Water District Operation Manual Part IV: Technical Field Guide- Measurement and Data Collection

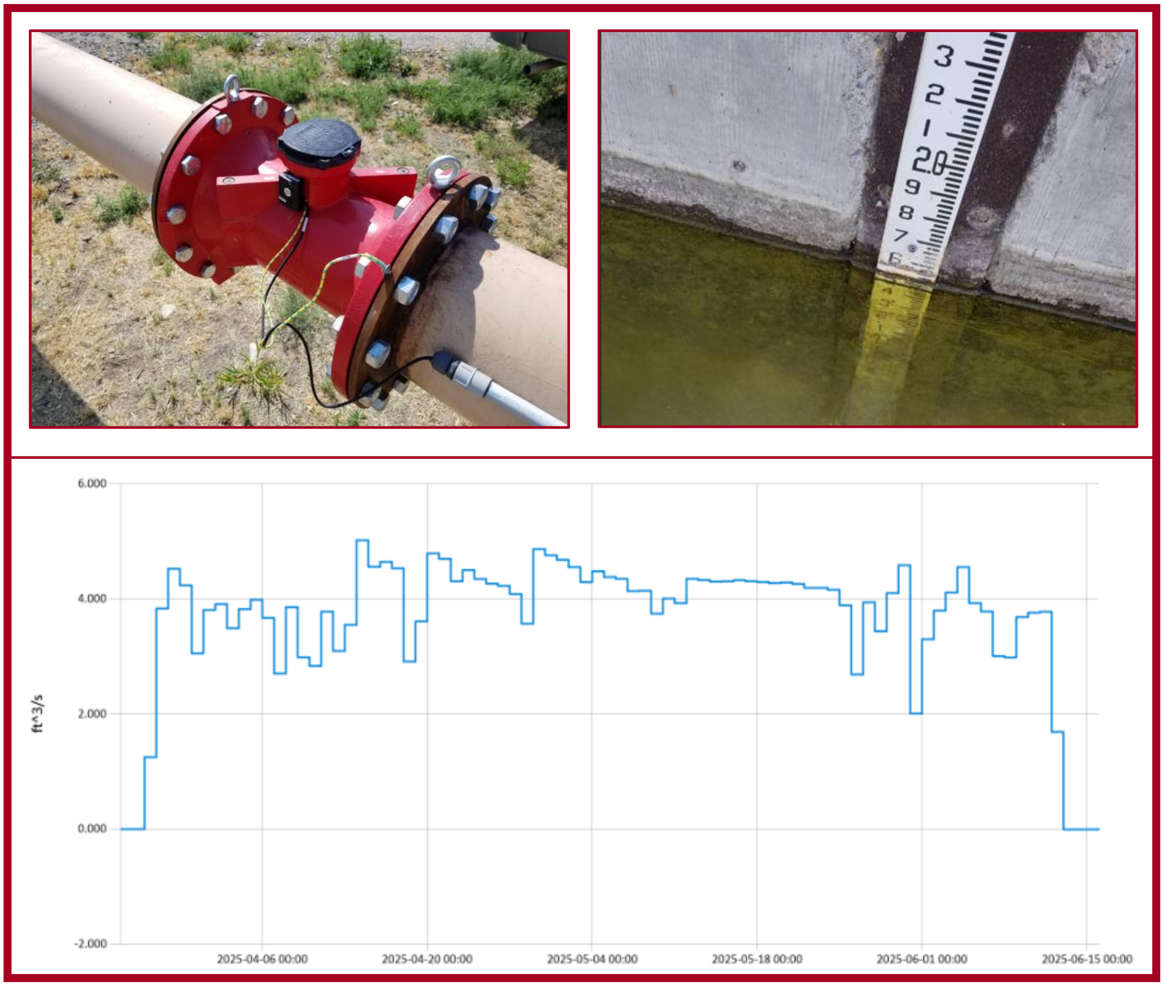

Photo Details: Ultrasonic Flow Meter (Top Left), Staff Gage (Top Right), Hydrograph (Bottom)

September 2025

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Part IV
Technical Field Guide – Measurement and Data Collection

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Purpose

Water distribution following the prior appropriation doctrine is the primary objective and responsibility for all Idaho watermasters. The Idaho Department of Water Resources (Department) supervises the distribution of water within water districts, but distributing water to users and the related accounting for water delivery is accomplished by watermasters as provided in Title 42, Chapter 6, Idaho Code. While the difficulty associated with these tasks depends upon the size and complexity of the individual water district, most of the principles and concepts involved are common to all districts.

This technical field guide for watermasters contains pertinent information about water measurement, data collection, and record keeping. This document is intended to be a reference guide when questions arise concerning water measurement, distribution, and how to manage a water district. This handbook is a companion to the *Water District Operation Manual Part I: Introduction to Water Districts, Part II: Water District Administrative Processes, Part III: Watermaster Handbook and the Water District Operation Manual: Appendices*.

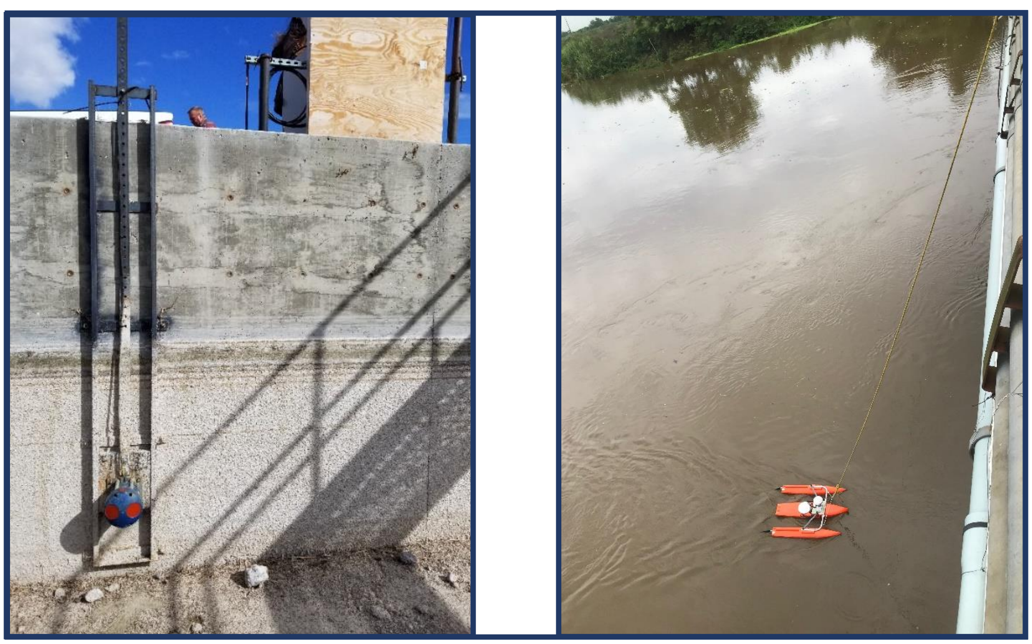

Figure 1. ADCP Channel Master in Canal (left). ADCP StreamPro measuring from bridge (right).

Basics of Flow Measurement

To properly distribute both surface and/or groundwater, a watermaster needs both the total discharge available for delivery and the quantity of water diverted by each water user.
Using the Freeman Equation (Equation 1) discharge is expressed as:

$$Q = VA$$ Equation 1

where: Q = discharge (cubic feet per second);
V = velocity (feet per second);
A = cross-sectional area (square-feet)

Measuring Discharge in an Open Channel

Discharge in an open channel may be determined either by measuring velocity and area directly or by using a pre-calibrated device, such as a weir or flume, installed in the channel. The minimum acceptable standards for open channel measurement are found in Appendix H, H1 or at the Department website https://idwr.idaho.gov/ > Water Data > Water Measurement > Guidelines. The measuring device must be properly constructed, installed, maintained, and operated. Successful installation of a measurement device will be determined by Department staff, water district watermaster, water measurement district hydrographer, or a water right examiner.

To make direct measurements, the following types of portable open channel velocity flow meters are acceptable to use:

- Price Type AA and Pygmy vertical axis current meters
- Horizontal axis propeller current meters (example: Ott or Hoff type meters)
- Electromagnetic sensors (propeller type or non-moving parts type)
- Acoustic Doppler Current Profiler (ADCP) or Acoustic Doppler Velocimeter (ADV)

Acoustic Doppler Methods

Direct velocity measurement in an open channel is accomplished using an Acoustic Doppler Current Profiler (ADCP) or Acoustic Doppler Velocimeter (ADV). The transducer (source) sends out sound waves directed into the column of water which scatter from particles in the water sending a signal back to the transducer (observer) as depicted in Figure 2. The transducer measures the response time of the soundwave emitted at a constant frequency calculating the velocity and area of the channel transect.

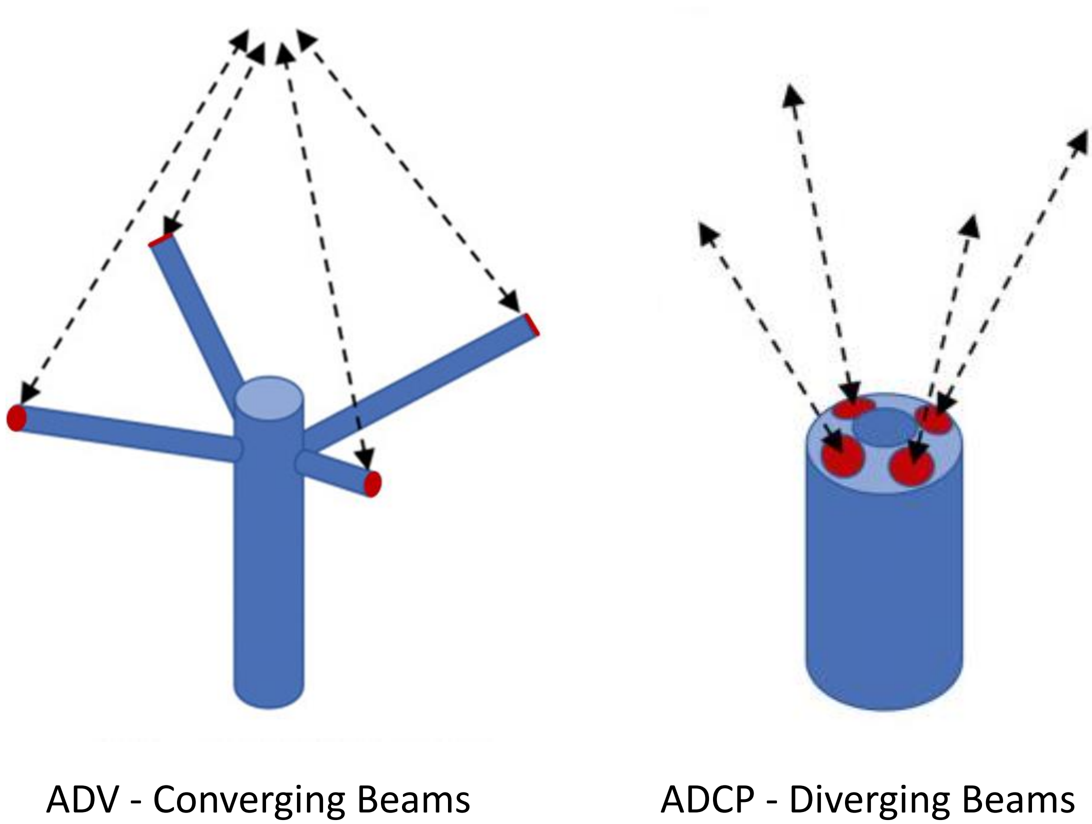

Figure 2. Acoustic Doppler Velocimeter (ADV) with converging beams on the left and Acoustic Doppler Channel Profiler (ADCP) with diverging beams on the right.

Acoustic Doppler Current Profiler (ADCP)

The ADCP method is generally used in larger streams or canals where it is not safe to wade. The transducers are usually installed on a pontoon style boat which is passed back and forth across a transect using ropes and pulleys to measure the velocity and area of the representative transect (Figure 3).

Figure 3. Acoustic Doppler Current Profiler (ADCP) Stream Pro installed in a pontoon boat operated by USGS staff (left) and IDWR staff (right). The image on left shows the details of the ADCP with transducers underneath and the image on the right features the ADCP measuring velocity and area as the boat travels across a transect while an operator controls the software and monitors incoming data.

Acoustic Doppler Velocimeter (ADV)

The ADV method is optimal for channels that are wadeable. The handheld device uses an acoustic transmitter to send a short pulse of sound concentrated in a narrow beam out from the transmitter to measure velocity in a small sample volume. A pressure sensor provides a depth measurement for calculation of the area. This unit is generally mounted on a wading rod, and measurements are taken at intervals across the transect by a field technician (Figure 4). To download software to process data from an ADV or ADCP device please visit the USGS website https://hydroacoustics.usgs.gov/midsection /software.shtml.

These meters should be used with standard discharge measurement methods pursuant to standards published by the US Geological Survey. All velocity meters with moving or rotating parts should be properly maintained and meet minimum spin test requirements or beam checks as specified by the meter manufacturer prior to each measurement.

Figure 4. A USGS hydrologist using an ADV device (FlowTracker) to make a direct velocity flow measurement across a transect.

Standard Measurement- Pre-Calibrated Devices

Standard weirs, flumes, and submerged orifices are pre-calibrated devices commonly used for measuring water in open channels. These standard measurement devices provide a fixed relationship between stage and flow, thus avoiding the need for velocity measurements. Various size weirs, flumes and submerged orifices are available, and each type and size have a separate rating, or relationship between head and flow.

Weirs

Most weirs have a sharp-edged metal plate, referred to as a blade or crest, which is placed perpendicular to the flow. This causes water to back up creating a pool before the water spills over the weir crest. Weirs are generally named for the shape of their crest and Figure 5 illustrates the common types of weirs. The depth of water above the bottom of the weir blade, or the weir crest, is called the head, commonly denoted by *H* or *h.* A weir can be contracted or suppressed as shown in Figure 6. which would change the equation used to calculate discharge. See Equations 2-4 for examples of how to calculate discharge for a weir.

Proper weir operation depends on maintaining free flow conditions over the weir crest. In free flow, water passes over the crest in a smooth laminar sheet with constant velocity. A correctly operating weir will have a nappe, or curtain of water which flows over the weir crest, exposed to air on both sides (Figure 7i). If the downstream water level rises high enough to influence the upstream conditions, the flow becomes turbulent, disrupts the velocity, and alters the discharge. When this happens, the weir is considered submerged, and the nappe becomes drowned (Figure 7ii). For more information about types of weirs and applications please refer to Chapter 7 of the *Water Measurement Manual* (2001).

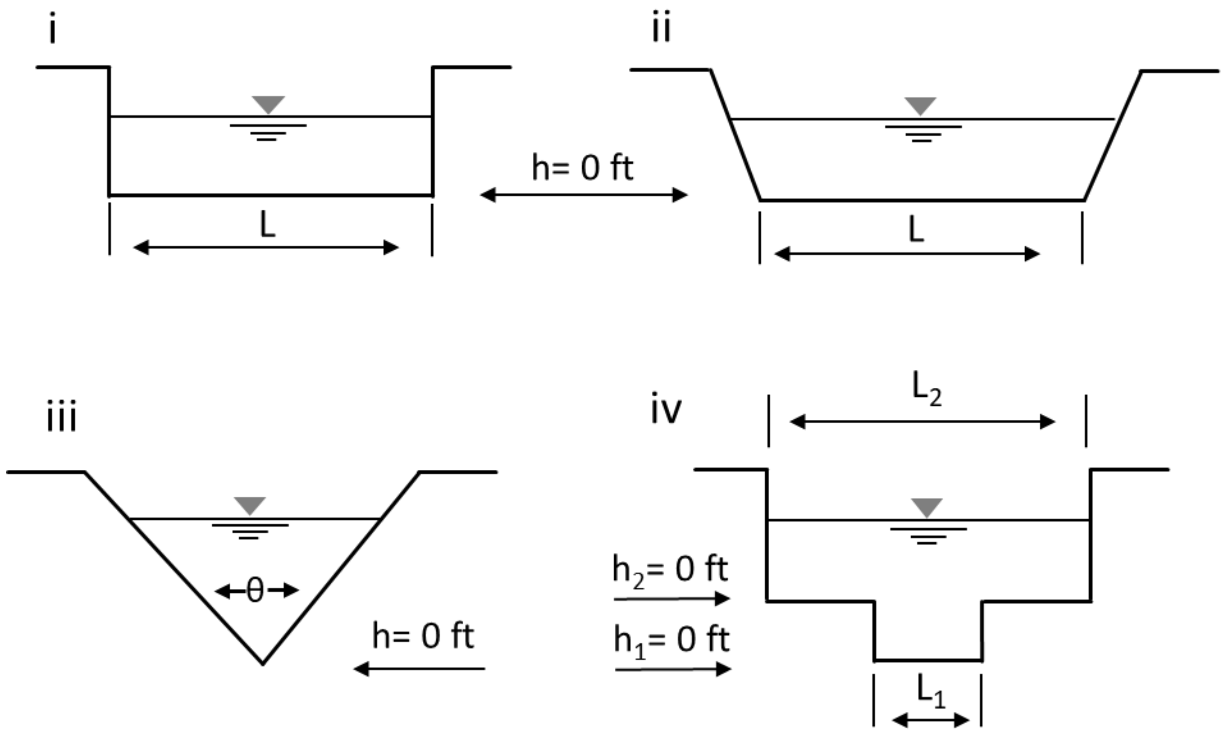

Figure 5.Rectangular weir (i), trapezoidal weir (Cipolletti) (ii), V-notch weir (iii), and compound weir (iv). The variables are h = Depth of water (head); L= Crest length; θ = angle of the V-notch, and the inverted triangle represents the water surface.

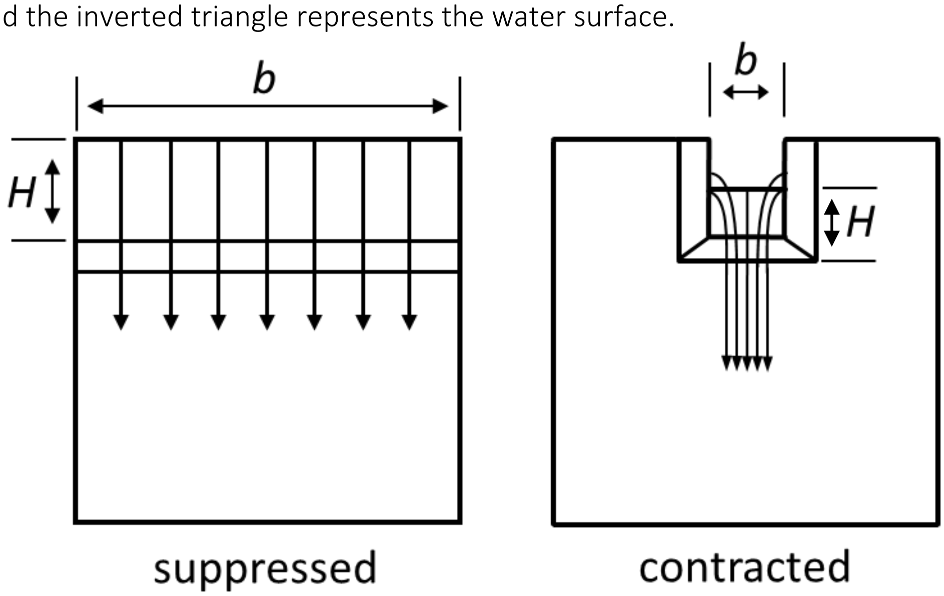

Figure 6. Diagram of suppressed and contracted weirs. Arrows indicate direction of flow. The variables are H = Depth of water (head) and b = Crest width.

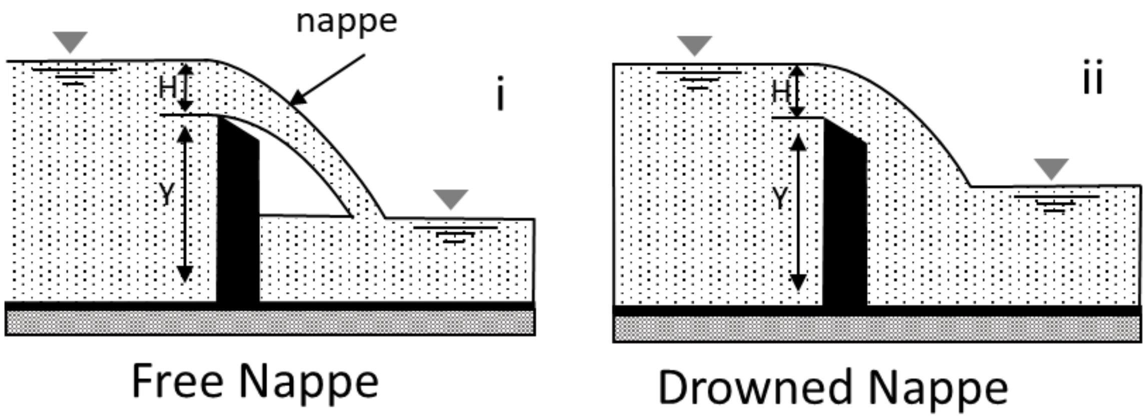

Figure 7. Diagram of a properly operating weir with air on both sides of the nappe (i) and an improperly operating weir with submerged conditions causing a drowned nappe (ii).

Flumes

A flume is a device having a constricted section, or throat, between an upstream converging section and downstream diverging section (Figure 8). Discharge is determined by measuring the depth of water at the proper location in the flume and then referring to appropriate tables. Standard flumes commonly used in Idaho include Parshall and ramped flumes (also called ramped broad crested weir). Some advantages of ramped flumes are they work well in larger canals, possibly more economical than other measurement structures, pass floating debris and sediment well, and require relatively little slope or fall. For more information about the types of flumes and their applications please refer to Chapter 8 of the *Water Measurement Manual* (2001).

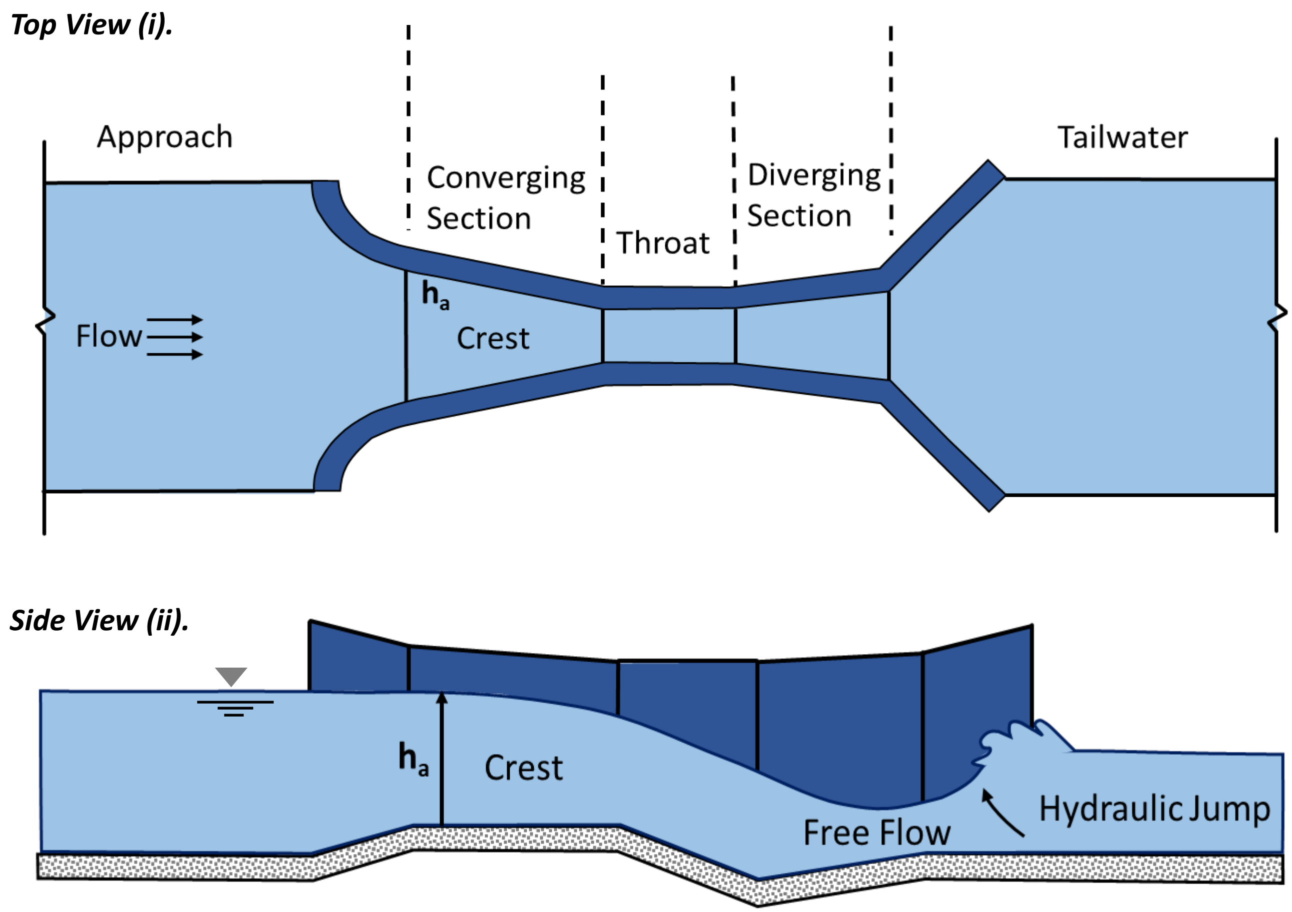

Figure 8. Basic schematic of a Parshall Flume top view (i) showing the width of the throat (b) relative to the direction of flow and side view (ii) showing the height of the side wall (h_a). The inverted triangle points towards the water surface.

Submerged Orifice

In the application of water measurement, an orifice is any fixed dimension opening with a sharp edge in a vertical wall or partition which is perpendicular to the flow of water. Both the upstream and downstream water surfaces are above the orifice. The difference in head or depth of water between the upstream and downstream surfaces must be obtained to determine discharge (Figure 9.). Like flumes, submerged orifices are better suited for channels with little to no elevational change. When selecting an appropriately sized submerged orifice for the range of flows in the system be sure to use the corresponding equation or rating table when calculating discharge.

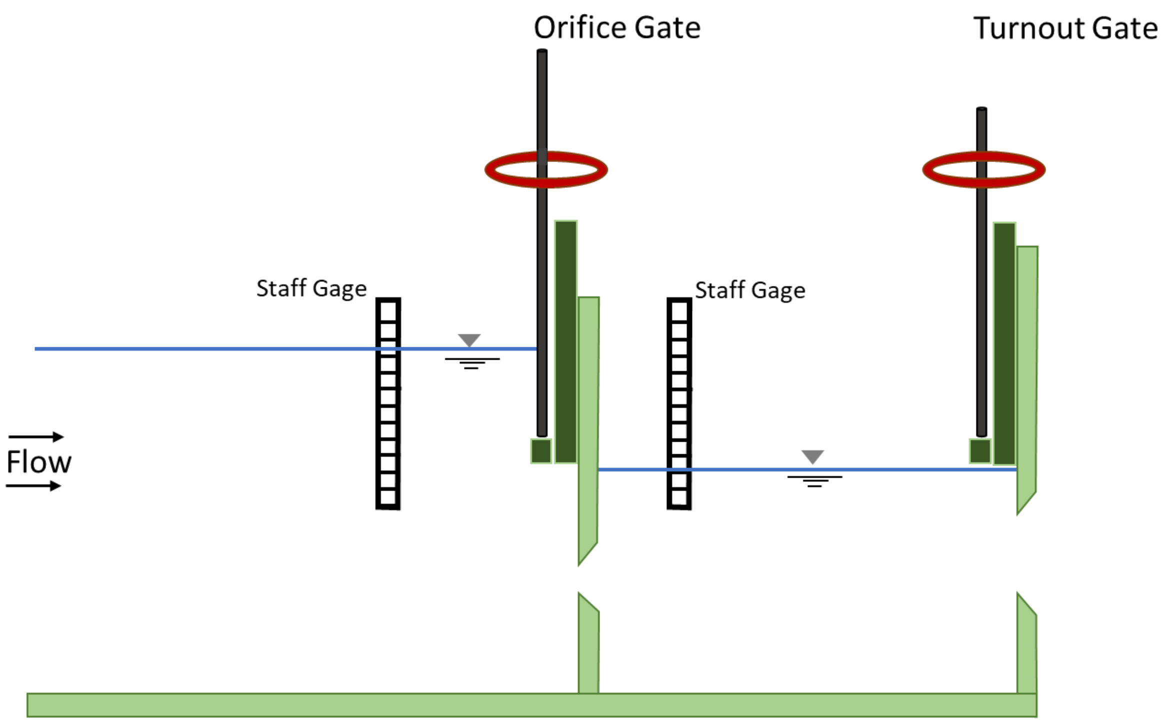

Figure 9. Basic schematic of a Constant Head Orifice (CHO) Turnout. A difference in water depth (Δh) is required to calculate the flow.

How to Read a Staff Gage

A staff gage is a ruler used to measure the depth of water. In the world of hydrology, the standard foot having 12 inches is scaled into tenths of a foot. For example, something measuring 2 inches would be 0.17 feet. Feet and tenths of feet are labeled numerically and marked with longer hash lines. Between the longer tenths lines are 4 hash lines used for measuring hundredths of a foot. The top of the hash is one hundredth and the bottom of the hash is another one hundredth. The pointed hash represents 5 hundredths (0.05), and measurements should be recorded to the hundredth of a foot if possible. To read the gauge and record the depth of water, identify the value in either feet plus tenths or feet minus tenths above the water line, and then count hashes down for hundredths (Figure 10). There are a variety of staff gages available depending on the depth of water being measured and the unit of measurement. To identify the different types of staff gages, please refer to Figure 11.

It is an extra challenge to read a staff gage in conditions that create poor visibility. Algae growth, overgrown vegetation and mineral deposits over time can obscure or even completely cover the staff gage. A good example is shown in Figure 12a. Encouraging water users to keep the staff gage clean with a soft bristled brush can help increase visibility and protect the gage markings.

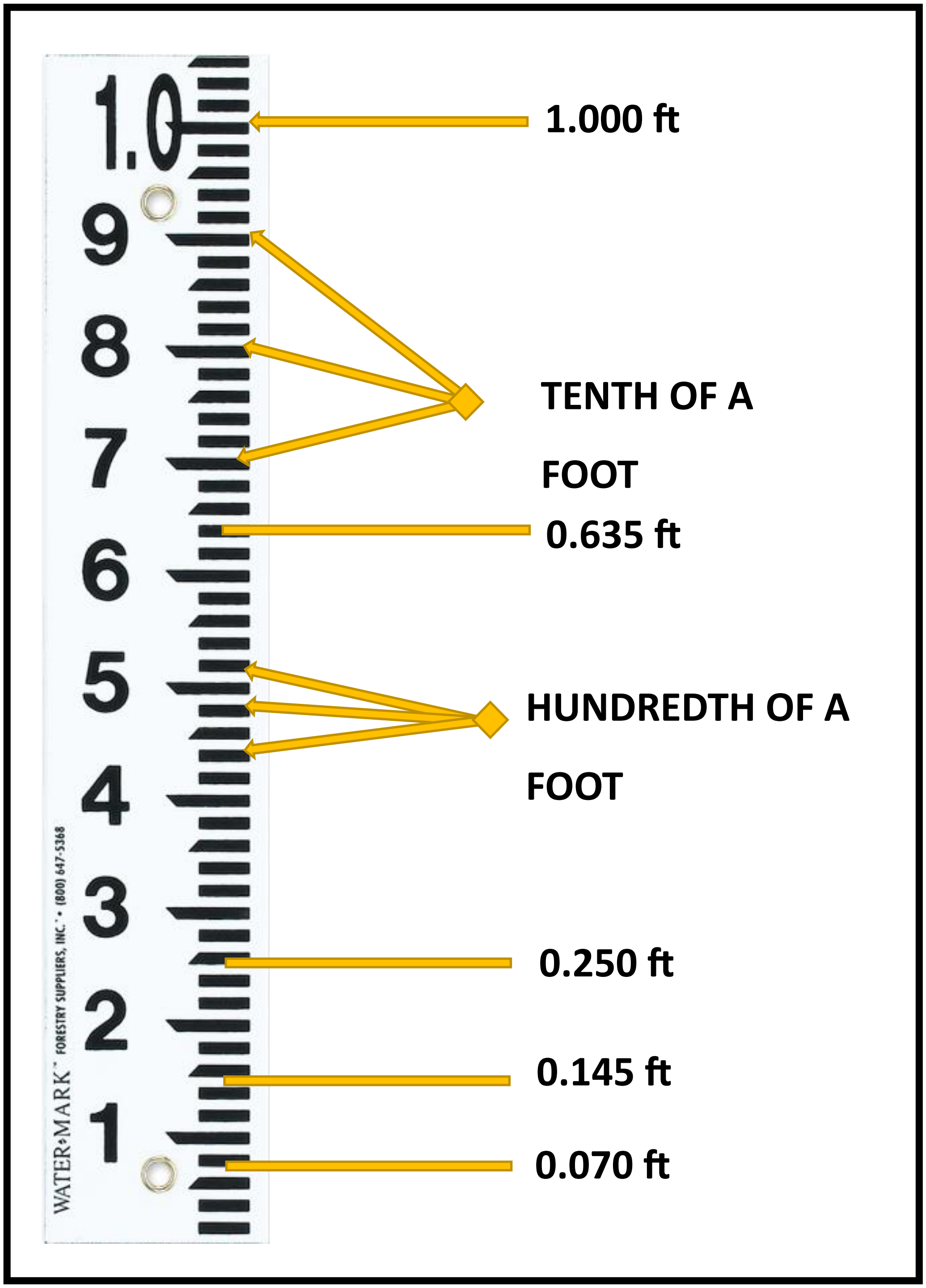

Figure 10. A typical staff gage used to measure depth of water in Idaho, style C, marked in tenths and hundredths of feet.

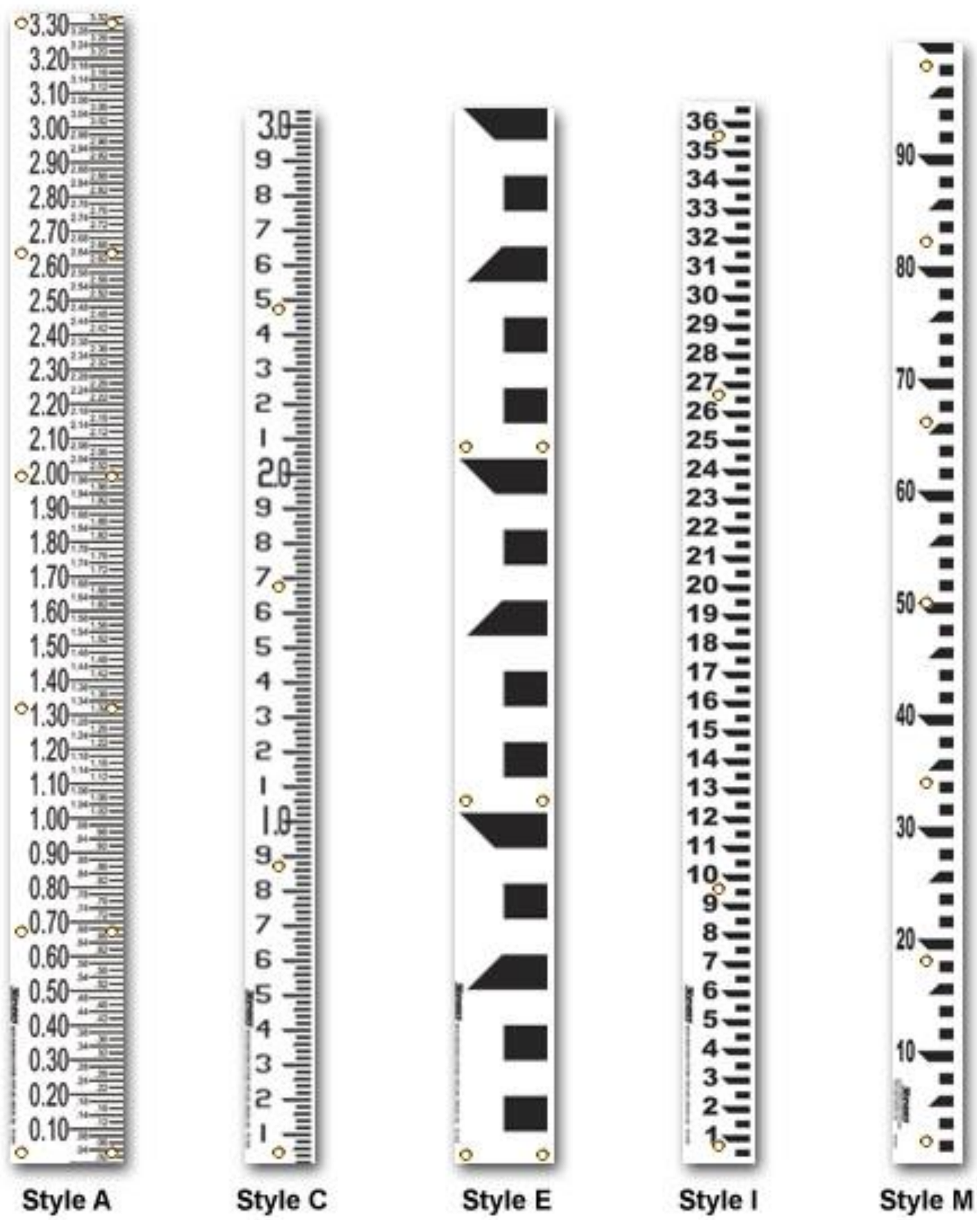

Figure 11. Staff gages commonly used. Style A is 4 inches wide, marked at every foot, tenth, and 0.02 foot. Style C has graduated marks every hundredth foot and numerical marks are printed every foot and tenth foot. Style E staff gage has graduated marks every tenth of a foot. Style I staff gages feature graduated marks every 0.25 inches and numerical marks every inch. Style M is a metric gage, 1 meter long, divided into centimeters with each decimeter numbered.

Rating Tables

The reason why pre-calibrated devices such as weirs and flumes are considered accurate tools to measure discharge is due to the fixed mathematical relationship between velocity and depth. Each size and type of weir or flume has a unique relationship or equation that governs the relationship between velocity and depth. Using the appropriate equation, the discharge at each step of change in depth is calculated and presented in a table, otherwise known as a rating table (Figure 12b). Some common equations used for calculating flow for various sizes of weirs or flumes and how to use a rating table in the field are described in this section . For all of the standard rating tables for weirs, flumes, and submerged orificies please refer to Appendix I.

Calculating flow using the Cone equation for a standard 90-degree contracted V-notch weir is expressed as:

$$Q = 2.49h^{2.48} \qquad \text{Equation 2}$$

where: Q = discharge in cfs;
h = head on the weir in ft

The rating table which matches Equation 2 can be found in Appendix E, Table A7-4.

Calculating flow using the using the Cipoletti equation for a Cipoletti weir is expressed as:

$$Q = 3.367Lh^{3/2} \qquad \text{Equation 3}$$

where: Q = discharge in cfs;
h = head on the weir in ft;
L = length of weir crest in ft

The rating table which matches Equation 3 can be found in Appendix E, Table A7-5.

The discharge equation used for Parshall Flumes (1- 8 ft) is expressed as:

$$Q = 4Wh^{1.522(W^{0.026})} \qquad \text{Equation 4}$$

where: Q = discharge in cfs;
h = head in ft;
W = throat width in ft

The rating table which matches Equation 4 can be found in Appendix E, Table A8-12.

Figure 12a. Staff gage on a fully contracted standard 90-degree V-notch weir. The rating table for this type of measuring device is in Table A7-4 of the *Water Measurement Manual* (Appendix E).

Figure 12b. A clip of Table A7-4 of the *Water Measurement Manual* (Appendix E). If the staff gage reads 0.35 feet on a 90-degree V-notch weir, the corresponding flow is 0.184 cfs.

Table A7-4. Discharge of 90° V-notch weirs, in ft^3/sec, computed from the formula $Q = 2.49h_1^{2.48}$.

Head *H*, ft	Discharge *Q*, ft³/sec	Head *H*, ft	Discharge *Q*, ft³/sec	Head *H*, ft	Discharge *Q*, ft³/sec	Head *H*, ft	Discharge *Q*, ft³/sec
0.20	0.046	0.65	0.856	1.10	3.15	1.55	7.38
.21	.052	.66	.889	1.11	3.23	1.56	7.50
.22	.058	.67	.922	1.12	3.30	1.57	7.62
.23	.065	.68	.957	1.13	3.37	1.58	7.74
.24	.072	.69	.992	1.14	3.45	1.59	7.86
.25	.080	.70	1.03	1.15	3.52	1.60	7.99
.26	.088	.71	1.06	1.16	3.60	1.61	8.11
.27	.097	.72	1.10	1.17	3.68	1.62	8.24
.28	.106	.73	1.14	1.18	3.75	1.63	8.36
.29	.116	.74	1.18	1.19	3.83	1.64	8.49
.30	.126	.75	1.22	1.20	3.91	1.65	8.62
.31	.136	.76	1.26	1.21	3.99	1.66	8.75
.32	.148	.77	1.30	1.22	4.08	1.67	8.88
.33	.159	.78	1.34	1.23	4.16	1.68	9.02
.34	.172	.79	1.39	1.24	4.25	1.69	9.15
.35	.184	.80	1.43	1.25	4.33	1.70	9.28
.36	.198	.81	1.48	1.26	4.42	1.71	9.42
.37	.212	.82	1.52	1.27	4.50	1.72	9.56
.38	.226	.83	1.57	1.28	4.59	1.73	9.70
.39	.241	.84	1.62	1.29	4.68	1.74	9.83

Non-Standard Measurement Open Channel

Rated Sections

A rated section may be authorized instead of a standard measuring device if requested and approved by the Department. For the Department to consider this method of measurement for approval, the rated section must be developed by an approved examiner. Approved examiners include: watermasters, Certified Water Right Examiners pursuant to Idaho Code § 42-217(a); Registered Professional Engineers; Registered Professional Geologists; and agents hired, employed or contracted to perform water measurement duties. The Department may require and/or provide additional or more specialized training for any examiner, including in-field review or training, at the discretion of the Department, or upon the request of the examiner or water district.

To develop a rated section of a channel, or a structure in a channel, a minimum of five separate discharge-stage measurements must be made to develop an acceptable rating curve or table. Discharge measurements that are used for developing a rating must be made using an ADCP or ADV device illustrated in the Basics of Flow Measurement (pages 1-4) of this manual. The section must be rated over the full range of flows in the channel to develop an acceptable rating table or rating curve. Rated sections require an accuracy of $\pm$10 percent and must have a permanent staff gage installed at an appropriate location. A copy of the developed rating table must be submitted with the annual watermaster report as described in Water District Operation Manual Part II or remain on file with the water district. If a rated section is in the process of being developed, the water level should be recorded at least once per week so when the rating is complete, the user can determine past diversions.

A series of discharge and corresponding stage or depth measurements at a measurement site can be plotted to produce a stage-discharge relationship or rating curve. The rating curve in turn can be used to determine discharge based on the stage. Stage can be obtained by observation of a fixed staff gage, or it may be continuously recorded by any type of stage recorder.

After a rated section is developed, both the rating and the physical section need to be maintained. Each season, at least two stage discharge measurements should be made and incorporated into the existing rating table. A rating curve generally becomes more accurate when more stage-discharge measurements are plotted. Since the stage can be affected by sedimentation, algae, or moss, it is important to keep the section clear of vegetation and debris. If there is suspicion that channel conditions alter the gage height, then a discharge measurement should be conducted, and a shift applied to the rating curve.

Many streams, rivers, and large canals within Idaho have gaging stations which are maintained by the United States Geological Survey (USGS). These stations are generally equipped with a staff gage and continuous stage recorder. A watermaster can observe the gage height or recorder and refer to USGS rating tables to determine discharge for that time of day. Regular stream discharge measurements are taken at these stations to maintain rating curves or tables and to determine gage shifts. Depending on their location, watermasters can often utilize existing USGS gaging stations for determining the available natural flow of the stream and proper distribution of water according to water right priority dates. Many of the existing USGS stream gaging stations are funded under cooperative agreements between the USGS, the Department, and the local water district.

Measuring Discharge in Closed Conduit

In-line or spooled flow sensor meters are commonly used devices for measuring flow in a pipe. These meters are usually installed in a horizontal pipe near the source or pump. Water is measured by obtaining an average velocity moving through the section of pipe. Since the cross-sectional area of the pipe is constant, the velocity is obtained using a sensor to detect changes in this variable. These changes have a proportional ratio that is used to determine discharge across a variety of flows.

Many spooled meters display two values: instantaneous discharge, usually in gallons per minute (gpm) or cubic feet per second (cfs), and a totalized volume in gallons or acre-feet. If the display is difficult to read, the user should be informed for repair. Closed conduit flowmeters will display the flow rate and totalized volume. It is important to standardize the units to control how often the totalizer rolls over. The totalizer should not roll over more frequently than every other year.

The Department has published a list of meters that have passed third party testing conducted at the Utah Water Research Laboratory (UWRL), a National Institute of Standards and Technology (NIST) traceable lab in Logan, Utah. Tests were conducted for both accuracy and repeatability on all submitted models. The list of meters that have passed testing and are approved (Approved Flow Meters List) for use may be found in H, H2 and on the Department website https://idwr.idaho.gov/ > Water Data > Water Measurement > Guidelines. Flow meters on the approved list can be purchased through vendors that specialize in measurement devices and installation or through local irrigation/sprinkler companies.

Standard Measurement

Ultrasonic Flow Meters

The ultrasonic theory states that the time it takes for a sound wave interacting with particles in the water to be sent one way and then returned is proportional to the rate of flow. Ultrasonic meters utilize signal transducers (sensors) which measure flow that can be clamped either on the outside (clamp-on) or mounted inside (wetted transducer) the pipe wall (Figure 13). The ultrasonic meters can be permanent or portable and can provide quick measurements without shutting down the flow in the pipe. The non-intrusive nature of the meter with repeatable and accurate flow measurement offers an economic approach to the measurement of large diameter piping (12” - 144”).

Ultrasonic transducer cables are delicate and vulnerable. The location of transducer attachment (wetted or clamp-on) should be carefully considered, and the transducers need to be sealed with a long-term silicone based acoustic gel (not water-soluble). When using ultrasonic meters there are conditions that need to be met to ensure proper installation and function.

1. The pipe needs to be relatively clean and smooth on both outside and inside walls.

2. The water c6annot have entrained air (often looks milky).

3. The meter requires longer straight run of pipe without any flow disturbers to make an accurate measurement.

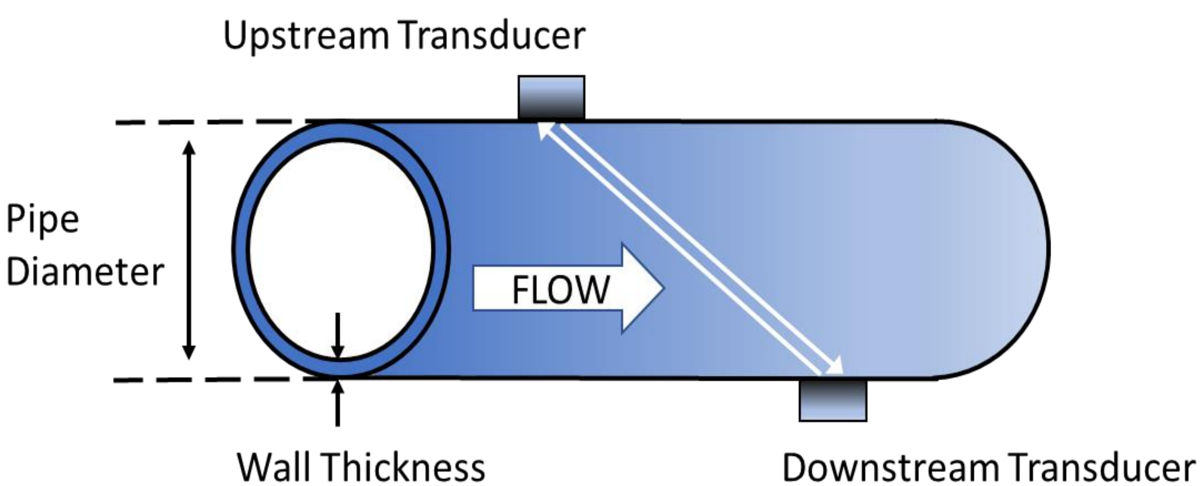

Figure 13. General schematic of an ultrasonic device with transducers attached to a pipe.

Electromagnetic Flow Meters (Mag Meters)

The basic physics of how magnetic flow meters work is Faraday's law of Induction, which states that voltage is proportional to the velocity across a conductor in a magnetic field. As water flows through the coil, the magnetic field changes, inducing a voltage that the sensors measure. Since the voltage is proportional to velocity and the area of the pipe is fixed the discharge volume can be calculated (Figure 14). Magnetic flow meters should be properly grounded to avoid stray voltage that may distort the measurement. Vibrations from pumps or other machines that may travel through the pipe should be minimized as well.

The sensors detect each conductive fluid particle within the meter body, which means mag meters can be installed in shorter sections of pipe and still maintain high levels of accuracy. This provides a cost-effective approach to retrofitting flow meters into existing irrigation systems generally without additional plumbing modifications.

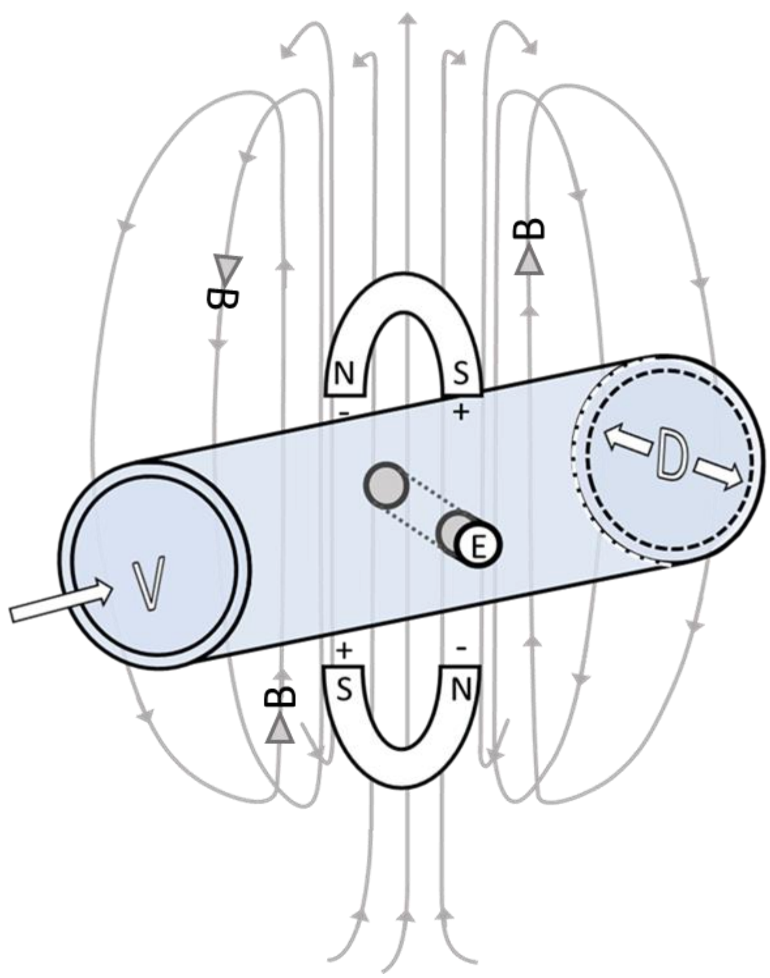

Figure 14. A general diagram of a non-conductive flow tube with an magnetic field. The voltage is proportional to the velocity across a conductor in a magnetic field. As water passes throgh the magnetic field (B), a voltage is induced and measured by the electrode sensors (E). The discharge (Q) is the product of the area using the inner diameter (D) and the velocity (V).

Non-Standard Measurement Closed Conduit

Hour Meter

In some cases, the director will approve measurement of volume diverted by recording the operating hours of the diversion pump with an hour meter (time clock). Timing a diversion with an hour meter can only be used on systems with one well that discharges to an open ditch or pond where:

- discharge is constant and not controlled by valves;
- groundwater levels do not change significantly during the annual season of use; and
- the rate of flow is measured annually by a groundwater district hydrographer.

The time clock must record the operational hours of the diversion pump (hours) to at least one-hour precision. An approved examiner using a standard meter will measure flow rate (gpm) at least once every three years. Volume is calculated in Equation 5 based upon flow rate measurements and hours of operation:

$$Volume\ (AF) = \frac{gpm \times hours}{5431} \qquad \text{Equation 5}$$

Elements to record and report for each diversion where the Time Clock method is used to determine volume include:

- rate of diversion measurement;
- analysis describing reasons why flow rate will remain constant (e.g. open discharge well pump operating at constant speed, flow not throttled, and drawing from an aquifer not experiencing significant draw down conditions); and
- time clock reading at time of measurement.

Power Consumption Coefficient (PCC)

The Department will ***consider*** a request for a variance to use PCC in place of an approved flow meter upon the submission of a completed Variance Request Form and a written plan. Water diverted from a pump powered by an electric motor may be estimated using the power consumption coefficient (PCC) method. PCC is a ratio that provides how many kilowatt hours are needed to pump 1 acre-foot of water. **The PCC method can be used once the applicant is issued a written variance approval letter from the Department. The PCC method can only be used for systems that are simple in design and operational characteristics.** The PCC method is most accurate in a system with a single electrical power meter dedicated to one pump.

Authorization to use the PCC method will only be granted for simple irrigation systems that consists of one (1) pump with one (1) power meter, and one (1) discharge point or one distinct flow and demand condition. An additional criterion is that groundwater levels in the vicinity of the diversion do not change significantly during the irrigation season.

The PCC method will not be approved as a substitute for a flow meter for complex systems where flow rate or total dynamic head at the pump varies due to multiple valve adjustments, multiple discharge locations in a pipeline, the method of delivery varies between open discharge, gated pipe, or sprinkler systems during an irrigation season, where multiple wells/pumps are tied together with common mainline(s), or if a variable frequency drive is used.

Two measurement factors are required to calculate the PCC as shown in Equation 6. The first factor is the rate of electrical energy consumed during operation of the pumping plant under typical conditions and has units of kilowatts (kW). The second factor is the measured flow rate units of gallons per minute (gpm) produced under the same typical conditions as the first factor.

$$PCC\left(\frac{kWh}{AF}\right) = \frac{kW \times 5431}{gpm} \qquad \text{Equation 6}$$

As shown in Equation 6, the PCC has units of kilowatt-hour per acre-feet, and the conversion factor, 5431, has units of gallon-hour per acre-feet-minute. Only an approved examiner using a standard meter should be allowed to make measurements for the two required factors. These two PCC factors must be measured at least once every three (3) years to capture any changes to the ratio, and subsequently the total annual volume.

Using the PCC and the total annual kilowatt-hours (kWh) of electrical energy consumed by the pumping plant, the total annual volume of water pumped is calculated in Equation 7.

$$Total\ Annual\ Volume\ (AF) = \frac{Total\ annual\ kWh}{PCC} \qquad \text{Equation 7}$$

The total annual kilowatt-hours used by the pump, as measured by each electric meter, will be supplied by the electrical utility to the Department pursuant to Idaho Code § 62-1302. The Department will enter into agreements to provide energy consumption data to a water district, water measurement district, groundwater district or irrigation district for the limited purpose of computing and reporting volume withdrawals. When using the PCC method for non-irrigation accounts, energy consumption data should be provided by the owner. Some utilities may release information with the owner's approval.

Alternative Methods for Estimating Discharge in Closed Conduits

When a closed system is not fitted with a meter, total discharge may be estimated using one of several methods described below. These methods should only be used temporarily until an adequate measuring device can be installed.

Nozzle Flow Rate

Discharge can be estimated by counting sprinkler heads and knowing the nozzle size in inches and pressure at the nozzle in pounds per square inch (psi). Often irrigation systems will have nozzles of varying sizes. The size of a given nozzle can be determined by inserting the shank end of a drill bit into the nozzle opening. A simple water pressure gage is required to measure the operating pressure at the sprinkler nozzle. Due to friction losses and elevation changes, sprinkler head pressures vary depending on location within the system. For this reason, it is necessary to obtain an average nozzle discharge or pressure measurement. This can be done by taking several measurements at different locations. The average rate multiplied by the total number of nozzles will provide a good estimate of total discharge.

Nozzle flow charts are generally provided by the manufacturer of a specific brand of nozzle, but a general table using a theoretical equation is helpful if the nozzle brand is unknown (Table 1).

Using Bernoulli's Equation (Equation 8) which relates the force of pressure (gravity *(g)* and head *(h)*) to velocity (*V*), we can substitute the dependent variable head (*h*) for pressure (*P*).

$$V = \sqrt{2gh} \quad \rightarrow V = \sqrt{2P} \qquad \text{Equation 8}$$

The area of a circle (Equation 9) relies on the relationship between the square of the radius (*r*) and the constant pi (π) can be rearranged to substitute the dependent variable (*r)* with diameter (*d*).

$$A = \pi r^{2} \rightarrow A = 0.7854d^2 \qquad \text{Equation 9}$$

Knowing the diameter of the nozzle outlet and the pressure of the water leaving the sprinkler we can calculate flow. The resulting formula used to produce Table 1 is Equation 10

$$Q = 28.9d^2\sqrt{P} \qquad \text{Equation 10}$$

Where:

d = diameter of sprinkler nozzle in inches; and
P = Pressure measured at sprinkler head, in psi.

Table 1. Nozzle flow rate in gallons per minute, referenced by pressure in psi and nozzle size in inches. Table produced using Equation 10.

Nozzle Flow Rate in Gallons Per Minute							
Pressure	Nozzle Size in Inches						
psi	3/32	1/8	9/64	5/32	11/64	3/16	13/64
20	1.14	2.02	2.56	3.16	3.82	4.54	5.33
25	1.27	2.26	2.86	3.53	4.27	5.08	5.96
30	1.39	2.47	3.13	3.86	4.68	5.56	6.53
35	1.50	2.67	3.38	4.17	5.05	6.01	7.05
40	1.61	2.86	3.61	4.46	5.40	6.43	7.54
45	1.70	3.03	3.83	4.73	5.73	6.82	8.00
50	1.80	3.19	4.04	4.99	6.04	7.18	8.43
55	1.88	3.35	4.24	5.23	6.33	7.53	8.84
60	1.97	3.50	4.43	5.47	6.61	7.87	9.24
65	2.05	3.64	4.61	5.69	6.88	8.19	9.61
70	2.13	3.78	4.78	5.90	7.14	8.50	9.98
75	2.20	3.91	4.95	6.11	7.39	8.80	10.33
80	2.27	4.04	5.11	6.31	7.64	9.09	10.67
85	2.34	4.16	5.27	6.51	7.87	9.37	10.99
90	2.41	4.28	5.42	6.69	8.10	9.64	11.31

Horsepower Equation

A third method of estimating discharge (Q) in cfs is by using the horsepower equation (Equation 11). This method can be used where there is a motorized pump which lifts water from a stream or canal into a pressurized system as shown in Figure 15.

$$Q = \frac{8.81(0.7HP)}{h+(2.31P)} \qquad \text{Equation 11}$$

Where:

- HP = motor horsepower (obtained from pump motor specification/nameplate) with a 70% efficiency assumed;
- h = vertical distance from water source to pump [static suction lift + vertical distance from pump to sprinkler (static discharge head)]; and
- P = Pressure measured at sprinkler head, in psi.

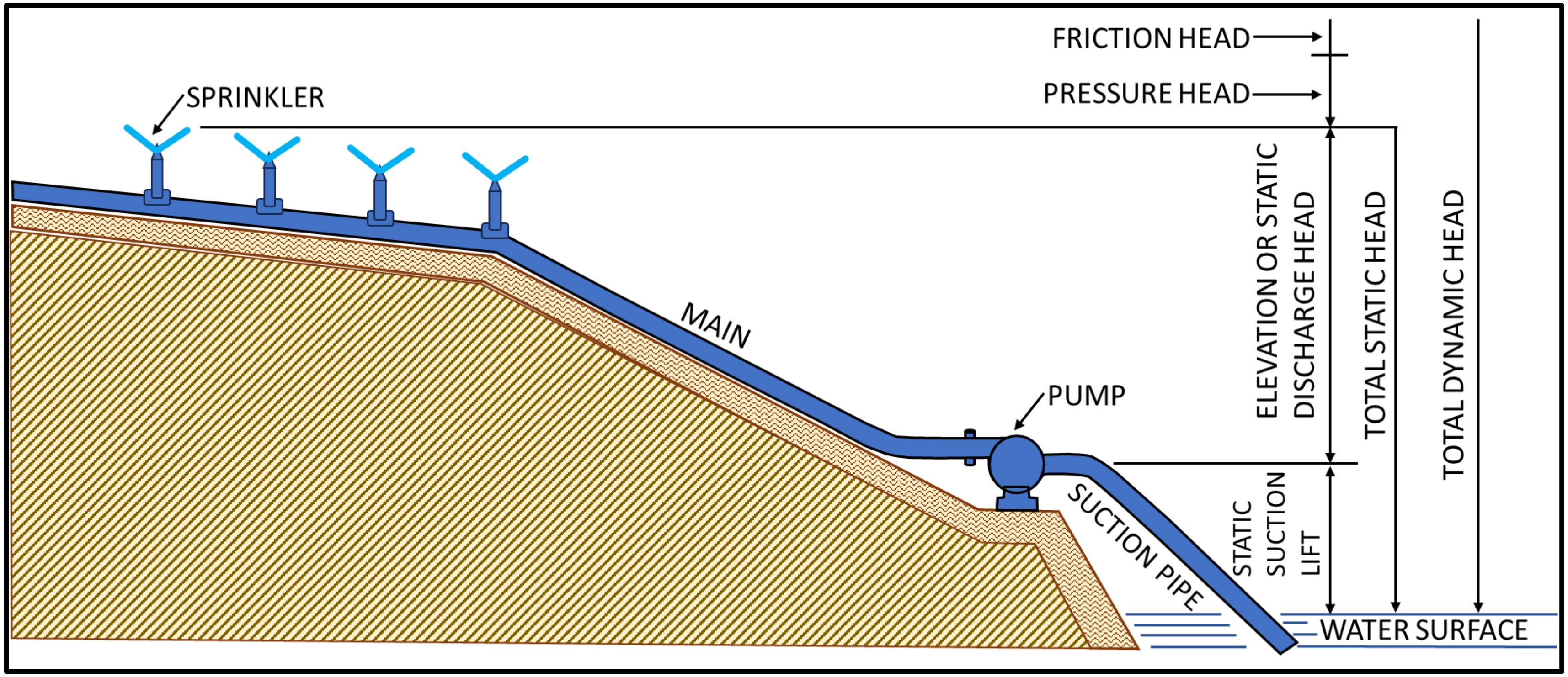

Figure 15. Illustration of system and total dynamic head for an irrigation system.

Department Installation Requirements

Many Idaho water users now use pressurized sprinkler irrigation systems. This conversion has created a need to measure discharge in pipes or closed irrigation systems. The Department has adopted the use of electromagnetic and ultra-sonic flow metering as the minimum standard for measuring water in closed conduits. Approved full profile magnetic flow meters and spooled ultrasonic flow meters must be installed with a minimum straight pipe length equivalent of three (3) pipe diameters upstream and two (2) pipe diameters downstream from the center of the meter spool. Approved clamp-on and wetted ultrasonic flow meter transducers must be located with a minimum straight pipe equivalent of ten (10) pipe diameters upstream and five (5) pipe diameters downstream of the nearest transducer. ***Manufacturer specifications for upstream and downstream straight pipe requirements may be greater or less than the IDWR requirements.*** All other manufacturers' installation specifications must be met. Guidance for determining proper installation can be found in Appendix H, H4.

Non-approved flow meters installed prior to the issuance of an IDWR measurement order may only be used as follows:

1. Request a variance by submitting to the Department, a Request for Variance of IDWR Approved Flow Meter Requirement (Variance) form. Please submit one Variance request for each meter or each well/diversion. Search for a Variance form on the Department website https://idwr.idaho.gov > Forms > Water Measurement Reporting > Variance or Extension of Time Request Forms.

2. The installed meter must be measured for accuracy and test within the error margin to be considered for a variance approval. If the non-approved flow meter meets the accuracy standards and the variance is approved, the flowmeter needs to be field tested for accuracy at least once every three years thereafter. If the non-approved meter is tested in the following years and the flowmeter does not test within the margin of error for accuracy, the variance will be withdrawn and a new meter from the Approved Flow Meter List will need to be installed before diversions may occur.

Inspection of Installed Measurement Devices

Field inspections made by the watermaster should be conducted as soon as possible after measurement device installation to confirm that the device is an approved type and meets the department installation standards. Data collected during the field inspection includes measurement device type and size, meter manufacturer, model and serial number, nominal size of meter and pipe, display flow rate and volume units, and meter installation date.

It is helpful to have photos of the overall diversion including the measuring device, close-up of any display, a wide view of the system clearly showing the position of the device and direction of flow, site tag ID number, horsepower of the pump(s), and locational information in the form of GPS coordinates. Thumbnail images of each flow meter on the approved list can be found in Appendix H, H3.

Location of Measurement

Measuring flow as close to the point of diversion as reasonable should be accommodated. For closed-conduit systems, an acceptable location is a section of straight pipe free of elbows, valves, and other fittings. Typically, this section of straight pipe should be at least 15 pipe diameters in length. On a system consisting of both a well and booster pump, it is preferable that the measurement location is upstream of the booster. If it is necessary to measure downstream of the booster, the location should be far below the booster (such as 20 or more pipe diameters prior to the measuring section) because the booster creates extreme turbulence which degrades meter performance and longevity. Most meter manufacturers recommend that meters be placed at least 10 pipe diameters downstream, and 5 pipe diameters upstream of minor turbulence causing fittings such as discharge heads, single elbows, and valves, and farther downstream if the disturbance is more severe, such as two elbows out of phase, pumps, and valves which significantly throttle flow.

Collecting and Recording Measurement Data

Data Collection Frequency

To quantify how much water is being delivered by the watermaster at each diversion and in total across the district, measurement data is critical. The collection depends on the type of measurement device and the frequency of data collection. Frequency of data collection by the watermaster or assistant watermaster often correlates to the water district budget.

Estimation – No Measurement Device(s)

If there is no measurement device at a diversion, then methods of estimation should be used. This can be done by communicating with the water user about the duration of water use and having the water right information. The estimated volume should be used in determining the assessment for the year and published in the watermaster report. Estimated data will not provide time-series data but it can be used to compare to the actual usage when a measurement device is installed.

Annually – Flowmeters

With any approved flowmeter the totalizing capability is used. The totalizer volume should be available at any time during the season for the watermaster to record the total volume in acre-feet delivered. This information can be collected manually from the display face. Annual volume data provides an annual time-series and should be an accurate total volume of water used because the value reflects all rates of flow as measured by the meter.

Weekly – Weir, flume, orifice.

Standardized measurement devices such as a weir, flume, or other open channel device that require a staff gage to be read manually, should be recorded at least weekly in cfs. The start and end date will need to be recorded, and any non-use would be recorded as 0 cfs. A weekly rate of flow will provide time-series data to calculate the total volume of water used, but it may not reflect all changes in rates of flow, reducing accuracy.

Daily and 15-Minute – Weir, Flume, Flow Meter

Standardized measurement devices such as weirs, flumes, or other open channel devices that have a transducer installed can be recorded and stored. The transducer will digitally record and store the depth of water (h) and can be downloaded as often as needed. Similarly with a flowmeter, the data output can be recorded and stored on a datalogger to be downloaded as often as needed. The frequency of data stored would depend on the memory logger and how often the data is downloaded.

For a diversion that is challenging to access and does not have a radio telemetry system, storing data at the daily level is sufficient to calculate the amount of water diverted. A daily time-series would still incorporate most changes in rates of flow. With a radio telemetry system, the data is generally logged every 15 minutes. The 15-minute time-series data will reflect any changes in the rate of flow that occur and is ideal for calculating the amount of water delivered. Processing data at this scale requires work in an advanced spreadsheet or application.

Data Entry and Record Keeping

The Department has several databases where watermasters can enter and store data. This is helpful for compiling the annual watermaster report and keeping a long-term record of diversion data. There are additional applications and maps available for data entry that watermasters can use in the field without the need for cellular reception. Please contact the Distribution Section for details on data entry and data automation.

Water Measurement Information System (WMIS)

The WMIS database includes ground and surface water diversions for which annual delivery totals are recorded (Figure 16). The WMIS database is the most appropriate place to enter annual volume data. Please contact the Department's Distribution section or email wmisinfo@idwr.idaho.gov to be assigned a username and password to begin data entry for your water district. You view the records without the ability to edit by using the Guest Login.

The WMIS database can be found at the Department website https://idwr.idaho.gov/ > Water Data > Water Diversion Measurement Network > Annual Time Series (WMIS).

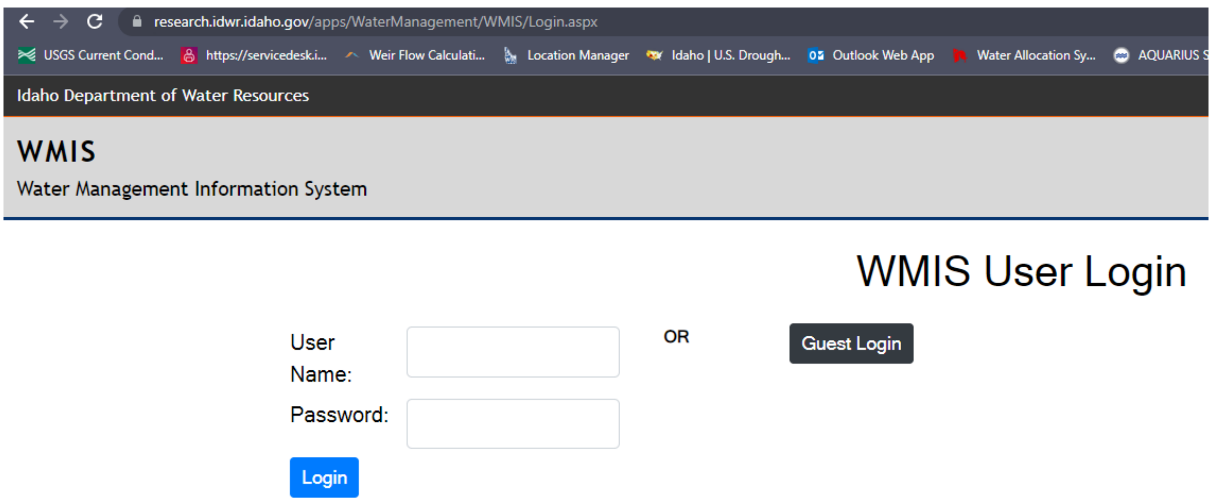

Figure 16. Screen clip of the WMIS login page

Water District Diversion Database (DWR Central)

View and print data and graphs for points of diversion including daily diversion records for certain surface water diversions and some groundwater diversions for which weekly or regular flow rate measurements are taken (Figure 17). Please contact the Department's Distribution section to be assigned a username and password to begin data entry for your district. You do not need to log in to view the records, only to edit or add new records.

DWR Central database can be found at the Department website https://idwr.idaho.gov/ > Water Data > Water Diversion Measurement Network > Daily Time Series (Water District Diversion Database).

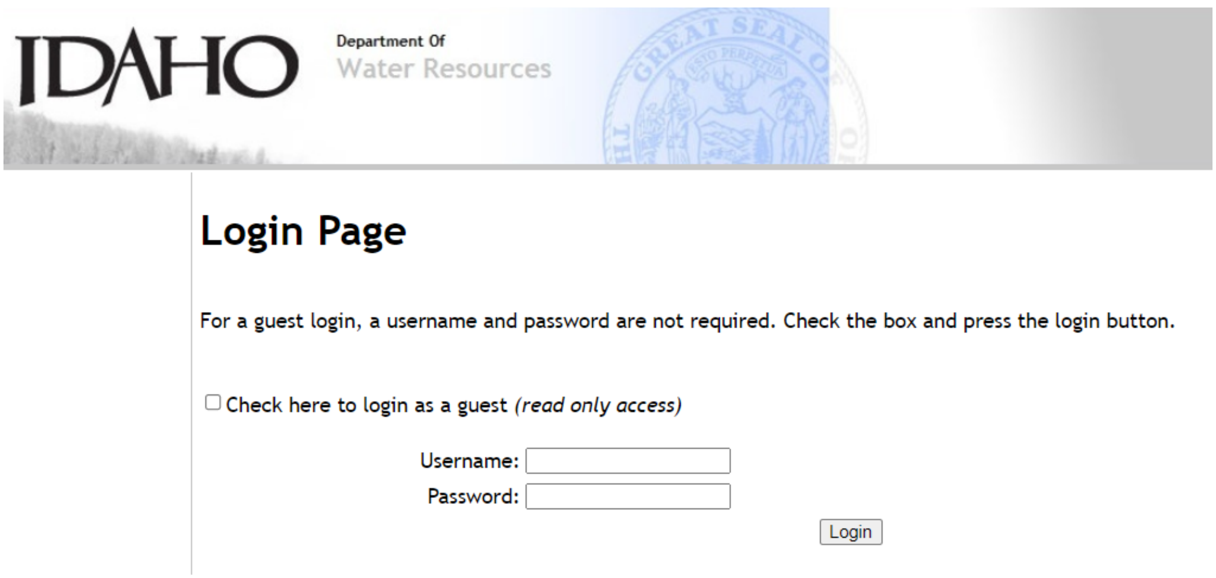

Figure 17. Screen clip of the DWR Central login page.

Aqua Info

Chart and download flow measurements in 15-minute and average daily time series. Water measurement data available in Aqua Info primarily originates from telemetry stations all over the state. Aqua Info (Figure 18) is an easy-to-use method to interface with telemetry data collected by the Department. All published data are provisional and subject to change.

Aqua Info can be found at the Department website https://idwr.idaho.gov/ > Water Data > Water Diversion Measurement Network > Telemetric Time Series (Aqua Info).

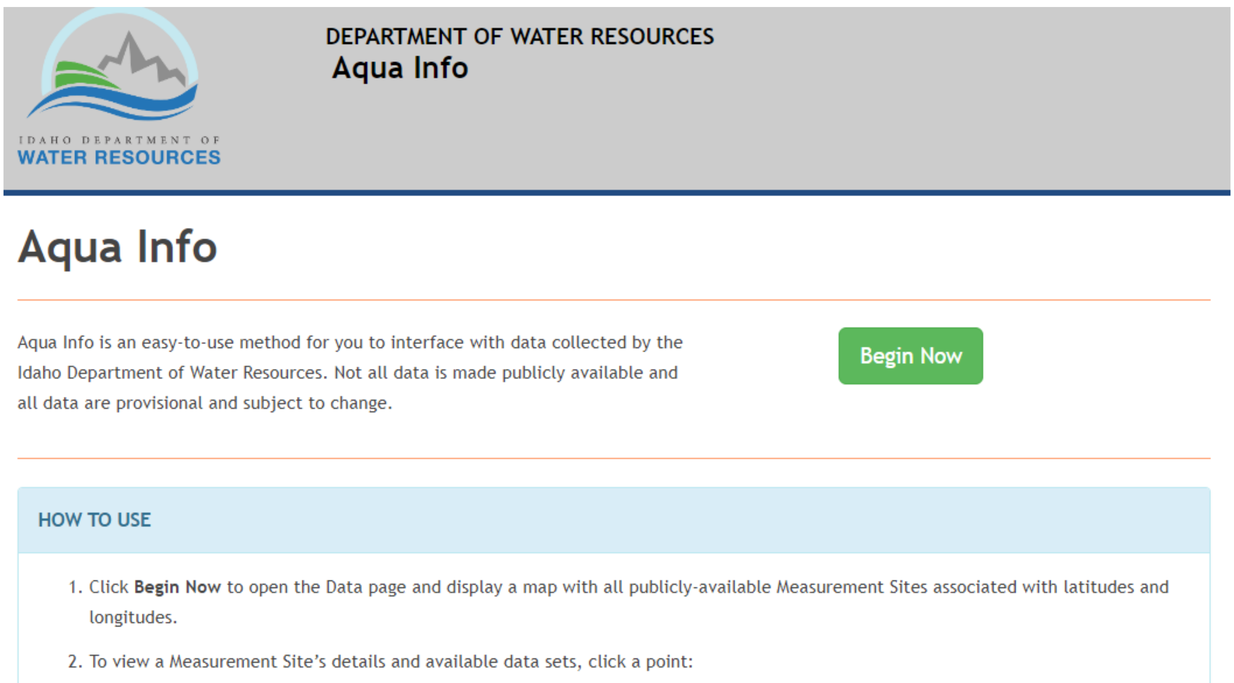

Figure 18. Screen clip of the Aqua Info page.

References

Reclamation, US BUREAU OF. "Water Measurement Manual." US Government Printing (2001).

URL: https://www.usbr.gov/tsc/techreferences/mands/wmm/WMM_3rd_2001.pdf

United States Department of the Interior | U.S. Geological Survey

URL: https://www.usgs.gov/hydroacoustics

Page Contact Information: gs-w_hawg_all@usgs.gov

WMIS

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wmisinfo@idwr.idaho.gov

Login Page

https://research.idwr.idaho.gov/apps/watermanagement/wmis/

DWR Central

Login Page

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Login Page

https://research.idwr.idaho.gov/apps/hydrologic/aquainfo