wucompliance@sfwmd.gov

Incorporated by reference in rule 40E-2.091 (F.A.C.)
Form 1387 (2014-07)

# South Florida Water Management District
# Alternative Method Calibration Report Form

Online reporting is available at www.sfwmd.gov/ePermitting

**PERMIT INFORMATION**

WATER USE PERMIT NUMBER: _______________ PERMITTEE NAME: ______________________

PROJECT NAME: _____________________________ COMPLIANCE CONTACT: _________________

**WELL/PUMP/STATION INFORMATION**

DISTRICT ID: _______________________________ NAME: _________________________________

**TIME CRITERIA – SELECT ONE**

☐ ELECTRIC CONSUMPTION – show calculations for converting kWh to hours run.

________________________________________________________________

________________________________________________________________

☐ PUMP HOUR METHOD – no supporting information required.

☐ LOG BOOK – no supporting information required.

**FLOW RATE CHECK – SELECT ONE**

☐ PUMP CURVE – describe how you determined flow rate and provide a copy of the pump curve.

________________________________________________________________

________________________________________________________________

☐ CARPENTER SQUARE – describe how you determined flow rate and provide calculations.

________________________________________________________________

________________________________________________________________

☐ SPRINKLER APPLICATION RATE – describe how you determined flow rate and provide calculations.

________________________________________________________________

________________________________________________________________

☐ BUCKET METHOD – describe how you determined flow rate and provide calculations.

________________________________________________________________

________________________________________________________________

☐ STRAP-ON or INSERTION TURBINE METER – provide the following:

METER MANUFACTURER: __________________ SERIAL # ON TEST METER: ______________

DATE OF LAST CALIBRATION: ________________



Incorporated by reference in rule 40E-2.091 (F.A.C.)
Form 1388 (2014-07)

# FLOW VERIFICATION (CALIBRATION) FORM

## CALIFORNIA METHOD

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name: ____________________________________________________

Site Contact/Phone Number:____________________/_____________________

District Facility ID: ________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other): ____________________

Facility water use accounting method:__________________________________

______________________________________________________________

**Flow Verification Information, Data and Calculations:**

Pipe inside diameter (D): _________(inches)

(D) Inches ÷ 12 = (D) ____________ (feet)

Length of level horizontal discharge pipe tested: ________(feet)

**If the flow is always constant because it is not controlled via a control valve, variable RPM/speed pump, or other method, do the following:**

Gap readings (**a**):

Minute 1_______(inch)

Minute 3________(inch)

Minute 5________(inch)

Average gap reading (**a**) = __________ Inches

(**a**) Inches ÷ 12 = (**a**)__________(ft)

Equation: (The calculation will require a scientific calculator)

Flow (**Q**) in pipe, cfs (cubic feet per second) when (a) and (D) are in (ft)

$\mathbf{Q} = 8.69 \times (1 - \mathbf{a} / D)^{1.88} \times D^{2.48}$

$\mathbf{Q} = 8.69 \times (\_\_\_\_\_\_\_\_\_)^{1.88} \times \_\_\_\_\_\_\_\_\_^{2.48}$

**Q** = __________(cfs)

Conversion Equation: cfs to gpm (gallons per minute)

**Q** = _____ (cfs) **X** 448.8 gpm/cfs

**Q** = ___________________________ gpm

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM = _____ **Q** = ________gpm

Flow condition 2 Med. Pump RPM= _____ **Q** = ________gpm

Flow condition 3 Min. Pump RPM= _____ **Q** = ________gpm

**Flow Verification Performed by (print name):** _____________________________

**Company and Title:** ____________________________________________________

**Phone Number:** ________________________________________________________

**Test Date:** ____________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## DOPPLER METER METHOD

## For Facilities Using Totalizing Flow Meters Only

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:_________________/___________________

Project Name:________________________________________________________

Site Contact/Phone Number: _______________________/___________________

District Facility ID: ___________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc): _______________________

Withdrawal type (ex. pumped, gravity, flow well, other): _____________________

Facility water use accounting method: Totalizing Flow Meter

---

**Flow Verification Information, Data and Calculations:**

**Permanent Existing Meter Information** (Manufacturer make, model, and serial number): ______________________________________________________

**Doppler Meter Used to Calibrate Permanent Esisting Meter:**

Manufacturer make, model, and serial number: ___________________________

Last calibration date of the Ultrasonic Flow Meter (Required) ________________

**Test Site Information**:

Pipe material _________________________________

Pipe inside diameter ____________

Transducer spacing ______________

Test location:

(Distance from Permanent Existing Meter _____________ (ft/in)

(upstream / downstream) __________________

Permanent Existing Meter reading (**P**):

Start Volume: ____________ gal

End Volume: _____________ gal

Elapsed test time _____________ min

(**P**) Resulting Flow rate ____________ gpm

Doppler Flow Meter reading (**E**):

Start Volume: ____________ gal

End Volume: _____________ gal

Elapsed test time _____________ min

(**E**) Resulting Flow rate ____________ gpm

Note: To reduce possible error, this comparative test will be performed simultaneously, whether the instrument used records in total volume (gal) per unit time or the standard (gpm) flow rate.

***Equation for calculating correction factor of Permanent Existing Meter:***

***1*** ÷ **P/E =** ***Correction Factor***

*where P = Permanent Existing Meter (gpm) and E = External Flow Meter (gpm)*

**Permanent Existing Meter Correction Factor** (**PMCF**) = _________________

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM or valve full open = _____ Q = _______gpm

Flow condition 2 Med. Pump RPM or valve half open = _____ Q = ______gpm

Flow condition 3 Min. Pump RPM or valve quarter open =_____ Q = _____gpm

PMCF (MAX) = ________________

PMCF (MED) = ________________

PMCF (MIN) = ________________

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results shown above.**

Note *(discovered problems):*_____________________________________________

*Recommendations:*__________________________________________________

**Flow Verification Performed by (print name):** ____________________________

**Company and Title:** ________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:** ________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## DOPPLER METER METHOD

## For Non-Metered Accounting Facilities

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:_________________/___________________

Project Name:______________________________________________________

Site Contact/Phone Number:______________________/____________________

District Facility ID:___________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc): _______________________

Withdrawal type (ex. pumped, gravity, flow well, other):______________________

Facility water use accounting method: ___________________________________

_____________________________________________________________________

**Flow Verification Information, Data and Calculations**:

**Doppler Flow Meter used** (manufacturer's make, model number):____________________________________________________________

**Last calibration date of the Doppler Flow Meter (Required):**______________

**Test Site Information:**

Pipe material tested________________________________

Pipe inside diameter ___________inches

Pipe wall thickness ___________inches

Transducer spacing _____________inches

Test location: Distance from potential turbulent flow (ex. valve, elbow, etc.):

(upstream) ___________ (ft/in)

(downstream) __________ (ft/in)

**Doppler Flow Meter reading**:

Start Volume: ____________gal

End Volume: ____________gal

Elapsed test time_____________min

Resulting Flow rate = _________gpm

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM or valve full open = _____ Q = _______gpm

Flow condition 2 Med. Pump RPM or valve half open = _____ Q = ______gpm

Flow condition 3 Min. Pump RPM or valve quarter open =_____ Q = ____gpm

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results.**

***The flow rate of each zone will be required for multiple zone systems.***

***If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results.***

Note *(discovered problems):*___________________________________________

*Recommendations:*________________________________________________

**Flow Verification Performed by (print name):** ______________________________

**Company and Title:** ______________________________________________________

**Phone Number:** _________________________________________________________

**Test Date:** _____________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## DYE TRACER OR COLOR METHOD

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

PermitNumber/Application Number:_______________/____________________

Project Name:____________________________________________________

Site Contact/Phone Number:_______________________/__________________

District Facility ID:_______________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.): ______________________

Withdrawal type (pumped, gravity, flow well, other):________________________

Facility water use accounting method: __________________________________

_________________________________________________________________

**Flow Verification Information, Data and Calculations:**

Uniform Canal Section Used:

- (A) Bottom width: _______ft
- (B) Width at water surface: ______ft
- (C) Water depth: _________ft
- (D) Distance along canal between start and end points: ______ft

**If the flow is always constant because it is not controlled via a control valve, variable RPM/speed pump, or other method, do the following:**

Stopwatch Readings:

| Reading | Travel Time (T) in Seconds |
|---|---|
| **1** | |
| **2** | |
| **3** | |
| **AVERAGE TIME** | (**T**) = |

**Average Water Velocity in Canal (V), in Feet per Second:**

**V** = D/T

**V** = _______ft/sec

**Canal Water Flow Area in Square Feet:**

Area = (A + B) **X** C/2

Area = _______$ft^2$

**Average flow in Canal (Q), in Cubic Feet per Second (cfs):**

**Q** = Area **X** (**V**)

**Q** = ________cfs

**Conversion from cfs to gpm**

**Q** = cfs **X** 448.8 gpm/cfs

**Q** = _________ gpm

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM = _____ **Q** = _______gpm

Flow condition 2. Med. Pump RPM= _____ **Q** = _______gpm

Flow condition 3. Min. Pump RPM= _____ **Q** = _______gpm

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** __________________________________________________

**Phone Number:** _____________________________________________________

**Test Date:** ________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## ELECTROMAGNETIC, FLOW PROBE AND OTHER VELOCITY FLOW METER METHODS

(See: Methods, Section C in Guidelines)

**Full Pipe (Case 1)**

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name:_____________________________________________________

Site Contact/Phone Number:_____________________/____________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.): ______________________

Withdrawal type (ex. pumped, gravity, flow well, other):_____________________

Facility water use accounting method: __________________________________

_____________________________________________________________

**Flow Verification Information, Data and Calculations:**

**Flow Verification Meter used** (manufacturer's make and model number):

______________________________________________________________

**Last calibration date of the Verification Meter (Required):**:______________

**If the flow is always constant because it is not controlled via a control valve, variable RPM/speed pump, or other method, do the following:**

Velocity meter readings: velocity (V) feet / second (ft/s)

1) _____ 2)_____ 3)_____ 4)_____ 5) _____
6) _____ 7) _____ 8) _____ 9) _____ 10) _____

**Average Velocity (V)** = _______ft/s

Area (**A**)= π **X** r²

π = 3.14

r = inside pipe diameter (ft) **/** 2

**Area** (**A**) = _______ ft²

Average flow in Pipe (Q), in Cubic Feet per Second (cfs):

Q = Area (**A**) **X** Average Velocity (**V**)

**Q =** ________**cfs**

Conversion from cfs to gpm

Q =cfs **X** 448.8 gpm/cfs

**Q =** _________ **gpm**

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM or valve full open = _____ **Q** = _______gpm

Flow condition 2 Med. Pump RPM or valve half open = _____ **Q** = ______gpm

Flow condition 3 Min. Pump RPM or valve quarter open =_____ **Q** =______gpm

***NOTE:***

***The flow rate of each zone (limit 3) will be required for multiple zone systems.***

***If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results.***

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** _________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:** _________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## ELECTROMAGNETIC, FLOW PROBE AND OTHER VELOCITY FLOW METER METHODS

(See: Methods, Section C in Guidelines)

**Partially Full Pipe (Case 2)**

**General Permit Information Required:**

Permit Number/Application Number_____________/_______________________

Project Name:_______________________________________________________

Site Contact/Phone Number:_____________________/______________________

District Facility ID:___________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.): _______________________

Withdrawal type (ex. pumped, gravity, flow well, other):______________________

Facility water use accounting method:___________________________________

___________________________________________________________________

## Flow Verification Information, Data and Calculations:

**Flow Verification Meter used** (manufacturer's make and model number):

_______________________________________________________________

**Last calibration date of the Verification Meter (Required): ________________**

Velocity meter readings: velocity (**V**) feet / second (ft/s)

2) _____ 2)_____ 3)_____ 4)_____ 5) _____

6) _____ 7)_____ 8)_____ 9)_____ 10)_____

Average (**V**) = _______ft/s

Cross-sectional Area of Partially filled Pipe ($ft^2$):

**Inside diameter (D) = _______(ft)**

- **Wet depth (d) = _______(ft)**
- **d/D =_______**
- **Multiplication Factor (from table below) =______________**

| $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ | $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ | $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ | $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ |
|---|---|---|---|---|---|---|---|
| 0.01 | 0.0013 | 0.26 | 0.1623 | 0.51 | 0.4027 | 0.76 | 0.6405 |
| 0.02 | 0.0037 | 0.27 | 0.1711 | 0.52 | 0.4127 | 0.77 | 0.6489 |
| 0.03 | 0.0069 | 0.28 | 0.1800 | 0.53 | 0.4227 | 0.78 | 0.6573 |
| 0.04 | 0.0105 | 0.29 | 0.1890 | 0.54 | 0.4327 | 0.79 | 0.6655 |
| 0.05 | 0.0147 | 0.3 | 0.1982 | 0.55 | 0.4426 | 0.8 | 0.6736 |
| 0.06 | 0.0192 | 0.31 | 0.2074 | 0.56 | 0.4526 | 0.81 | 0.6815 |
| 0.07 | 0.0242 | 0.32 | 0.2167 | 0.57 | 0.4625 | 0.82 | 0.6893 |
| 0.08 | 0.0294 | 0.33 | 0.2260 | 0.58 | 0.4724 | 0.83 | 0.6969 |
| 0.09 | 0.0350 | 0.34 | 0.2355 | 0.59 | 0.4822 | 0.84 | 0.7043 |
| 0.1 | 0.0409 | 0.35 | 0.2450 | 0.6 | 0.4920 | 0.85 | 0.7115 |
| 0.11 | 0.0470 | 0.36 | 0.2546 | 0.61 | 0.5018 | 0.86 | 0.7186 |
| 0.12 | 0.0534 | 0.37 | 0.2642 | 0.62 | 0.5115 | 0.87 | 0.7254 |
| 0.13 | 0.0600 | **0.38** | **0.2739** | 0.63 | 0.5212 | 0.88 | 0.7320 |
| 0.14 | 0.0668 | 0.39 | 0.2836 | 0.64 | 0.5308 | 0.89 | 0.7384 |
| 0.15 | 0.0739 | 0.4 | 0.2934 | 0.65 | 0.5404 | 0.9 | 0.7445 |
| 0.16 | 0.0811 | 0.41 | 0.3032 | 0.66 | 0.5499 | 0.91 | 0.7504 |
| 0.17 | 0.0885 | 0.42 | 0.3130 | 0.67 | 0.5594 | 0.92 | 0.7560 |
| 0.18 | 0.0961 | 0.43 | 0.3229 | 0.68 | 0.5687 | 0.93 | 0.7612 |
| 0.19 | 0.1039 | 0.44 | 0.3328 | 0.69 | 0.5780 | 0.94 | 0.7662 |
| 0.2 | 0.1118 | 0.45 | 0.3428 | 0.7 | 0.5872 | 0.95 | 0.7707 |
| 0.21 | 0.1199 | 0.46 | 0.3527 | 0.71 | 0.5964 | 0.96 | 0.7749 |
| 0.22 | 0.1281 | 0.47 | 0.3627 | 0.72 | 0.6054 | 0.97 | 0.7785 |
| 0.23 | 0.1365 | 0.48 | 0.3727 | 0.73 | 0.6143 | 0.98 | 0.7816 |
| 0.24 | 0.1449 | 0.49 | 0.3827 | 0.74 | 0.6231 | 0.99 | 0.7841 |
| 0.25 | 0.1535 | 0.5 | 0.3927 | 0.75 | 0.6319 | 1 | 0.7850 |

**$D^2$ X Multiplication Factor = Wet cross-sectional area (A) = ________ $ft^2$**

<u>Average flow in partially filled Pipe (**Q**), in Cubic Feet per Second (cfs)</u>:

**Q** = (**A**) Wet cross-sectional area **X** Average Velocity (**V**)

**Q** = ________cfs

**<u>Conversion from cfs to gpm</u>**

**Q** =cfs **X** 448.8 gpm/cfs

**Q** = _________ gpm

**Flow Verification Performed by (print name):** ______________________________

**Company and Title:** ______________________________________________________

**Phone Number:** ________________________________________________________

**Test Date:** ___________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## ELECTROMAGNETIC, FLOW PROBE AND OTHER VELOCITY FLOW METER METHODS

(See: Methods, Section C in Guidelines)

**Open Trapezoid Channel (Case 3)**

**General Permit Information Required:**

Permit Number/Application Number: _________________/_________________

Project Name: ____________________________________________________

Site Contact/Phone Number:______________________/__________________

District Facility ID: _________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.): ______________________

Withdrawal type (ex. pumped, gravity, flow well, other):_____________________

Facilities water use accounting method:_________________________________

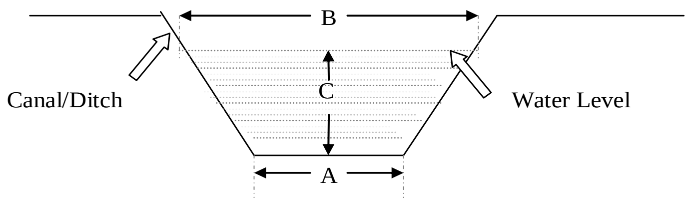
_________________________________________________________________

**Flow Verification Information, Data and Calculations:**

**Flow Verification Meter used:** (manufacturer's make and model number):

______________________________________________________________

**Last calibration date of the Verification Meter (Required):** _______________




Canal Section used:

- (**A**) Bottom Width: ____ft
- (**B**) Width at water surface: ____ft
- (**C**) Water Depth: _____ft

Electromagnetic, Flow Probe or other Test-Meter Readings:

Velocity

Readings ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ **Avg. Velocity:__**

(ft/s)

Average Flow in the Canal Gallons per Minute (gpm):

= Canal Water Flow Area x Average Water Velocity in the Canal

Canal Water Flow Area (Square Feet):

Water Flow Area = (A + B) **x** C / 2

Water Flow Area = (____ft **+** ____ft) **x** _____ft / 2

Water Flow Area = _____ $ft^2$

Average Flow in the Canal (gpm):

Q = Water Flow Area **x** Average Flow Velocity

Q = _____ $ft^2$ **x** _____ ft/s **x** 448.9 conversion to gpm

Q = ________ gpm

**Open Canal Flow for OTHER Shaped Ditch Sections:**

**Important Note:** For assistance in selecting the best method for measuring flow, determining the water flow area of non-uniform canal sections and the technique for collecting velocity data at multiple points, please refer to Section B and Section C (Appendix A and C) in this document. The data collection form (FD 9000-11) for Streamgaging method may be used for all non- trapezoidal shaped open channels.

**Flow Verification Performed by (print name):** ____________________________

**Company and Title:** ____________________________________________________

**Phone Number:** ______________________________________________________

**Test Date:** ___________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## FLOAT VELOCITY METHOD

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:_________________/__________________

Project Name: ____________________________________________________

Site Contact/Phone Number:_______________________/__________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.): ______________________

Withdrawal type (pumped, gravity, flow well, other):________________________

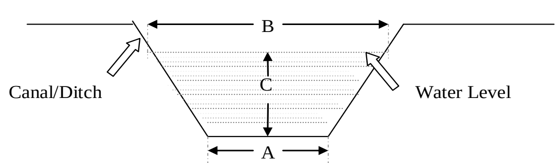
Facility water use accounting method: ___________________________________

_________________________________________________________________

**Flow Verification Information, Data and Calculations:**

- This method should be selected as a last resort for flow verification. If possible, other methods listed in Section C should be used.

- Ditch Section Used (trapezoidal shaped cross-section):



- ○ (A) Bottom width: ___ ft
- ○ (B) Width at water surface: ___ ft
- ○ (C) Water depth: ___ ft
- ○ (D) Distance along ditch between starting and ending points: ____ ft

- Description of Floats used for test: ______________________________
- Number of Floats used (from table below): _____

| Ditch Width at Water Surface (ft) | Number of Floats |
|---|---|
| 0 - 10 | 1 |
| 10 - 15 | 2 |
| 15 - 20 | 3 |
| 20 - 25 | 4 |

Note: For ditches wider than 15 ft. use the numbers of floats indicated in the table above. Add the corresponding numbers of floats and rows for Run 1 through Run 3. Attach all additional float readings on a separate page.

- Float Readings:

Run 1

| Float Number | Travel Time (T, Seconds) |
|---|---|
| 1 | |
| 2 | |
| AVERAGE ($T^1$) = | |

Run 2

| Float Number | Travel Time (T, Seconds) |
|---|---|
| 1 | |
| 2 | |
| AVERAGE ($T^2$) = | |

Run 3

| Float Number | Travel Time (T, Seconds) |
|---|---|
| 1 | |
| 2 | |
| AVERAGE ($T^3$) = | |

Average Travel Time for All Floats and All Runs:

$T = (T^1 + T^2 + T^3) / 3 =$ _______ seconds

Average Water Velocity in the Ditch (Feet per Second):

V = 0.85 x D ft/T seconds

> Where: 0.85 is a constant that adjusts surface velocity to average channel velocity, D is the test travel distance and T is the average time to travel the test distance.

V = 0.85 x ___ ft/____ seconds

V = _____ ft/s

Cross-Sectional Area of Channel Section Used for Test:

A = (a + b) x c/2

A = (_____ ft + _____ ft) x _____ ft/2

A = _____ $ft^2$

Average Flow in the Ditch ($ft^3/s$):

Q = V x A

Q = ____ ft/s x ____ $ft^2$

Q = ____ $ft^3/s$

Conversion to Gallons per Minute (gpm):

Q in $ft^3/s$ X 448.8 = Q in gpm

Q = _______ gpm

**Flow Verification Performed by (print name):** ____________________________

**Company and Title:** ________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:** _______________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## ORIFICE MANOMETER METHOD

## OPEN PIPE DISCHARGE

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:_________________/_________________

Project Name:____________________________________________________

Site Contact/Phone Number:_______________________/__________________

District Facility ID: __________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.): _______________________

Withdrawal type (ex. pumped, gravity, flow well, other):______________________

Facility water use accounting method:___________________________________

_________________________________________________________________

**Flow Verification Information, Data and Calculations:**

**Orifice Manometer used (manufacturer's make and model number:**

______________________________________________________________

**Last calibration date of the Orifice Manometer (Required):_______________**

**NOTE: Pipe must be flowing full when orifice plate is installed**

Pipe Inside Diameter (D) = ____ inches

Orifice Diameter (d) = ____ inches

Length of Level Horizontal Discharge Pipe Tested: __________________ft

**Manometer Measurements:**

Levels of Water (H) in Manometer:

($H^1$) _____inch, ($H^2$) _____inch, ($H^3$) _____inch

Average hydraulic head (H):

$H = (H^1 + H^2 + H^3) / 3 =$ _____ inches

Coefficient (C) from graph below:

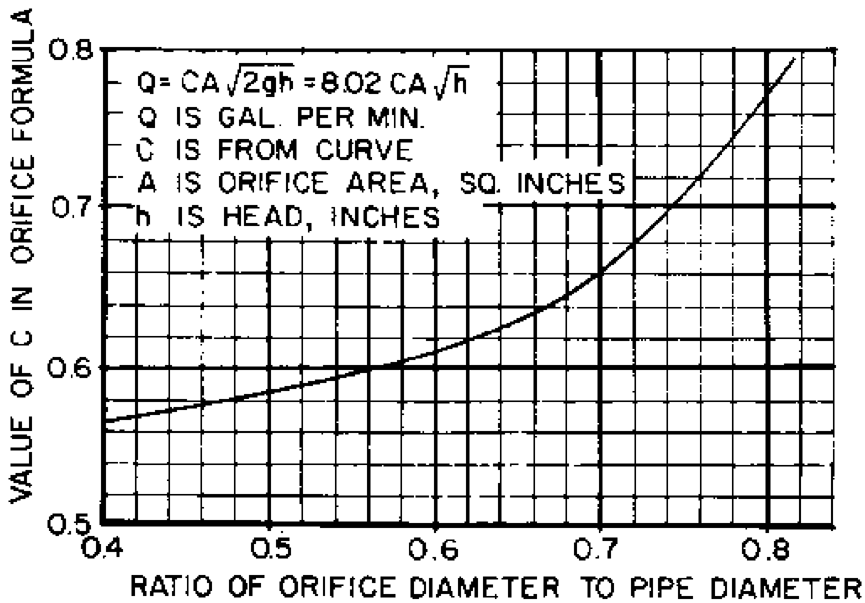
Ratio of orifice diameter to pipe diameter = (d) inches / (D) inches;

Orifice diameter (d) = _____inches

Pipe inside diameter (D) = _____inches

Ratio = ________

From graph below, (C) = ________




Cross-Sectional Area (A) of Orifice ($in^2$):

A = (π x $d^2$)/4

A = (3.14 X ____$^2$)/4

A = ________ $in^2$

Flow (Q) in Pipe (gpm):

Q = 8.02 x C x A x $H^{0.5}$

Q = 8.02 x _______ x ______ x _____

Q = _______ gpm

**Flow Verification Performed by (print name):** ______________________________

**Company and Title:** ______________________________________________________

**Phone Number:** _________________________________________________________

**Test Date:** _____________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## PITOT TUBE MANOMETER METHOD

(See: Methods, Section C in Guidelines)

**Full Pipe Flow (Case 1)**

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name:_____________________________________________________

Site Contact/Phone Number:________________/_________________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:__________________________________

_______________________________________________________________

**Flow Verification Information, Data and Calculations:**

**Pitot Tube instrument used (manufacturer's make and model number): ____________________________________________________________**

**Last calibration date of the Pitot Tube (Required): ______________________**

Pipe Inside Diameter = ____ inches / 12 inches per foot = _____ ft

Length of leveled horizontal discharge pipe tested: ________________ ft

| **Manometer Readings, H (inches)** | | | | | | | | | | | **Average** |
|---|---|---|---|---|---|---|---|---|---|---|---|

(H) in ft = _____ inches / 12 inches / ft = ______ft

Velocity (V) in Pipe (ft/s):

V = $\sqrt{2 \times g \times H}$ ; where g is the acceleration due to gravity (32.2 ft/s$^2$)

V = $\sqrt{2 \times 32.2 \times \_\_\_\_\ ft}$

V = ______ ft/s

Cross-Sectional Area (A) of Pipe (ft$^2$):

A = π x D$^2$/4

A = 3.14 x _____$^2$/ 4

A = _______ ft$^2$

Flow (Q) in Pipe (ft$^3$/s):

Q = A x V

Q = _______ ft$^2$ x _______ ft/s

Q = ________ ft$^3$/s

Conversion to gpm:

Q = ________ $ft^3/s$ x 448.8 gpm/cfs

Q = __________ gpm

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** _________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:** _________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## PITOT TUBE MANOMETER METHOD

(See: Methods, Section C in Guidelines)

**Partial Pipe Flow (Case 2)**

**General Permit Information Required:**

Permit Number/Application Number:________________/____________________

Project Name:________________________________________________________

Site Contact/Phone Number:________________/__________________________

District Facility ID:___________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:_____________________________________

______________________________________________________________________

## Flow Verification Information, Data and Calculations:

**Pitot Tube instrument used (manufacturer's make and model number): ____________________________________________**

**Last calibration date of the Pitot Tube (Required): ______________________**

| Manometer Readings, H (inches) | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ | ____ | Average (H)=____ |
|---|---|---|---|---|---|---|---|---|---|---|---|

Length of Leveled Horizontal Discharge Pipe Tested: _______ ft

(H) = ______ inches / 12 inches / ft = ______ ft

Velocity (V) in Pipe (ft/s):

V = $\sqrt{2 \times g \times H}$ ; where g is the acceleration due to gravity (32.2 ft/s$^2$)

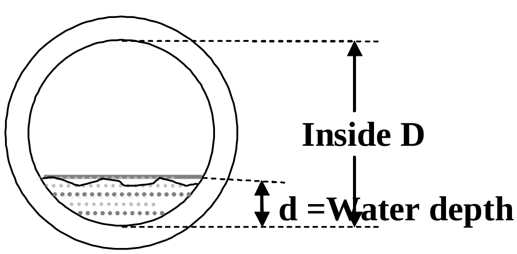
V = $\sqrt{2 \times 32.2 \times \_\_\_\_ \; ft}$

(V) = ______ ft/s

Cross-Sectional Area (A) of Partially filled Pipe (ft$^2$):

Important Note:

To determine the water flow area in pipes that are not flowing full or half full measure the inside pipe diameter D and height of the water in the pipe, d.



Pipe Inside Diameter (D) = ______ inches / 12 = _______ft

Wet Depth in pipe (d): ______inches / 12 = _______ft

Based on the value $\frac{d}{D}$ find the multiplication factor in the table below:

| $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ |
|---|---|
| 0.01 | 0.0013 |
| 0.02 | 0.0037 |
| 0.03 | 0.0069 |
| 0.04 | 0.0105 |
| 0.05 | 0.0147 |
| 0.06 | 0.0192 |
| 0.07 | 0.0242 |
| 0.08 | 0.0294 |
| 0.09 | 0.0350 |
| 0.1 | 0.0409 |
| 0.11 | 0.0470 |
| 0.12 | 0.0534 |
| 0.13 | 0.0600 |
| 0.14 | 0.0668 |
| 0.15 | 0.0739 |
| 0.16 | 0.0811 |
| 0.17 | 0.0885 |
| 0.18 | 0.0961 |
| 0.19 | 0.1039 |
| 0.2 | 0.1118 |
| 0.21 | 0.1199 |
| 0.22 | 0.1281 |
| 0.23 | 0.1365 |
| 0.24 | 0.1449 |
| 0.25 | 0.1535 |

| $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ |
|---|---|
| 0.26 | 0.1623 |
| 0.27 | 0.1711 |
| 0.28 | 0.1800 |
| 0.29 | 0.1890 |
| 0.3 | 0.1982 |
| 0.31 | 0.2074 |
| 0.32 | 0.2167 |
| 0.33 | 0.2260 |
| 0.34 | 0.2355 |
| 0.35 | 0.2450 |
| 0.36 | 0.2546 |
| 0.37 | 0.2642 |
| **0.38** | **0.2739** |
| 0.39 | 0.2836 |
| 0.4 | 0.2934 |
| 0.41 | 0.3032 |
| 0.42 | 0.3130 |
| 0.43 | 0.3229 |
| 0.44 | 0.3328 |
| 0.45 | 0.3428 |
| 0.46 | 0.3527 |
| 0.47 | 0.3627 |
| 0.48 | 0.3727 |
| 0.49 | 0.3827 |
| 0.5 | 0.3927 |

| $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ |
|---|---|
| 0.51 | 0.4027 |
| 0.52 | 0.4127 |
| 0.53 | 0.4227 |
| 0.54 | 0.4327 |
| 0.55 | 0.4426 |
| 0.56 | 0.4526 |
| 0.57 | 0.4625 |
| 0.58 | 0.4724 |
| 0.59 | 0.4822 |
| 0.6 | 0.4920 |
| 0.61 | 0.5018 |
| 0.62 | 0.5115 |
| 0.63 | 0.5212 |
| 0.64 | 0.5308 |
| 0.65 | 0.5404 |
| 0.66 | 0.5499 |
| 0.67 | 0.5594 |
| 0.68 | 0.5687 |
| 0.69 | 0.5780 |
| 0.7 | 0.5872 |
| 0.71 | 0.5964 |
| 0.72 | 0.6054 |
| 0.73 | 0.6143 |
| 0.74 | 0.6231 |
| 0.75 | 0.6319 |

| $\frac{d}{D}$ | Multiplication Factor = $\frac{WetArea}{D^2}$ |
|---|---|
| 0.76 | 0.6405 |
| 0.77 | 0.6489 |
| 0.78 | 0.6573 |
| 0.79 | 0.6655 |
| 0.8 | 0.6736 |
| 0.81 | 0.6815 |
| 0.82 | 0.6893 |
| 0.83 | 0.6969 |
| 0.84 | 0.7043 |
| 0.85 | 0.7115 |
| 0.86 | 0.7186 |
| 0.87 | 0.7254 |
| 0.88 | 0.7320 |
| 0.89 | 0.7384 |
| 0.9 | 0.7445 |
| 0.91 | 0.7504 |
| 0.92 | 0.7560 |
| 0.93 | 0.7612 |
| 0.94 | 0.7662 |
| 0.95 | 0.7707 |
| 0.96 | 0.7749 |
| 0.97 | 0.7785 |
| 0.98 | 0.7816 |
| 0.99 | 0.7841 |
| 1 | 0.7850 |

Multiplication Factor = _________

Wet cross-sectional area (**A**) = $\mathbf{D^2}$ **X** Multiplication Factor

Wet cross-sectional area (**A**) = ________ft²

Average flow in partially filled Pipe (Q), in Cubic Feet per Second (cfs):

Q = (A) X (V)

Q = ________cfs

Conversion from cfs to gpm

Q = cfs  X 448.8 gpm/cfs

Q = __________ gpm

**Flow Verification Performed by (print name):** _____________________________

**Company and Title:** ____________________________________________________

**Phone Number:** ______________________________________________________

**Test Date:** __________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## PROPELLER METER METHOD

## For Facilities Using Totalizing Flow Meters Only

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name:_____________________________________________________

Site Contact/Phone Number:________________/_________________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:__________________________________

_________________________________________________________________

**Flow Verification Information, Data and Calculations:**

**Permanent Existing Meter Information** (Manufacturer make, model, and serial number): ______________________________________________________

**Propeller Meter Used to Calibrate Permanent Existing Meter (**Manufacturer make, model, and serial number)**:**

______________________________________________________________

**Last calibration date of the Propeller Flow Meter (Required):**_____________

**Test Site Information**:

Pipe material ______________________________

Pipe inside diameter ___________ Transducer spacing _____________

Test location: (Distance from Permanent Existing Meter _______ (ft/in)

Permanent Existing Meter reading (**P**):

Start Volume: ___________ gal

End Volume: ____________ gal

Elapsed test time ____________ min

(**P**) Resulting Flow rate ___________ gpm

Propeller Flow Meter reading (**E**):

Start Volume: ___________ gal

End Volume: ____________ gal

Elapsed test time ____________ min

(**E**) Resulting Flow rate ___________ gpm

Note: To reduce possible error, this comparative test will be performed simultaneously, whether the instrument used records in total volume (gal) per unit time or the standard (gpm) flow rate.

***Equation for calculating correction factor of Permanent Existing Meter:***

***1* ÷ P/E = *Correction Factor***

*where P=Permanent Existing Meter (gpm) and E= External Flow Meter (gpm)*

**Permanent Existing Meter Correction Factor** (**PMCF**) = ________________

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM or valve full open = _____ Q = _______gpm

Flow condition 2 Med. Pump RPM or valve half open = _____ Q = ______gpm

Flow condition 3 Min. Pump RPM or valve quarter open =_____ Q = ____gpm

PMCF (MAX) = _________ PMCF (MED) = _______ PMCF (MIN) = ________

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results shown above.**

Note *(discovered problems):*___________________________________________

*Recommendations:*_______________________________________________

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** _______________________________________________

**Phone Number:** ___________________________________________________

**Test Date:**____________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## PROPELLER METER METHOD

## For Non-Metered Accounting Facilities

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name:_____________________________________________________

Site Contact/Phone Number:________________/_________________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:__________________________________

_____________________________________________________________

**<u>Flow Verification Information, Data and Calculations</u>**:

**Propeller Flow Meter used (manufacturer's make, model number):**

______________________________________________________________

**Last calibration date of the Propeller Flow Meter (Required)**:_____________

**Test Site Information:**

Pipe material tested________________________________

Pipe inside diameter:_________inches  Pipe wall thickness: _______inches

Transducer spacing _____________inches

Test location: Distance from potential turbulent flow (ex. valve, elbow, etc.):

(upstream) ___________ (ft/in)

(downstream) __________ (ft/in)

**Propeller Flow Meter reading**:

Start Volume: ____________gal

End Volume: ____________gal

Elapsed test time:_____________min

Resulting Flow rate = _________gpm

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM or valve full open = _____  Q = _______ gpm

Flow condition 2 Med. Pump RPM or valve half open = _____  Q = ______ gpm

Flow condition 3 Min. Pump RPM or valve quarter open =_____  Q = ____ gpm

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results.**

**The flow rate of each zone (limit 3) will be required for multiple zone systems.**

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results.**

Note *(discovered problems):*_____________________________________________

*Recommendations:*_________________________________________________

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** __________________________________________________

**Phone Number:** _____________________________________________________

**Test Date:**___________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## TRAJECTORY METHOD

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:_________________/____________________

Project Name:________________________________________________________

Site Contact/Phone Number:_________________/__________________________

District Facility ID:____________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

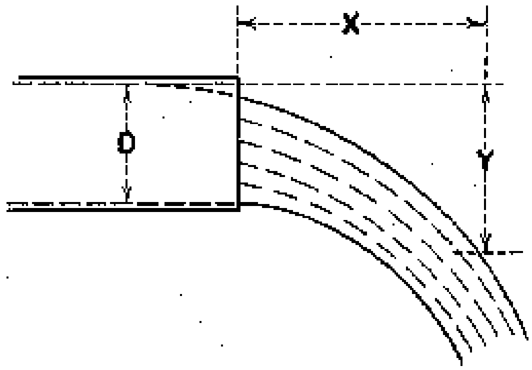
Withdrawal source: (ex. well, lake, canal name, etc.):________________________

Withdrawal type (ex. pumped, gravity, flow well, other):______________________

Facility water use accounting method:____________________________________

_____________________________________________________________________

**Flow Verification Information, Data and Calculations:**




**Pipe is flowing**

Information from the diagram shown above:

Pipe inside diameter (D): ________(inches)

(D) inches ÷ 12 = (D) ____________feet (ft)

(R) Pipe radius = (D)ft ÷ 2 = ________(ft)

Length of level horizontal discharge pipe tested: _______(ft)

(X) pitch in inches _______ , _______, _______, ______

(X) average inches ÷ 12 = (X) ___________ (ft)

(Y) fall in inches_______ , _______, _______, ______

(Y) average inches ÷ 12 = (Y) ___________ (ft)

If the flow is always constant because it is not controlled via a control valve, variable RPM/speed pump, or other method, do the following:

Velocity (V) in Pipe (ft/s):

$$V = X \times \frac{\sqrt{g}}{\sqrt{2Y}} = \sqrt{g} \times \frac{X}{\sqrt{2Y}} \;;$$

where g is the acceleration due to gravity (32.2 ft/$s^2$) and X, Y are expressed in ft.

V = $\sqrt{32.2}$ x $\frac{X}{\sqrt{2Y}}$ = 5.67 x $\frac{X}{\sqrt{2Y}}$

V= 5.67 x $\frac{\_\_\_}{\sqrt{2x}\_\_\_\_\_}$ = _____ft/s

Cross-Sectional Area (A) of Pipe (ft$^2$):

A = π x $(R)^2$

A = 3.14 x _____

A = _______ (ft$^2$)

Flow (Q) Equation:

Q= A x V; where A is expressed in ft$^2$ and V is expressed in ft/s

Q= _____ft$^2$ x ______ ft/s

Q = __________(cfs)

Conversion Equation: (csf) to gpm (gallons per minute)

Q = _____(cfs) X 448.8 gpm / (cfs)

Q=_______gpm

**If normal operations use a control valve or variable RPM pump to regulate flows repeat the above to simulate the operational conditions anticipated. These can be the maximum, minimum, and median flows expected.**

Flow condition 1 Max. Pump RPM = _____ Q = _______gpm

Flow condition 2 Med. Pump RPM= _____ Q = _______gpm

Flow condition 3 Min. Pump RPM= _____ Q = _______gpm

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results shown above.**

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** _________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:**__________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## Ultrasonic Meter Method

## For Facilities Using Totalizing Flow Meters <u>Only</u>

(See: Methods, Section C in Guidelines)

**<u>General Permit Information Required:</u>**

Permit Number/Application Number:________________/____________________

Project Name:________________________________________________________

Site Contact/Phone Number:________________/___________________________

District Facility ID:___________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):_______________________

Withdrawal type (ex. pumped, gravity, flow well, other):_____________________

Facility water use accounting method:___________________________________

_____________________________________________________________________

**Flow Verification Information, Data and Calculations:**

**Permanent Existing Meter Information (Manufacturer make, model, and serial number):** ______________________________________________

**Ultrasonic Meter Used to Calibrate Permanent Existing Meter (Manufacturer make, model, and serial number):**

__________________________________________________________

**Last calibration date of the Ultrasonic Flow Meter (Required):**____________

**Test Site Information**:

Pipe material ________________________________

Pipe inside diameter ___________

Transducer spacing _____________

Test location:

(Distance from Permanent Existing Meter ____________ (ft/in)

(upstream / downstream) _________________

Permanent Existing Meter reading (**P**):

Start Volume: ___________ gal

End Volume: ____________ gal

Elapsed test time ____________ min

(**P**) Resulting Flow rate ___________ gpm

Ultrasonic Flow Meter reading (**E**):

Start Volume: ___________ gal

End Volume: ____________ gal

Elapsed test time ____________ min

(**E**) Resulting Flow rate ___________ gpm

Note: To reduce possible error, this comparative test will be performed simultaneously, whether the instrument used records in total volume (gal) per unit time or the standard (gpm) flow rate.

***Equation for calculating correction factor of Permanent Existing Meter:***

***1*** ÷ **P/E =** ***Correction Factor***

*where P=Permanent Existing Meter (gpm) and E= External Flow Meter (gpm)*

**Permanent Existing Meter Correction Factor** (**PMCF**) = ________________

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM or valve full open = _____ Q = ______ gpm

Flow condition 2 Med. Pump RPM or valve half open = _____ Q = ______ gpm

Flow condition 3 Min. Pump RPM or valve quarter open =_____ Q = ____ gpm

PMCF (MAX) = ________ PMCF (MED) = ________ PMCF (MIN) = ________

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results shown above.**

Note *(discovered problems):*___________________________________________

*Recommendations:*__________________________________________________

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** ______________________________________________

**Phone Number:** _________________________________________________

**Test Date:**_______________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## ULTRASONIC METER METHOD

## For Non-Metered Accounting Facilities

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name:_____________________________________________________

Site Contact/Phone Number:________________/_________________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:__________________________________

_________________________________________________________________

**Flow Verification Information, Data and Calculations**:

**Ultrasonic Flow Meter used (manufacturer's make, model number):**

______________________________________________________________

**Last calibration date of the Ultrasonic Flow Meter (Required):** ____________

**Test Site Information:**

Pipe material tested_______________________________

Pipe inside diameter ___________inches

Pipe wall thickness ___________inches

Transducer spacing _____________inches

Test location: Distance from potential turbulent flow (ex. valve, elbow, etc.):

(upstream) ___________ (ft/in)

(downstream) __________ (ft/in)

**Ultrasonic Flow Meter reading**:

Start Volume: ___________ gal End Volume: ___________ gal

Elapsed test time: ________min Resulting Flow rate = _________gpm

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM or valve full open = _____ Q = _______gpm

Flow condition 2 Med. Pump RPM or valve half open = _____ Q = ______gpm

Flow condition 3 Min. Pump RPM or valve quarter open =_____ Q = ____gpm

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results.**

**The flow rate of each zone will be required for multiple zone systems.**

**If necessary, attach on separate page(s) all calculations, notes and photos to clearly identify the test site conditions and the obtained results.**

Note *(discovered problems):*_____________________________________________

*Recommendations:*__________________________________________________

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** _________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:**____________________________________________________________

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# FLOW VERIFICATION (CALIBRATION) FORM

## VERTICAL PIPE METHOD

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name:_____________________________________________________

Site Contact/Phone Number:________________/_________________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:__________________________________

_______________________________________________________________

**Flow Verification Information, Data and Calculations:**

**Reference Table for Flow from Vertical Pipes (gpm)**

| | Rise of Water Spout Above Edge of Pipe (inches) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pipe Inside Diameter (inches)** | **3** | **3.5** | **4** | **4.5** | **5** | **5.5** | **6** | **7** | **8** | **10** | **12** |
| **2** | 38 | 41 | 44 | 47 | 50 | 53 | 56 | 61 | 65 | 74 | 82 |
| **3** | 81 | 89 | 96 | 103 | 109 | 114 | 120 | 132 | 141 | 160 | 177 |
| **4** | 137 | 151 | 163 | 174 | 185 | 195 | 205 | 222 | 240 | 269 | 299 |
| **6** | 318 | 349 | 378 | 405 | 430 | 455 | 480 | 520 | 560 | 635 | 700 |
| **8** | 567 | 623 | 684 | 730 | 776 | 821 | 868 | 945 | 1020 | 1150 | 1270 |
| **10** | 950 | 1055 | 1115 | 1200 | 1280 | 1350 | 1415 | 1530 | 1640 | 1840 | 2010 |

**Reference: Colt Industries, 1974**

The flow (Q in gpm) through the pipe is calculated according to the formula:

$Q = 5.68 \times K \times D^2 \times H^{1/2}$

where:

K is a coefficient which ranges from 0.87 to 0.97 for pipes from 2 inches to 6 inches in diameter.

D = Pipe Inside Diameter (in)

H = Rise of water spout above edge of pipe (in)

Calculate Coefficient, K:

K = 0.87 for 2 in pipes and 0.97 for 6 in pipes as long as H is within 6 inches to 24 inches. Linear interpolation can be used to adjust K for pipe diameters between 2 and 6 inches.

(K) Calculation Example for a pipe with a 4-inch inside diameter:

$K_{4\text{ in pipe}}$ = 0.97 - [(4 – 2) / (6 – 2)] x (0.97 – 0.87)

$K_{4\text{ in pipe}}$ = 0.92

Test Data:

K = _____

D = _____inches

H = _____inches

Calculate Flow (Q) in Pipe (gpm):

$Q = 5.68 \times K \times D^2 \times H^{1/2}$

$Q = 5.68 \times \_\_\_\_\_ \times \_\_\_\_\_^{2} \times \_\_\_\_\_\_^{1/2}$

Q = _____ gpm

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** _________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:**___________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## VOLUMETRIC METHOD

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:________________/____________________

Project Name:________________________________________________________

Site Contact/Phone Number:________________/__________________________

District Facility ID:___________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):_______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:____________________________________

_____________________________________________________________________

**<u>Flow Verification Information, Data and Calculations</u>**:

- Container Information (choose only one (A or B) below):
  a)
  b) Weight Information:
     - ✓ Weight of Container when Empty (**E**): ________ lbs
     - ✓ Weight of Container when Full of Water(**F**): _______ lbs

  c) Volume Information:
     - ✓ Volume of Container when Full with Water (**Vgal**):______ gallons
     - ✓

Note: The container must be large enough that it will take no less than 15 seconds to fill. The timing device must be a stop watch, capable of reading in at least 1/10 seconds.

**If the flow is always constant because it is not controlled via a control valve, variable RPM/speed pump, or other method, do the following:**

Measurement Information:

| Measurement Number | Time to Fill Container (Seconds) |
|---|---|
| 1 | . |
| 2 | . |
| 3 | . |
| AVERAGE TIME (**T**) | . |

---

(A) Weight

<u>Average Flow (gpm) from Pipe **Using Container Weight** Information</u>:

Weight of Water only in Container: (**F**)______ lbs **–** (**E**)______ lbs = ______ lbs

Water = 62.4 lbs / cubic feet (ft$^3$)

Volume of Water In Container (**Vft$^3$**): ____lbs / 62.4 lbs / ft$^3$ = _____ ft$^3$

7.48 gallons of water = one cubic foot

Equation:

**Q** = (**V ft$^3$**) **X** 7.48 gal / ft$^3$ **X** 60 sec/ min **÷** (**T**) sec

Where:

Q = Flow rate (gpm) from pipe

V = Volume of water (gal) in container

T = Average time to fill container

**Q** =__________gpm

---

## (B) Volume

Average Flow (gpm) from Pipe **Using Container Volume** Information:

Equation:

**Q** = (**V)** gal **X** 60 sec/ min ÷ (T) sec

Where:

Q = Flow rate (gpm) from pipe

V = Volume of water (gal) in container

T = Average time (sec) to fill container

**Q** =__________gpm

**If the flow changes due to control valves, variable RPM/speed pumps or other methods, repeat the process above to record those variable flows. These flows can be the maximum, minimum, and median flows expected to be used during typical water use conditions.**

Flow condition 1 Max. Pump RPM _____ or valve full open: Q = _______ gpm

Flow condition 2 Med. Pump RPM _____ or valve ___open: Q = _______ gpm

Flow condition 3 Min.  Pump RPM ______ or valve___ open:   Q = _______ gpm

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** __________________________________________________

**Phone Number:** _____________________________________________________

**Test Date:**___________________________________________________________

# FLOW VERIFICATION (CALIBRATION) FORM

## Weir Method

(See: Methods, Section C in Guidelines)

**General Permit Information Required:**

Permit Number/Application Number:________________/___________________

Project Name:_____________________________________________________

Site Contact/Phone Number:________________/_________________________

District Facility ID:_________________________________________________

*(If not known, use site name and GPS coordinates or site map referencing location to known landmarks)*

Withdrawal source: (ex. well, lake, canal name, etc.):______________________

Withdrawal type (ex. pumped, gravity, flow well, other):____________________

Facility water use accounting method:__________________________________

___________________________________________________________________

**Notice:**

The following rectangular suppressed weir flow verification method is specific to flash-board riser type structures without end contraction. A Florida Registered Professional Engineer must verify that all the conditions shown in section C of this document (for this method) are applicable.

All other structures will require the submittal by a Florida Registered Professional Engineer of a flow verification/calibration plan, for approval by the SFWMD.

**<u>Flow Verification Information, Data and Calculations:</u>**

- Name and number of Florida Registered P.E. (Required): ________________________________________________________________

- Attach photographs and or a site drawing that shows this structure meets the required conditions for the following test procedure.

**<u>Weir Information:</u>**

Length of Crest, (L) = _______ft

Weir Elevation* = __________ft (reference)

Upstream Water Surface Elevation* = __________ft

Distance from the weir to the water surface elevation point = _____ft

* Important Note: Not necessary, if the height of water above the top of the weir can be measured directly.

<u>Head on Weir (H):</u>

H = the height of water above the top of the weir in inches ÷ 12 or;

(Note, measurement must be to closest ½ inch)

(Example: 9 ½ inches = 0.792 ft)

H = Water Surface Elevation ( – ) Weir Elevation

H = ______ ft

<u>Weir Equation</u>:

$Q\ (ft^3/s) = C \times L, ft \times (H, ft)^{1.5}$

Where the Weir Coefficient (C) = <u>3.13</u>

Flow (Q) = <u>3.13</u> X _______ ft X (______ ft) $^{1.5}$

Flow (Q) = ________ $ft^3/s$

Conversion from cfs to gpm:

Q = _______ $ft^3/s$ X 448.8 gpm/cfs

Q = _______gpm

**Flow Verification Performed by (print name):** ___________________________

**Company and Title:** _________________________________________________

**Phone Number:** ____________________________________________________

**Test Date:**___________________________________________________________