Standard Operating Procedure

Total Discharge

WQDWQPBFM-03, Version 1.0
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Water Quality Planning Bureau

Author: Elizabeth McWilliams, Monitoring and Assessment Section

Approvals:

/s/ Chris Faubion	5/21/2020
Chris Faubion, Technical Review	Date
/s/ Wil George	5/20/2020
Wil George, Technical Review	Date
/s/ Katie Makarowski	5/20/2020
Katie Makarowski, Quality Assurance Review	Date
/s/ Galen A. Steffens	7/15/2020
Galen Steffens, Water Quality Planning Bureau Chief, DEQ	Date

Signatures on file

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Although the WQPB follows this SOP in most cases, there may be situations where an alternative methodology, procedure, or process is used to meet specific project objectives. In such cases, the project manager is responsible for documenting deviations from these procedures in the Quality Assurance Project Plans (QAPPs), Sampling and Analysis Plans (SAPs), and end of project summary reports.

Document Revision and Version History

Revision Date	Version number	Summary of change(s)	Revised sections(s)	Revised by
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Acronyms

ADP	Acoustic Doppler Profiler
DEQ	Montana Department of Environmental Quality
DNRC	Department of Natural Resources
DSR	Digital Stage Recorder
FPA	Fixed Period Average
GPS	Global Positioning System
LWE	Left Water's Edge
MBMG	Montana Bureau of Mines and Geology
PT	Pressure Transducer
QAPP	Quality Assurance Project Plan
RWE	Right Water's Edge
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
SWAMP	Surface Water Assessment and Monitoring Program
USGS	United States Geological Survey
WQPB	Water Quality Planning Bureau

1.0 PURPOSE

This document describes the Montana Department of Environmental Quality (DEQ) Water Quality Planning Bureau (WQPB) Standard Operating Procedure (SOP) for measuring stream depth and velocity and calculating total discharge. Discharge is the volume of water that passes through a channel cross-section at a point in time, usually expressed in cubic feet per second or cubic meters per second. Some methods apply only to wadable streams and rivers, and other methods can be applied to unwadeable conditions such as during runoff, flooding, or on large rivers (Flynn and Suplee, 2010). Some types of dataloggers and stage-discharge rating curves are also discussed in this document.

2.0 APPLICABILITY

Total discharge data are useful for many water quality investigations. Projects may use discharge data to help interpret water quality data as it pertains to seasonality, floods, and droughts, total maximum daily load development, and hydrologic models. Depending on the scope of the project the data may either be instantaneous or continuous method.

If the waterbody is wadable, the following methods may be applicable:

1. Flow Meter Method (i.e. Hach Marsh McBirney and OTT MF Pro meters) (**Section 10.1**)
2. Float Method (**Section 10.2**)
3. Visual Estimation Method (**Section 10.3**)

If the waterbody is unwadeable (e.g., during high flow conditions or for large rivers), the following methods may be applicable:

1. Float Method (**Section 10.2**)
2. Gage Method (if available) (**Section 10.4**)
3. Acoustic Doppler Profiler (ADP) for open channels (i.e. Sontek RiverSurveyor M9) (**Section 10.5**; DEQ, 2014)

If short term continuous discharge is needed, water level dataloggers such as pressure transducers (PTs) or digital stage recorders (DSRs), can be installed to regularly record water depth throughout the period of deployment to approximate the hydrograph. Then, instantaneous measurements are periodically collected using a flow meter or an ADP, and a stage-discharge rating curve is developed to relate water depth to water discharge (**Section 10.6**).

NOTE: Any reference to specific equipment, manufacturer, or supplies is for descriptive purposes only and does not constitute an endorsement of a particular product or service by the author or by DEQ.

3.0 METHOD SUMMARY

Total discharge should be measured or calculated after chemical and biological information has been collected at a site to minimize disturbance (Makarowski, 2020).

Table 1: Discharge methods and descriptions

Method	Description
Flow Meter Method	A meter with a top setting rod is used to record velocity and depth at even intervals on a cross-section.
Float Method	A reach is identified and the reach length is measured. The average area of a cross section is measured or estimated, an organic object is tossed into the stream and the time it takes to travel the reach is timed to calculate velocity, total discharge is calculated, and a correction coefficient is applied.
Visual Estimation Method	Discharge is visually estimated by field personnel in the field.
Gage Method	Total discharge data is retrieved from a hydrologic gaging network online.
Acoustic Doppler Profiler (open channel) Method	A device that calculates total discharge by measuring water depth and velocity by measuring the doppler shift or change in acoustic signals being reflected off the particles in the water across a cross-section.
Water Level Dataloggers and Rating Curves Method	A datalogger that continuously measures water depth levels is installed at a site and periodic discharge meter measurements are collected to correlate water depth to discharge through a rating curve.

After total discharge has been measured, calculated, or estimated in the field, the total discharge value must be recorded on the Site Visit Form (**Section 11**). If needed, additional calculations in the office are completed and recorded before the Site Visit Form is scanned.

4.0 DEFINITIONS

Acoustic Doppler Profiler: An instrument that measures depth and velocity by creating a profile with a doppler shift.

Capillary action: The way liquid moves through a porous space.

Digital Stage Recorders: An instrument that uses capillary action and temperature data to determine a stream’s stage.

Discharge: The volume of water that passes through a channel cross-section at a point in time. Units are either cubic feet per second (cfs) or cubic meter per second (cms).

Doppler Shift: The change in sound frequency as the signals reflect off particles in the water

Flow Meter: An instrument that measures water velocity

Thalweg: The deepest location in a stream cross section.

Pressure Transducers: An instrument that uses barometric pressure and water density to determine a stream’s stage

Rating Curve: A graphed curve that shows the relationship between a streams discharge and stage.

Stream Stage: The height of water in a stream.

Water’s Edge: The left and right water’s edge is determined by facing downstream.

Velocity: The speed of the water in a channel. Units are either feet per second or meters per second.

5.0 Health and Safety Warnings

Field personnel should be aware of job hazards associated with collecting total discharge data that could result in personal injury or loss of life. Driving, boating, wading, and tool use safety are especially pertinent to the procedures contained in this SOP. Personnel should be aware of unstable banks, loose substrate, and swift currents when wading and standing in running water. DEQ field personnel should review and sign the Water Quality Division Job Hazard and Analysis form and review the Waterborne Operations Procedure (DEQ, 2016) before collecting data.

Stilling Well Installation
When installing a water level datalogger stilling well, the field personnel crew should consist of at least two persons. The minimum personal protective equipment requirement for each member involved with installation must consist of hard hat, safety glasses, ear protection, and heavy gloves. Waders are often required although steel toed boots may be worn at the discretion of the members when installing a stilling well. Working with heavy pipe and post-pounders from an elevated position (e.g. on a ladder) upon potentially mobile substrates in flowing water poses a unique and continuous safety risk. Pounding the stilling well into the substrate generates loud noise as well as strong vibration of the pounding device.

6.0 Cautions

Field personnel must be cautious when using equipment around water. Water may damage electronics if seals are damaged or left open. Do not allow any equipment to be washed downstream. Maintain appropriate equipment care and maintenance (e.g., battery removal and replacement, sensor cleanings, firmware updates, o-ring or other seal replacement).

Installed batteries should be removed from meters when not being used for an extended period of time (3+ months) to avoid damaging the housing or circuitry.

The same units (feet or meters) must be used throughout the data collection process for velocity readings, depth readings, and tape measurements during a sampling event.

Reference staff gages may be installed near or attached to a water level datalogger stilling well. If the gage is attached to the stilling well, any undesirable circumstances (e.g., shifting of the stilling well within the substrate) may affect the staff gage as well (Amman, 2004).

7.0 Interferences

Field personnel should choose a site with an even laminar flow (i.e., runs or glides) when collecting total discharge data. Avoid uneven flow locations (e.g., pools, riffles, and bends), obstructions (e.g., log jams, vegetation) and undercut banks (**Section 10.1**).

The discharge-stage rating curve may be used to extrapolate stream discharges outside the range of manually measured flows. Low flow extrapolation may be performed using the rating curve; however, there is no assurance that such values will be accurate. High flow extrapolation has greater limitations than low flow extrapolation. Prior to conducting high flow extrapolation, an attempt should be made to determine peak discharge using one of the indirect methods described in Chapter 9 of Rantz et al. (1982).

When using an Acoustic Doppler Profiler (ADP), avoid locations having strong local magnetic fields (in comparison to the Earth's magnetic field). Large steel structures, such as overhead truss bridges or power lines are a common source for these large local magnetic fields and may result in ADP compass errors (DEQ, 2014).

NOTE: For more information about the interferences that may occur when using an ADP, read the appropriate SOP (DEQ, 2014).

8.0 Personnel Qualifications/Responsibilities

Field personnel must be trained by experienced personnel and must demonstrate proficiency in all applicable field protocols as described in this SOP before collecting data in the field. Training should be repeated as necessary when using an ADP.

9.0 Equipment and Supplies

Equipment and supply lists vary for the type of method. Always make sure that field personnel have all required items before following procedures in **Section 10**.

9.1 Flow Meter Method

- ❑ Flow meter (i.e. Marsh McBirney, MF Pro…etc.)
- ❑ Sensor attachment (if applicable)
- ❑ Case
- ❑ Top setting wading rod
- ❑ Measuring tape (10^{th} ft. or m. see Project SAP)
- ❑ Bank pins
- ❑ Screwdriver (if applicable, for changing batteries)
- ❑ Applicable power source
    - o Spare batteries (Marsh McBirney requires 2 D alkaline batteries)
    - o Charger cable (MF Pro)

9.2 Float Method

- ❑ Flagging
- ❑ Field tape
- ❑ Bank pin
- ❑ Range finder
- ❑ Biodegradable floating objects (i.e., oranges or sticks)
- ❑ Stopwatch (seconds)

9.3 Estimation and Online Gage Methods

No equipment or supplies are needed for the estimation method, but it is helpful if the field personnel understand what a reasonable discharge value may be based on estimated stream volume and velocity.

No equipment or supplies are needed for the online gage method, but it is helpful to know if a discharge gage is near the site and the gage number.

9.4 ADP Method (DEQ, 2014)

- ❑ Field computer (Dell Toughbook) with RiverSurveyor Live PC installed, charger and power invertor
- ❑ Pirani Bluetooth Dongle (in ADP pelican case)
- ❑ Handheld PDA as backup for field computer (procedures for using the personal digital assistant (PDA) are not described in this SOP)
- ❑ ADP System (1 large pelican case) including all cables, connections, PCM, GPS antenna, batteries, and survey tripod
- ❑ Base Station (1 large pelican case) all cables, connections, PCM, GPS antenna and batteries
- ❑ Hydroboard
- ❑ Tether Rope (plus backup) with carabineer clip (plus backup)
- ❑ Five-gallon bucket (to store tether rope)
- ❑ Sea anchor (modified for use in rivers)
- ❑ Flagging
- ❑ Walkie Talkies
- ❑ Safety Cones
- ❑ Lifejackets
- ❑ Waders
- ❑ Field Measurement Forms
- ❑ Jetboat (for manned boat measurements)
- ❑ Boom assembly (for manned boat measurements)
- ❑ Kayak or other small boat for emergency retrieval during bridge measurements

9.5 Water Level Datalogger Method (DEQ, 2010)

- ❑ Stilling well – 2-inch diameter galvanized pipe with a solid welded point
- ❑ Black pipe cap with 5/8-inch holes for security bolt
- ❑ 4-inch long (1/2-inch diameter) security bolt with pre-drilled lock hole
- ❑ All-weather padlock and key
- ❑ Heavy wire or wire clothes hanger
- ❑ Roll Pins – stainless steel (1/4-inch diameter by 3 inches long)
- ❑ Self-tapping or sheet metal screws – stainless steel
- ❑ Permanent marker
- ❑ Heavy duty post pounder
- ❑ Screw drivers
- ❑ Level
- ❑ Gloves
- ❑ Waders
- ❑ Hardhat

- ❑ Tape measure
- ❑ Vice grips
- ❑ Hammer
- ❑ Wire cutter
- ❑ Cordless drill, batteries and bits (1/2-inch drill works best)
- ❑ Pipe cutter
- ❑ 6-foot ladder
- ❑ Water level recorder, communications cable, laptop or palmtop computer
- ❑ Flowmeter and associated equipment

10.0 PROCEDURAL STEPS

Site locations where discharge measurements are required will be specified in the project SAP, but the field personnel on site may need to determine which discharge method is most suitable at the site (if not already specified in the SAP) and will need to choose a specific location where to collect discharge data (e.g., set up a cross section, implement the float method). Below outlines a rudimentary guideline for collecting total discharge measurements:

1. Choose a location
2. Determine method
3. Collect measurements
4. Record information

10.1 SELECTING A LOCATION TO MEASURE DISCHARGE

A cross-section for a flow meter should be:

- In a straight reach with laminar flow (e.g., a glide)
- Free of undercut banks and physical obstructions (e.g., boulders, tree snags or submerged vegetation, pipes, inflowing or out flowing side channels or tributaries, other obstructions)
- Free of flow modifications (i.e., swirls, eddies, vortices, backward flow, and dead zones)
- Avoid areas downstream of sharp bends, upstream or downstream of vertical drops or where stream empties into a stationary body of water

When using the float method, stream reaches should meet the same criteria and should also measure at least twice the mean wetted width (≥50 ft.) in length.

NOTE: Use best professional judgment in choosing the best site when all the above criteria do not exist.

10.2 FLOW METER METHOD

The flow meter method is a common instantaneous method to determine total discharge of a wadeable stream. A representative cross section is determined and divided into equidistant sections so that no section contains more than 10% of flow. For narrow streams, 10-15 points may be sufficient and for wider streams, 20-30 points may be necessary. A flow meter with top setting rod can only be used in streams that have sufficient water depth to reliably use the instrument (≥0.2 in).

See **Appendix C** for what settings are needed to collect flow data for different types of flow meters.

A top setting wading rod is used in conjunction with a flow meter to determine the depth and velocity of a given water profile, from the stream bottom to the water surface. Velocity is either recorded automatically by the flow meter or manually by field personnel on a Total Discharge Form (**Appendix A**). Typically, if measurements are recorded by the meter, total discharge is also calculated by the meter at the end of the collection and recorded directly onto the Site Visit Form before leaving the site. If measurements are recorded by field personnel on a form, total discharge must be calculated in the office, then recorded on the Site Visit Form (**Section 11**).

NOTE: If recording on a form, it may be helpful to have a team of two: one person to measure the depth and velocity and the other to record the information on the form.

10.2.1 Collecting Depth and Velocity Data

After selecting a location at the site (**Section 10.1**) use a field measuring tape to set up a cross-section:

- Stretch the tape across the cross-section perpendicular to flow from left water's edge to right water's edge.
- Use bank pins or stakes to secure the ends of the tape in place.
- Make sure the tape is taught and not sagging.

NOTE: It is acceptable to extend the tape beyond the water's edge on either bank to allow for ease of securing the tape.

Depth and velocity will be measured at equidistant points on the cross-section from left water's edge to right water's edge (determined facing upstream) and recorded either by the meter or by field personnel on a form. The measured distances, depth, and velocity are used to calculate discharge of each section of the cross-section, and section discharges are added together to determine the total discharge.

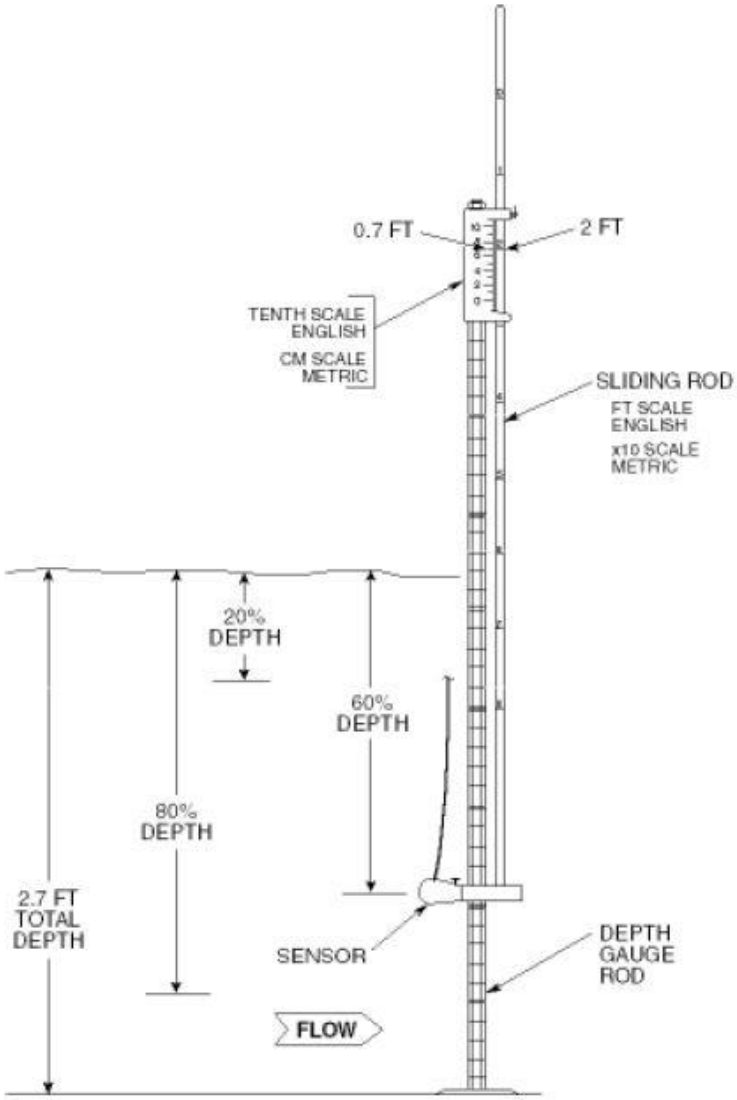

Figure 1: Top setting wading rod and depths (Marsh-McBirney, 1990)

The procedure is the same for all meters that require distances, depths, and velocity to be recorded on a Total Discharge Form:

1. Determine the wetted width of the cross-section from the tape.

2. Determine the distance between the points of measurement to the nearest tenth of a foot/meter:
   - For narrow streams, divide the wetted width by 10-15
   - For wide streams, divide the wetted width by 20-30

NOTE: No individual section should contain more than 10% of the total discharge (OTT Hydromet, 2015). If it appears that greater than 10% of the total discharge is passing through any individual section of the cross-section, either:

- Divide the wetted width by a larger number to produce more points where measurements are collected across the cross-section (preferred if measurements have not begun yet), or

- Add additional measurement points within the section of the cross-section that has proportionally more flow (preferred if measurements are already in progress and recording on a form).

3. Record the locations of the points of measurement on the Total Discharge Form before collecting the data (if applicable).

4. Attach the flow meter sensor to the top-setting wading rod and securely fasten the set screw. Adjust meter settings, as needed (**Appendix C**).

5. At each measurement point along the tape, position the base of the wading rod on the channel substrate, stand downstream and at least 18” off to the side of the rod to avoid disrupting the flow measurement, and hold the wading rod upright at approximately an arm’s length.

NOTE: Avoid pushing the base of the top setting rod into the stream bed when measuring flow in streams with soft substrate.

6. Measure water depth using the depth gage rod of the top-setting wading rod and record on the form. Top setting rods have graduated markings to note the depth. Single marks are 0.1 ft., double marks are 0.5 ft., and triple marks are 1.0 ft.

7. Position the sensor at the desired height. **Figure 1** illustrates the set up for a top setting wading rod and sensor:
   - If the depth is less than 2.5 ft., position the sensor at 60% depth from the water surface. To set the sensor at 60% depth, adjust the sliding rod to line up the foot scale with the tenth scale on top of the depth gage rod. For example, if the water depth is 1.7 ft., line up the “1” on the sliding rod with the “7” on the tenth scale on top of the depth gage rod.If the depth is greater than 2.5 ft., measurements will have to be collected at 20 and 80% depths from the water surface and averaged to determine the water’s velocity at that point (Harrelson et al, 1994). To set the sensor at 20% depth, <u>multiply</u> the total depth by 2 and move the sliding rod to that value (Marsh-McBirney, 1990). To set the sensor at 80% depth, <u>divide</u> the total depth by 2 and move the sliding rode to that value (Marsh-McBirney, 1990).

8. Position the sensor so that it is facing perpendicularly into the flow.

9. Once in position, begin a new fixed-point averaging interval, wait for 30 seconds, and record the velocity reading on the form or in the meter. See **Appendix C** on how to set the fixed-point averaging intervals.

NOTE: At left water’s edge and right water’s edge (the initial and final points of measurement, respectively) the depth and velocity will each be recorded as “0” and noted as either “LWE” or “RWE” in the notes column on the Total Discharge Form.

10. Repeat at each measurement point along the tape.

These steps may differ if a discharge calculating flow meter is used. See **Appendix B** on how to enter data into the OTT MF Pro Flow meter.

10.3 Float Method

The float method is often used when the flow meter method cannot be used (e.g., unwadeable, high flow conditions, or meter is unavailable) and when there is no gage station nearby. A uniform reach of the stream is identified and the average cross-sectional area of the reach is estimated. A small stick or other biodegradable floating object is tossed into the stream and is timed to determine how long it takes the object to traverse the stream reach length to determine the velocity. Cross-sectional area (width and depth) is then multiplied by velocity with a coefficient to determine total discharge.

NOTE: This semi-quantitative method tends to overestimate the flow due to higher velocity near the surface. A velocity adjustment coefficient (0.85) is used to reduce the likelihood of overestimates.

10.3.1 Collecting Data

1. Identify the stream reach to be measured (criteria described in **Section 10.1**). Mark the start and end of the reach with flagging or by driving a bank pin into the ground.

2. Determine the mean wetted width (ft or m) and record it on the Total Discharge Form:
   - Measure at least 3 cross sections throughout the reach with a field tape (if wadable),
   - Measure at least 3 cross sections throughout the reach with a range finder, or
   - Make a visual estimation

3. Determine the mean water depth (ft or m) and record it on the Total Discharge Form:
   - Measure multiple points throughout the reach (if wadable), or
   - Make a visual estimation

4. Determine the total reach length (ft or m) using a tape; follow the curvature of the channel.

5. Determine the water surface velocity:
   - Toss a small stick or other biodegradable floating object (e.g.., an orange) upstream of the first marker into the thalweg.
   - Begin timing with a watch or stopwatch (in seconds) when the object passes the upstream marker.
   - Stop timing when the object reaches the downstream marker.
   - Record the float time on the Total Discharge Form.
   - Complete three measurable floats.

NOTE: Make sure that the object is heavy enough to stay in the main current and travels through the reach without obstructions or snags. If it does not, repeat the measurement.

6. Complete the following calculations on the Total Discharge Form:
   - **Cross-sectional area** (ft^2 or m^2) = Mean width **x** Mean depth
   - **Average float time** (sec) = (Float time 1 **+** Float time 2 **+** Float time 3) **/** 3
   - **Float velocity** (ft/sec or m/s) = (Reach Length **/** Average float time)
   - **Discharge** (ft^3/sec or m^3/sec) = Cross-sectional area **x** Float velocity

- **Adjusted Discharge** (ft^3/sec or m^3/sec) = Discharge **x** 0.85

7. Record the adjusted discharge on the Site Visit Form.

10.4 Estimation Method

The estimated flow method should only be used on very small streams that will not support the use of the flow meter method or the float method. The field personnel measures or estimates the width, depth, and average velocity of a channel cross section and calculates the total discharge in the field.

10.4.1 Collecting Data

After selecting a location at the site (**Section 10.1**) and determining a cross section, the field personnel is to estimate or measure the following and complete the calculation in the field. The recorded value for discharge ft^3/sec or m^3/sec) must be a single value and not a range.

- **Estimate or measure wetted width** (ft or m)
- **Estimate or measure mean depth** (ft or m)
- **Estimate velocity** (ft/sec or m/sec)
- **Calculate discharge** (ft^3/sec or m^3/sec) = Width **x** Depth **x** Velocity

Record the calculated discharge on the Site Visit Form.

Field personnel are encouraged to include remarks about the flow in the summary section. Field personnel can improve accuracy of estimates by:

- Practice guessing what the discharge will be at a site where the flow meter method is used and comparing guesses to the calculated value
- Timing the filling of a known volume (e.g., to measure a trickle out of a culvert)
- Taking measurements whenever possible (e.g., measure actual width and mean depth in small streams rather than estimating)

10.5 Online Gage Method

Other organizations such as the US Geological Survey (USGS), the Montana Bureau of Mines and Geology (MBMG) along with the Department of Natural Resources and Conservation (DNRC) collect real time discharge data in the state of Montana along some waterbodies of interest. If a project is relying on discharge data from a gage at or near a monitoring site, the project manager should:

1. Verify that the gage is operating during the projects timeframe,
2. Note in the project SAP which gage it is (gage number and name) is applicable to which sites, and
3. Notify field personnel that the gage exists before the field personnel visits the monitoring site.

10.5.1 USGS gage

To locate a USGS gage:

- Visit https://waterdata.usgs.gov/mt/nwis/rt
- Either select a site on the “Daily Streamflow Conditions” map, or go to the “Current Streamflow Conditions Table” to select a site.
- Once a site is selected, the USGS gage number, and station name are listed.

- The location of the gage is available through the “Location map” under the “Available data for this site” pulldown.

To determine the discharge at a certain date and time:

- Go to the desired USGS gage page.
- Select at a minimum “Discharge” from the Available Parameters, and “Table” for the Output format.
- Select a date range that will include the date of the site visit.
- Locate the closest date and time listed on the Site Visit Form under the Field Measurements section.
- Record the discharge.

NOTE: As of February 2019, the USGS has their “Next Generation” gage station webpages in development.

10.5.2 SWAMP Network

To locate a MBMG/DNRC Surface Water Assessment and Monitoring Program (SWAMP) Station:

- Visit http://mbmg.mtech.edu/swamp/
- Select Web Mapping Application or Stream Gauge Listing.
- Once a site is selected, view the report.
- The location of the station is listed on the web page.

To determine the discharge at a certain date and time:

- Go to the desired SWAMP station
- Select a date range that will include the date of the site visit
- Download the data.
- Locate the closest date and time listed on the Site Visit Form under the Field Measurements section.
- Record the discharge.

See **Section 11** for how to record discharge from a gage on the Site Visit Form.

10.6 Acoustic Doppler Profiler (ADP) Method

An acoustic doppler profiler is a datalogger that uses sound frequency to determine the velocity of particles in the water and area of the cross section to determine the discharge of the waterbody. For more information about ADPs and instructions for use, see the Acoustic Doppler Profiler (ADP) SOP (DEQ, 2014).

10.7 Water Level Dataloggers and Rating Curve Method

There are multiple types of water level dataloggers that measure fluctuating water surface elevation. Digital stage recorders (DSRs), such as AquaRod and TruTrack instruments, record water stage using capillary action and temperature data. Pressure transducers (PTs), such as HOBO U20-001, use barometric pressure and water density (normally calculated from water temperature) to determine water stage.

All water level dataloggers need a reference point or reference staff gage to give context to the total water depth and the datalogger reading. It is critical for the reference point or staff gage to be secured. Any shift in the original placement will directly affect the stage-discharge rating curve. If the staff gage is attached to the stilling well, any undesirable circumstances (e.g. shifting of the stilling well within the substrate) may affect the staff gage as well (Amman, 2004). The stilling well designs discussed in this SOP do not prevent fine sediment from being deposited into the well. At the time of the datalogger's routine inspection, the datalogger should be removed and any fine sediment should be flushed out of the well by repeatedly pouring water into the stilling well using a bucket.

Figure 2: Reference Staff gage and stilling well deployed in field (Big Pipestone Creek, 2010)

When deploying any datalogger, a Continuous Datalogger Form must be filled out and attached to the Site Visit Form (**Appendix A**).

10.7.1 Choosing a Location and a Deployment Site

Water level dataloggers should be deployed on a section of a waterbody where the stage-discharge relationship is relatively constant (Rantz, *et al*. 1982). An ideal monitoring location will have both section and channel controls:

- A section control occurs where a break in slope or reduction in channel geometry downstream of the monitoring site regulates low flow stage.
- A channel control occurs where channel morphology (i.e., the combination of size, slope, roughness, alignment, constrictions and expansions, and shape of the channel) dictates the stage-discharge relationship at high flows.

Most natural channels have compound controls, that is, section controls at low flow and channel controls at high flows (Rantz, *et al*. 1982). Note that reach-scale channel gradient and the length of reach under channel control are generally negatively correlated (Rantz, *et al*. 1982).

The hydraulic controls downstream of the site should be both stable and sensitive (Rantz, *et al*. 1982). A stable control is unlikely to change over the course of deployment, meaning that the stage-discharge relationship will likely remain constant. A sensitive control shows a closer relationship between the water depth per unit increase of stream discharge. An unstable control may change the stage-discharge relationship over the course of deployment, such as:

- A natural accumulation of wood downstream where wood may aggrade or degrade under varying flows
- An adjustable man-made flow control structure such as an irrigation head gate used to manually control flows.

Choose a site along the section that satisfies the following criteria (Rantz, *et al*. 1982):

- The channel is generally straight for approximately 100m up- and downstream from the site.
- The total flow is confined to one channel at all stages and no flow bypasses the site as subsurface flow.
- The streambed is not subject to scour and fill and is free of aquatic growth.
- Banks are permanent, high enough to contain floods, and are free of brush.
- Unchanging natural controls are present (e.g., a bedrock outcrop or other stable riffle for low flow and a channel constriction for high flow, or a falls or cascade that is un-submerged at all stages).
- A pool is present upstream from the hydraulic control to ensure recording of stage at extremely low flow and to minimize the effects of high water velocities on the instrumentation.
- The gage site is far enough upstream from the confluence with another stream or lake inlet to avoid a variable back water influence upon stage.
- A satisfactory reach for measuring discharge at all stages is available within reasonable proximity of the gage site (it is not necessary that low and high flows be measured at the same stream cross section).
- The site is readily accessible for ease in installation and operation of the instrumentation.

10.7.2 Digital Stage Recorders

Digital stage recorders (DSRs) such as AquaRod and Trutrack instruments are deployed in a stilling well and measure water height through capillary action. A reference staff gage is installed either nearby or attached to the stilling well. This is needed to correlate any recorded manual water level observations to the DSR water level readings (Amman, 2004). The staff gage should be graduated in tenths and hundredths of feet and should be at least 3.33 feet (Amman, 2004).

Follow the calibration and maintenance procedures (if applicable) described in the appropriate equipment manual. Different models of DSRs will require different user and manufacture calibration and maintenance. Most DSRs should be kept clean as biofouling may interfere with the sensors ability to measure water depth. Handle DSRs with care as equipment may be damaged or calibration accuracy may decrease if dropped or jolted.

10.7.3 Pressure Transducers

Pressure transducers (PTs) such as HOBO U20 dataloggers are deployed in a stilling well and measure the absolute pressure at that point. If deployed below the water surface, the datalogger will record the atmospheric pressure plus water head pressure. It is recommended to deploy a second PT above the water surface to record the atmospheric pressure. The difference between those two datalogger readings determine the water head which is then used to calculate water depth. A reference point will also assist in compensating for water depth (Onset, 2018):

- If the reference point is above the datalogger (i.e., top of stilling well), record the water level as a negative number.

- If the reference point is below the datalogger (i.e., stream bed), record the water level as a positive number.
- Wait 20 min for temperature equalization before reading and recording the reference point.
- Record the date and time the reference point was determined; this information may be needed for data compensation later.

NOTE: To correct water level data for barometric pressure with the HOBO U20 dataloggers, see the HOBOware Pro Barometric Compensation Assistant User's guide (Onset, 2017).

Follow the calibration and maintenance procedures (if applicable) described in the appropriate equipment manual. Some PTs do not allow for user calibration or battery replacement. Most PTs should be cleaned, as biofouling may disrupt pressure sensory accuracy. Handle PTs with care as calibration accuracy may decrease if dropped or jolted.

10.7.4 Stilling Wells

It is important to install water level dataloggers into stilling wells to protect from wind and water turbulence (Rantz, *et al*., 1982). Stilling wells will also protect the datalogger from other weather conditions.

The DSR stilling well design is based off the Montana DNRC design for AquaRod digital stage recorders (Amman, 2004). See **Appendix D** for DSR stilling well specifications and installation instructions. The PT stilling well design is based off the Onset Corp. recommendations for the U20-001 series dataloggers (Onset, 2018). Additional technical notes are available on the Onset website to assist in PT stilling well construction.

10.7.5 Stage-Discharge Rating Curve

To develop a rating curve, instantaneous total discharge will need to be collected throughout the time of datalogger deployment. Create a stage-discharge relationship by plotting the in-situ stream discharge against the stage readings (DEQ, 2010).

For most natural channels, the rating-curve should approximate a power-function (i.e. linear with log-log transformation) which relates gage height to discharge and subsequently can be used to create a hydrograph for the period of observation by converting each in-situ stage measurement into an estimate discharge (DEQ, 2010).

NOTE: A hydrograph developed from this process that is based on one or two years of discharge data is of limited reliability in the estimation of future discharge parameters given that stream flow is highly variable from year to year (DEQ, 2010).

The accuracy and precision of a rating curve depends primarily upon (DEQ, 2010):

- the inherent stability and sensitivity of the channel under the range of flows,
- the selection of an appropriate monitoring site,
- the number of years that the monitoring is conducted,
- the number of manual discharge measurements performed each year, and
- the range of flows over which discharge measurements are performed.

11.0 Data and Records Management

All hardcopy documentation of the data, such as completed Site Visit Forms, Total Discharge Forms, and Continuous Datalogger Forms are kept and maintained by the Water Quality Planning Bureau (WQPB). Data collected will be reviewed, verified, and stored based on the WQPB Quality Control and Quality Assurance procedures (**Section 12.0**) and the Quality Assurance Project Plan (QAPP) for the project.

All calibrations, checks, and maintenance are to be recorded in the Maintenance/Calibration Log Book.

11.1 Recording on Site Visit Form

The method that is used to collect total discharge will need to be indicated on the Site Visit Form under the Field Measurement section. An example of a Site Visit Form is available in **Appendix A**.

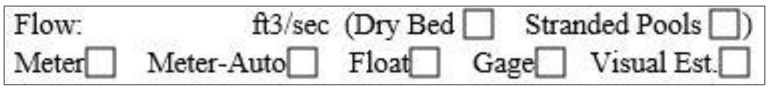
Flow: ft3/sec (Dry Bed ☐ Stranded Pools ☐)
Meter ☐ Meter-Auto ☐ Float ☐ Gage ☐ Visual Est. ☐

Figure 3. The discharge portion of the Field Measurement section

- If flow is calculated or estimated in the field, record the total discharge at the site
- If flow is 0 ft^3/s then indicate if that is because the stream bed is dry or is made up of stranded pools
- If the flow meter method without field calculations is used check the “Meter” box
- If the flow meter method with field calculations is used check the “Meter-Auto” box
- If the float method is used check the “Float” box
- If the visual estimation method is used check the “Visual Est.” box.
- If there is a discharge gage at the site check the “Gage” box
- If the ADP is used check the “Meter-Auto” box

If a Total Discharge Form was filled out for the flow meter method or float method, check the “Total Discharge” box under the Field Assessment section.

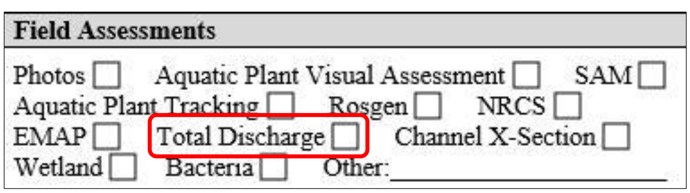
Field Assessments
Photos ☐ Aquatic Plant Visual Assessment ☐ SAM ☐
Aquatic Plant Tracking ☐ Rosgen ☐ NRCS ☐
EMAP ☐ Total Discharge ☐ Channel X-Section ☐
Wetland ☐ Bacteria ☐ Other:____________

Figure 4 The Field Assessments section

11.2 Discharge Calculations

All discharge calculations or estimates that are done in the field (Float and Estimation Methods) must be recorded on the Site Visit Form before leaving the site.

Any discharge calculations that are not done in the field (Flow Meter Method with a Total Discharge Form) must be performed in the office and the results recorded on the Site Visit Form before the field forms (e.g., Site Visit Form and Total Discharge Form) are filed. The location of a spreadsheet that calculates the discharge of a cross-section is available in **Appendix A**.

11.3 Continuous Datalogger Form

Field personnel are to fill out a Continuous Datalogger Form (**Appendix A)** whenever a datalogger is deployed. Include the same Site Visit Code from the Site Visit Form used at the deployment along with the correct Project ID. The sampling medium, interval, datalogger make/model, and serial number must be recorded. It is important to record the Launch Date and Time (when the datalogger began logging) and the Deployment Date and Time (when the datalogger is collecting field data). The Latitude and Longitude should be of where the datalogger was deployed. This location may be different than what is listed on the Site Visit Form. Field personnel are to describe any key information about the dataloggers deployed location and draw a map to assist in the retrieval.

A photocopy of the deployed Continuous Datalogger Field Form must be made to take into the field for the datalogger retrieval. Additional information at the bottom of the form is to be filled out when the datalogger is retrieved. Including the retrieval Site Visit Code, date/time, comment, and file name if given.

Field personnel are encouraged to elaborate about the retrieval condition on the Site Visit Form summary section and take pictures of the datalogger at the time of retrieval.

11.4 Maintenance/Calibration Log Book

Field meters should have a water-resistant Calibration/Maintenance Log Book dedicated to that meter. Each log book must include the Manufacturer, Model, and Serial Number of the meter to distinguish it from other meter's log books. All maintenance (i.e., battery replacement, charging, cleaning) and zero checks must be recorded in the equipment's log book.
Each entry in the log book must include:

- Who did it (personnel must initial),
- When it was done (date),
- What was done (i.e. zero check, battery replacement, repairs, cleanings, and any corrective actions),
- Any relevant information (e.g. batteries leaked and damaged circuitry)

12.0 Quality Control and Quality Assurance

It is the responsibility of field personnel to collect good and accurate data at the time of collection, to fill out forms properly, and to record information correctly.

All equipment users must be familiar with the equipment and be able to troubleshoot common problems in the field. Routine inspections and repairs (or notification of need for repair) are necessary to ensure quality of collected data. It is up to the user to be thorough with observations and quick with repairs or notifications. Otherwise, loss of data may occur.

Equipment must be checked and verified before field use. Velocity meters should be calibrated or "zero checked" in a bucket of standing water. See the appropriate user manual on how to perform a calibration or zero check.

13.0 References

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APPENDIX A – FIELD FORMS

The following forms are included in this appendix:

- Total Discharge Calculation Spreadsheet
- Site Visit Form Example (Front) (**NOTE**: DEQ modifies this form to meet project-specific needs)
- Total Discharge Form (Front and Back)
- Continuous Datalogger Form (Front) for Digital Stage Recorder and Pressure Transducer dataloggers

TOTAL DISCHARGE CALCULATION SPREADSHEET

An Excel spreadsheet template is available for DEQ staff here.

If a flow meter and Total Discharge Form were used in the field (**Section 10.2**), the total discharge for the channel will need to be calculated before the SVF is processed. The information recorded on the Total Discharge Form is to be entered into the spreadsheet. The final Total Discharge result is to be recorded on the Site Visit Form, and the spreadsheet is to be saved with the following name convention:

Waterbody_StationID_YYMMDD_(SiteVisitCode)_FLOW

	A	B	C	D	E	F	G	H	I	J	K
1		CHANNEL DISCHARGE									
2		Date:			Site Visit Code:		Station ID:				
3		Waterbody:			Location:						
4		Personnel:								Conversion Tool	
5		Distance from initial point (ft)	Depth (ft)	Velocity (ft/sec)	Width (ft)	Area (ft^2)	Discharge (ft^3/sec)	Notes		Feet	Meters
6	1				0.00	0.00	0.00	LWE		0	0.00
7	2				0.00	0.00	0.00			1	0.30
8	3				0.00	0.00	0.00			2	0.61
9	4				0.00	0.00	0.00			3	0.91
10	5				0.00	0.00	0.00			4	1.22
11	6				0.00	0.00	0.00			5	1.52
12	7				0.00	0.00	0.00			6	1.83
13	8				0.00	0.00	0.00			7	2.13
14	9				0.00	0.00	0.00			8	2.44
15	10				0.00	0.00	0.00			9	2.74
16	11				0.00	0.00	0.00			10	3.05
34											
35	29				0.00	0.00	0.00			28	8.53
36	30				0.00	0.00	0.00			29	8.84
37	31				0.00	0.00	0.00			30	9.14
38	32				0.00	0.00	0.00			40	12.19
39	33				0.00	0.00	0.00			50	15.24
40	34				0.00	0.00	0.00			60	18.29
41	35				0.00	0.00	0.00			70	21.34
42	36				0.00	0.00	0.00			80	24.38
43	37				0.00	0.00	0.00			90	27.43
44	38				0.00	0.00	0.00			100	30.48
45	39				0.00	0.00	0.00			328.1	100.0
46		Width Check (Pass/Error)	Mean Depth (ft)	Mean Velocity (ft/s)	Total Area (ft^2)		Total Discharge (ft^3/s)			1 foot = 0.3048 meters	
47		PASS	0.00	0.00	0.00		0.00			1 meter = 3.281 feet	

Figure 5: Discharge_Template screenshot example

This is an example Site Visit Form and gives a general idea of the format. Project-specific Site Visit Forms are created to reflect specific documentation requirements and project IDs.

Place Site Visit Label Here

Site Visit Form

Project ID:__________________

Date: __________ **Time:** __________ **Personnel:** ________________________

Waterbody:________________________ Location: ____________________

Station ID: __________ HUC: __________ County: __________ AUID: __________

Latitude: __ __ . __ __ __ __ __ __ Longitude: __ __ __ . __ __ __ __ __ __ Elevation: ________ ft m

Field Duplicate to ☐ Field Blank ☐ Trip Blank ☐ Field Equipment Blank ☐

Samples Collected		Sample ID	Sample Collection Information/Preservation
Water	☐		GRAB EWI BACT
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Sediment	☐		SED-1
Analysis:			Preserved: None Other:
Benthic Chl-a	☐		Sample Method: C=Core H=Hoop T=Template N=None
Composite at Lab ☐ AFDW ☐ Visual Est. <50 mg/m2 ☐			Sample Location: R=Right C=Center L=Left
Transect: A__-__ B__-__ C__-__ D__-__ E__-__			F__-__ G__-__ H__-__ I__-__ J__-__ K__-__
Phytoplankton Chl-a	☐		D1 Filtered:______mL D2 Filtered:______mL
Phytoplankton CNP	☐		CN Filtered:______mL P Filtered:______mL
Algae	☐		PERI-1-MOD PERI-1 OTHER:
Macroinvertebrates	☐		MAC-R-500 OTHER: # of Jars:

Field Measurements	Time: am pm	Field Assessments
Water Temp: °C °F	Air Temp: °C °F	Photos ☐ Aquatic Plant Visual Assessment ☐ SAM ☐
Bar. Pressure: mm/Hg	SC: uS/cm	Aquatic Plant Tracking ☐ Rosgen ☐ NRCS ☐
pH: DO: mg/L	Turbidity: NTU	EMAP ☐ Total Discharge ☐ Channel X-Section ☐
Turbidity: Clear ☐ Slight ☐ Turbid ☐ Opaque ☐		Wetland ☐ Bacteria ☐ Other:
Flow: ft3/sec (Dry Bed ☐ Stranded Pools ☐)		Only Transect F ☐ Total Site Length______m
Meter ☐ Meter-Auto ☐ Float ☐ Gage ☐ Visual Est. ☐		Transect Length_____m Average Wetted Width_____m

Data Loggers	
	Temperature ☐ YSI ☐ MiniDOT ☐ EC ☐ TruTrack ☐ AquaRod ☐ Weather Station ☐
	Deployed ☐ Cleaned/Checked ☐ Retrieved ☐

Chemistry Lab Information		
Lab Samples Submitted to:	Account #:	Term Contract Number:
Invoice Contact:		
Contact Name & Phone:		EDD ☒ Format: MT-eWQX Compatible
1) Relinquished By & Date/Time:	1) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	1) Received By & Date/Time:
2) Relinquished By & Date/Time:	2) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	2) Received By & Date/Time:

Lab Use Only - Delivery Temperature: Wet Ice_____°C Dry Ice_____°C Rev. 3/6/2019

Place Site Visit Label Here

Total Discharge – Flow Meter

Date: ________________ **Personnel:** ____

Waterbody: ____

Reach: EMAP layout **Nearest Transect (A-K):** ________________ **Averaging Interval:** ________________

** circle units used **

	Distance from initial point (ft) or (m)	Depth (ft) or (m)	Velocity (ft/sec) or (m/sec)	Comments (Record LWE and RWE)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				

Total Discharge = cfs

Place Site Visit Label Here

Total Discharge – Float Method

Date: ________________ **Personnel:** ____

Waterbody: ____

Nearest Transect (A-K): ____________________

Data Collected	
Average width: ________ (ft) or (m) Average depth: (ft) or (m) Longitudinal Distance: ________ (ft) or (m)	Travel time 1: seconds Travel time 2: seconds Travel time 3: seconds

**** circle units used ****

Comments:____

Discharge calculations
Channel area = Average width x Average depth **Channel area = x = (ft^2) or (m^2)**
Average travel time= (Sum of Travel times 1, 2, and 3) / 3 **Average travel time= (________ + ________ + ________) / 3 = ________ seconds**
Velocity = Longitudinal distance ÷ average travel time **Velocity = ________ ÷ ________ = ________ (ft/sec) or (m/sec)**
Discharge = Channel area x Velocity **Discharge = x = (cfs) or (m^3/sec)**
Correction Factor = 0.85 Total Discharge = discharge x correction factor **Total discharge = x 0.85 = cfs**

Total Discharge = cfs

conversions
1 m = 3.28084 ft
1 m^3/sec = 35.31467 cfs

Place Site Visit Label Here

Continuous Data Logger Field Form

(One Station per page)

Project ID:____________________

Date: ______________________________

Waterbody: ______________________________

Station ID: ______________________________

YSI, Surveyor, AquaRod, or Mini DOT Data Logger	
Medium:	Water Air Other:________
Interval *(hh:mm)*:	
Logger Make/Model:	
Serial #:	
Launch Date/Time:	
Deployment Date:	
Deployment Time:	
Latitude (*dd.dddd*):	
Longitude (*ddd.dddd*):	
Deployment Location & Additional Information:	
Data Logger Deployment Map:	
Retrieval Site Visit Code:	
Retrieval Date:	
Retrieval Time:	
Retrieval Comment:	
Electronic File Name:	

Temperature or Electrical Conductivity Data Logger	
Medium:	Water Air Other:________
Interval *(hh:mm)*:	
Logger Make/Model:	
Serial #:	
Launch Date/Time:	
Deployment Date:	
Deployment Time:	
Latitude (*dd.dddd*):	
Longitude (*ddd.dddd*):	
Deployment Location & Additional Information:	
Data Logger Deployment Map:	
Retrieval Site Visit Code:	
Retrieval Date:	
Retrieval Time:	
Retrieval Comment:	
Electronic File Name:	

Weather Station Data Logger	
Medium:	Water Air Other:________
Interval *(hh:mm)*:	
Logger Make/Model:	
Serial #:	
Launch Date/Time:	
Deployment Date:	
Deployment Time:	
Latitude (*dd.dddd*):	
Longitude (*ddd.dddd*):	
Deployment Location & Additional Information:	
Data Logger Deployment Map:	
Retrieval Site Visit Code:	
Retrieval Date:	
Retrieval Time:	
Retrieval Comment:	
Electronic File Name:	

APPENDIX B – EQUIPMENT HELP SHEETS

These sheets are to help personnel to prepare equipment for the field and for use in the field.

If the equipment is calibrated or has maintenance done record this information in Equipment Calibration/Maintenance Log book:

- Date (when it happened)
- User (who did it)
- What was done (i.e. battery change, zero check and adjust, battery removal)

NOTE: Users should reference the appropriate user manual whenever necessary.

OTT MF Pro Set Up

Cautions and Critical Information
An internal rechargeable battery powers the MF Pro. It is strongly recommended to bring the power cord and a means of charging into the field. The rechargeable battery has approximately 18 hours of use. Do not store in direct sunlight, high temperature environments (closed vehicle in direct sunlight) battery may overheat and cause a fire or explosion

The sensor and cable connect to the handheld meter. Only finger tighten the sensor connector. Never use tools for tightening. Disconnect the meter and the sensor cable when not in field use.

If any error or FAIL is reported - Do not use until problem is resolved. See the manual's Troubleshoot section on how to resolve the issue.

Pre-Field Before using this equipment check:

- Charge the batteries fully
- Check the settings, make sure that the settings match the what is listed in **Table 2**
- Check for a firmware update
- Perform a Zero Check to verify that the sensor is reading correctly

Post-Field After the field season, and when the meter will not be used for 3 or more months:

- Charge the batteries fully
- Check the sensor and cable for any damage or fouling, clean as necessary
- Wipe down and clean case as necessary
- Make sure that the meter has all of its cables and chargers.

This meter has been designed with multiple uses in mind. The meter should be set up as the following to ensure proper data collection for instream velocity and discharge.

Table 2: OTT MF Pro Setting options

Main Menu	Sub Menu	Description/Reason
Velocity Calibration		Zero Check, follow user manual instructions
Filter Parameters		Fixed Period Avg. = 30s (default)
Wet/Dry Threshold		Default (20.00%)
Auto Zero Depth	On	If On, the meter will zero calibrate when the sensor is taken out of water; if "Off" the user will have to manually zero the sensor after 30 minutes of flow measurements.
EMI		Default (50 Hz.)
Clock		Sets Time and Date (Does not support Daylight Savings Time)
USB		Select Mass Storage for computer connection. CDC option is only used to update firmware.
Language		English
Units		Units for Velocity, Flow, Depth, and Area
Beeper		On/Off
Flow Calculation		Mid-Section Calculation
Station Entry		Fixed Station Entry, Top reference
Measurement Resolution		0.01

OTT MF PRO FIELD HELP SHEET

Field Check List

- ❑ Flow meter (MF Pro.)
- ❑ Sensor attachment
- ❑ Charge cord
- ❑ Adjustable meter mount
- ❑ Case
- ❑ Operating instructions
- ❑ Top setting rod
- ❑ Field Tape (10th ft. or m. see SAP)
- ❑ Bank Pins

Turn On Meter

Press and hold Power Button until beep is heard
Once the sensor is connected, Press "OK"

Turn Off Meter

Press Power Button and Confirm power off

NOTE: Meter goes to sleep if it has not been used in a few moments. The meter does not turn off unless the power button is pressed and power is confirmed to being turned off.

Collecting stream discharge in the field:

1. Stretch a field tape across the cross-section perpendicular to flow from left water's edge to right water's edge.

Select **Profiler Menu** to collect stream discharge information:

2. Sampler: Enter in user initials
3. Choose "Stream"
    a. Name: Use Site ID from Site Visit Form
    b. Stage Reference: If none is available press "Enter"
4. Stream width
    a. "Enter Stream width from tagline zero": enter the tape number at left water's edge
    b. "Enter tagline offset": enter the tape number at right water's edge
    c. "Enter desired number of stations":
        i. For narrow streams: 10-15 stations
        ii. For wide streams: 20-30 stations
5. Station Page
    a. Edge/Obstructions: Where are you at in the cross section?
        i. Left Edge of Water
        ii. Right Edge of Water
        iii. Open Water
    b. Distance to Vertical: The location of the next reading.
    c. Set Depth: How deep is the water?
        i. Edge of water must always be "0"
    d. Measure Velocity: Measures water velocity
        i. Edge of water at "0" depth will always have a velocity of "0".
        ii. Choose the number of points that will be collected on the vertical at that station.
        iii. Meter will collect velocity, wait 30 seconds
        iv. Press "Main" to go back to the Station screen
    e. Press "Next" to go to the next station
6. Repeat Station Page as necessary
7. Save Data and Exit: Name file with Site Visit Code number

To View Data on Meter
Return to main menu and select Profiler → File → Files are named by: Time Started, Date (MM.DD), File Name. (No year is recorded.)

How to Record
Record calculated Discharge on the Site Visit Form and mark Meter-Auto.
Do **not** check off Total Discharge in Field Assessments (no form was used)

Select **Real-Time** to collect real-time velocity.

- Capture: Stores the velocity information in the memory until the user exits the Real-Time mode.
- Clear: Erase the last captured information or all of the captured information that has not been saved.
- Save: Saves the Captured information to a file. Name file as necessary.
- Settings: Change Real-Time settings if needed (FPA vs. RC filter modes)
- Files: Views the saved data.

MARSH-MCBIRNEY SET UP

Pre-Field

- Check Batteries (2 x D's)
    - Unscrew bottom and inspect
- Set up Fixed Point Average (FPA)
    - Press the ↑ and ↓ keys at the same time to set FPA (Fixed Point Average)
    - Press the ↑ keys to read appropriate average (5 sec. for zero check, 30 sec. for field use)
- Set up Units
    - Press the On/C and OFF keys at the same time to set units and beeper
        - FT/S or M/S
        - No beeper or with beeper (indicated by beeper symbol in bottom right)
- Zero Check
    - Clean sensor with soap and water (Do not use hydrocarbon solvents)
    - Set FPA to 5 sec.
    - Fill 5-gallon bucket with water,
    - Place sensor in bucket of water (minimum 3" away from side and bottom)
    - Wait 10-15 min (Water must not have movement)
    - Flow meter zero stability is +/- 0.02 over a 5 sec.
- Zero Adjust
    - Set up as for Zero Check
    - Press STO and RCL buttons at the same time, number 3 will display
    - Press down key to count down from 3 – 2 – 1, number 32 will display
    - The unit will count down from 32 to 0 and turn off.

If there is any concern that the velocity is not being correctly reported during the field season: go through the zero check and zero adjust procedures.

See manual for information on reported error types.

Post-Field

- Remove batteries
- Clean sensor

MARSH-MCBIRNEY FIELD HELP SHEET

Field Check List

- ❑ Case
- ❑ Top setting rod
- ❑ Measuring Tape (10th ft. or m. see Project SAP)
- ❑ Bank Pins
- ❑ 2 D batteries
- ❑ Screwdriver
- ❑ Discharge Form

Cautions and Critical Information

Make sure to bring extra batteries and a screwdriver to replace batteries in the field.

Fixed Point Average

Press the "↑" and "↓" buttons simultaneously until display reads "FPA". Once FPA is selected used the "↑" and "↓" buttons to select 30 sec. This setting will collect velocity readings for 30 seconds and display the average velocity over that period.

Collecting stream width, depth, velocity in the field:

1. Stretch a field tape across the cross-section perpendicular to flow from left water's edge to right water's edge.
2. Divide width by how many stations need to be measured.
    a. For narrow streams: 10-15 stations,
    b. For wide streams: 20-30 stations
3. Record the stations on the Total Discharge Form.
4. Turn on meter
5. Set FPA to 30 sec.
6. Stand downstream of first station
7. At each station record the water depth on the form and set the sensor to correct height
   Be careful to not push the base of the rod into soft substrates
8. Press "ON/C" and wait 30 seconds and record the velocity on the form
9. Repeat steps 6 and 7 as necessary to complete the cross-section
10. Turn off meter

KEY FUNCTION SUMMARY

One-Key Functions

ON/C - Turns Unit ON. Clears the display and restarts the meter.

OFF - Turns Unit OFF.

↑ - Increments FPA, TC, and Memory Location.

↓ - Decrements FPA, TC, and Memory Location.

RCL - Alternates Between Recall and Real-Time Operating Modes.

STO - Stores Values In Memory.

Two-Key Functions

ON/C **OFF** - Change Units, Turns Beeper ON/OFF.

↑ **↓** - Alternates Between FPA and rC Filtering.

ON/C **STO** - Clears Memory.

RCL **STO** - Initiates zero adjust sequence. Zero stability is ± 0.05 ft/sec.

1 FPA = Fixed Point Average **2** TC = Time Constant Filtering

Error Codes

Error #1 Problem with sensor drive circuit. Check sensor disconnect.

Error #2 Memory full error. Memory must be cleared before another reading can be stored.

Error #3 Incorrect zero-adjust-start sequence. Reinitiate zero-adjust-start sequence.

Error #4 Zero offset is greater than the zero adjust range. Repeat the zero-adjust procedure. If the error is still displayed, the unit needs servicing.

Error #5 Conductivity lost or noise detected during zero adjust. Usually caused by the sensor being out of the water.

APPENDIX C – DIGITAL STAGE RECORDER STILLING WELL DESIGNS

Digital Stage Recorders are deployed in stilling wells to protect the dataloggers from any damage that could be caused by weather, flow, or vandals.

AQUAROD® STILLING WELL DESIGN (DEQ, 2010)

Refer to the Water Stage Recorder Standard Operating Procedure (DEQ, 2010) for more information on AquaRod stilling well design.

It is recommended to have the stilling wells constructed by a machine shop.

AquaRod Stilling Well	
Material	Galvanized steel pipe
Length	7 to 10 feet, (dependent on instrument length and expected water level surface during deployment.)
Width	2 inches
Top	Black pipe cap with 5/8” drilled through with locking bolt.
Holding	AquaRod Head rests on bolts (1/2” bolts 5/8” long)
Bottom	2” point welded (for driving stilling well into substrate)
Staff Gage Holes	reference staff gage (if necessary)
Inlet Holes	6 to 12 inlet holes to allow for water movement.

Table 3: AquaRod stilling well specifications

These stilling well designs do not prevent fine sediment from being deposited within the well. Remove the digital stage recorders and pour water into the stilling well (using a bucket) to wash out the fine sediment during servicing visits.

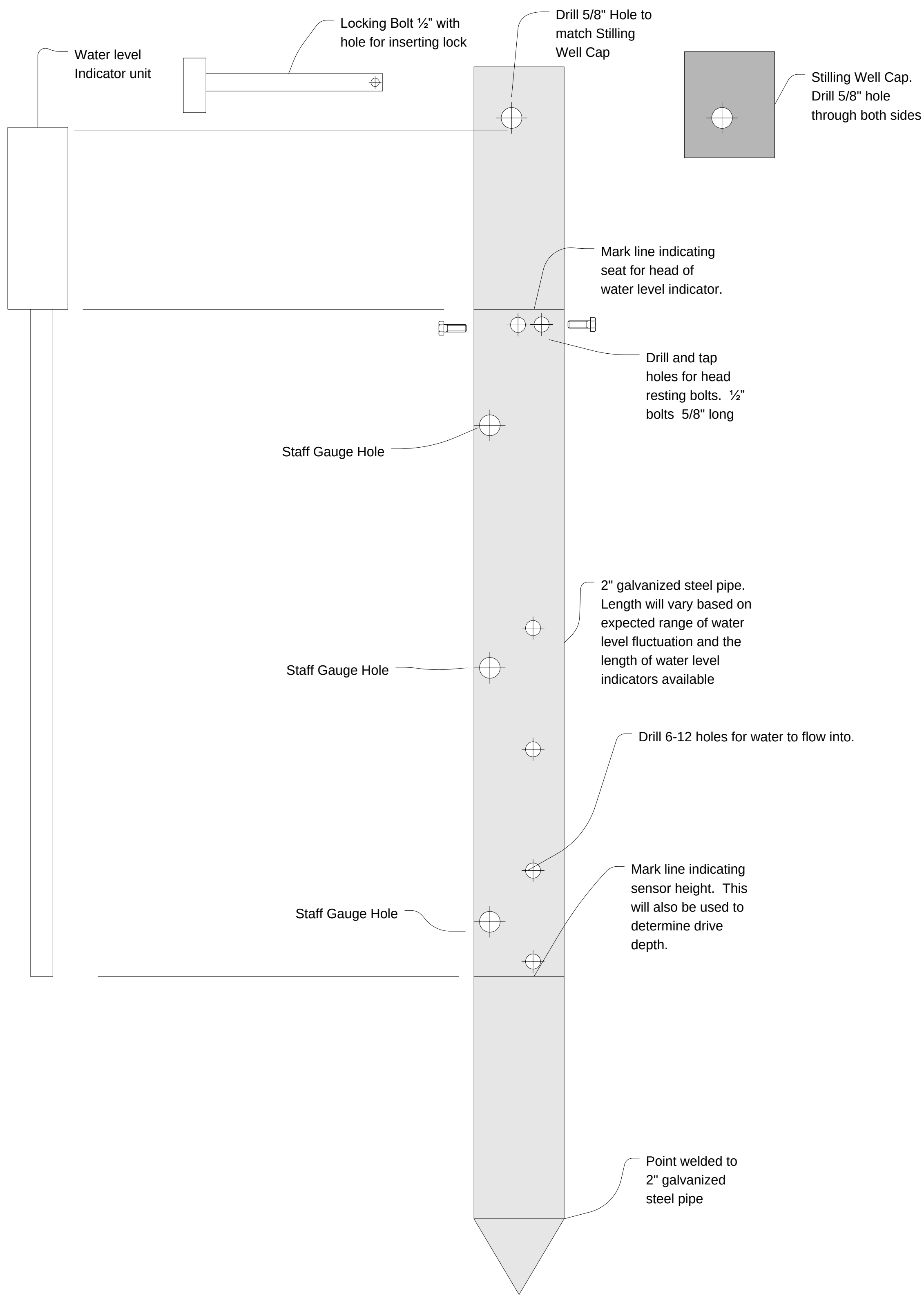

Figure 6: A Likeness of the Original AquaRod® Stilling Well Design (DEQ, 2010)

TruTrack® Water Level Recorder (DEQ, 2010)

Refer to the Water Stage Recorder Standard Operating Procedure (DEQ, 2010) for more information on TruTrack stilling well design.

It is recommended to have the stilling wells constructed by a machine shop.

TruTrack Stilling Well	
Material	Galvanized steel pipe
Length	7 to 10 feet, (dependent on instrument length and expected water level surface during deployment.) Split in two with threads in the middle. Includes threaded union join
Width	1 ½" inches
Top	Black pipe cap with 5/8" drilled through with locking bolt.
Holding	TruTrack hangs from internal hanger "The DSR-TT is seated using a single bolt that runs through its attached key-ring holder. A wire attached to the apex of either DSR is secured to the top of the stilling well for retrieving the instrument from inside the well."
Bottom	2" point welded (for driving stilling well into substrate)
Inlet Holes	3 to 6 inlet holes to allow for water movement. (done by installation personnel or machine shop? "pre-measured and drilled in the stilling well before going to the field to reduce the amount of time and tools needed.")

Table 4: TruTrack stilling well specifications

These stilling well designs do not prevent fine sediment from being deposited within the well. Remove the Digital stage recorder and pour water into the stilling well (using a bucket) to wash out the fine sediment during servicing visits.

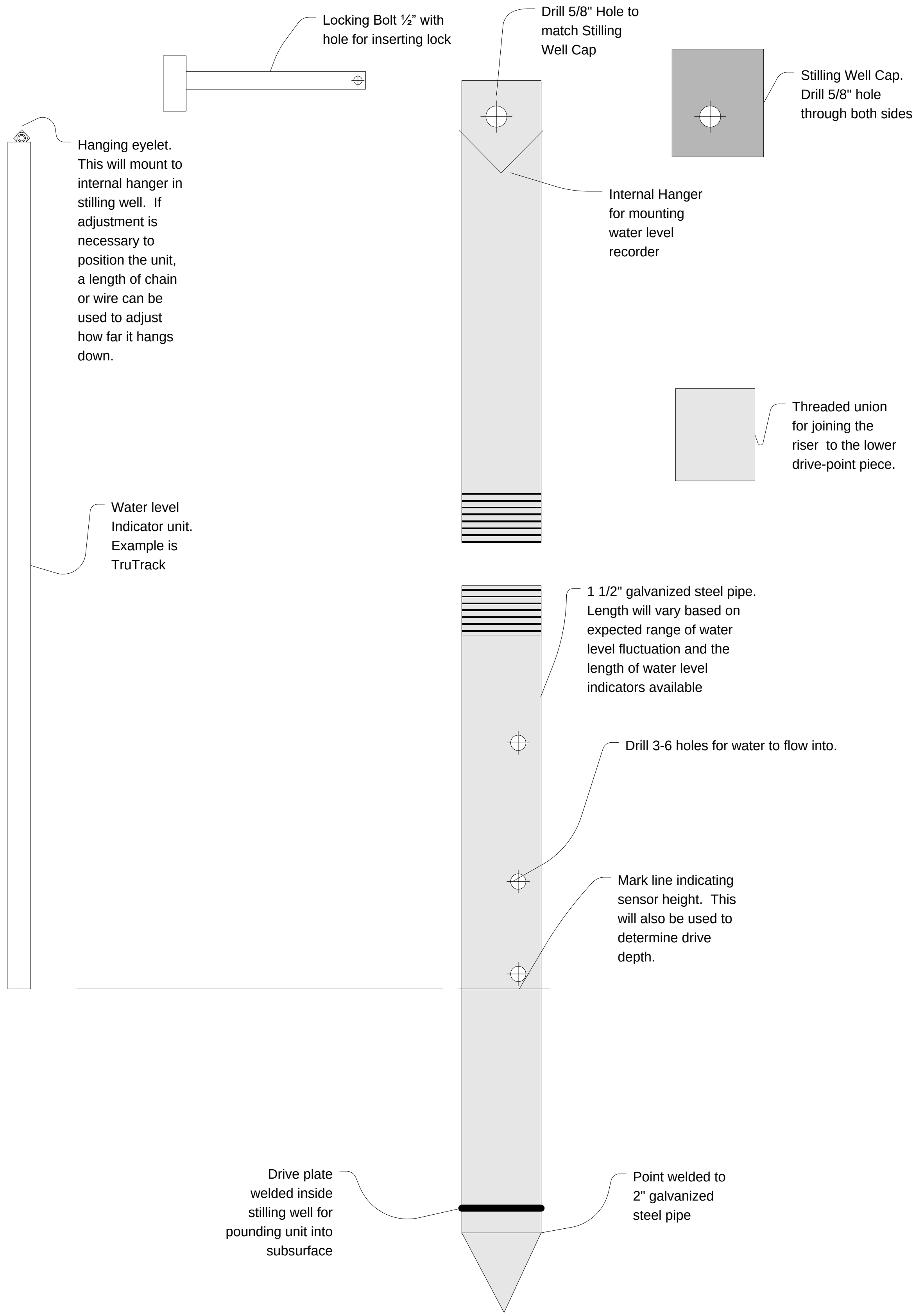

Figure 7: Jointed stilling well for TruTrack® Water Level Recorder (DEQ, 2010)