Standard Operating Protocols

for Aquatic Monitoring of the California Environmental Monitoring and Assessment Framework

Cannabis Program

November 2024

The California Department of Fish and Wildlife (CDFW) developed this document to provide staff with standardized guidelines for carrying out aquatic field methods of the California Environmental Monitoring and Assessment Framework. This is a living document, and the contents are subject to change or updates. Input and feedback on the methods, as well as suggestions for improvement, are encouraged.

Prepared by:

Chris O'Keefe, Patrick Kolence, Ethan Baruch, Trevor Gandell, Maggie McCann, Michael Paccassi, Elijah Portugal, Patrick Scott and Kelly Souza

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Introduction

To support Senate Bill 94 (SB94), as well as the overarching mission of the California Department of Fish and Wildlife (CDFW) as a public trust agency, CDFW is developing a statewide monitoring framework titled the California Environmental Monitoring and Assessment Framework (CEMAF, or Framework). The CEMAF is being developed by Cannabis Program staff in the Office of Cannabis, with the intention of having the Framework locally implemented by teams of regional monitoring staff and headquarter-supported. This document describes the essential components and aquatic protocols of the statewide program.

The goal of this monitoring effort is to assess the direct and indirect effects of cannabis cultivation and other ecological drivers on terrestrial and aquatic species and their habitats in California. Implementing the aquatic and terrestrial protocols and conducting future analyses will provide information needed to assess the magnitude, spatial, and temporal extent of the direct and indirect effects of cannabis cultivation. The aquatic data will facilitate assessments of streamflow, stream habitat conditions and aquatic biodiversity.

Depending on the environment and needs of each region, the methods may differ. The success of the program will be contingent on 1) all staff following the same, standardized protocols for the methods applicable in their regions, 2) consistent and centralized data storage, and 3) timely data processing and analyses. Data will be integrated across multiple spatial scales ranging from subwatersheds to ecoregions to statewide, making standardized data collection, storage, and processing imperative. Data will be assessed across multiple temporal scales to evaluate trends in biodiversity and to identify causal pathways that predict biotic responses under varying scenarios to determine if, and to what extent, external drivers affect wildlife and their habitats.

This living document may be refined as the Cannabis Program continues to grow and improved field methods are developed. Changes will be documented in Appendix A. Any questions about these protocols or feedback on ways in which they may be improved, should be directed to Office of Cannabis staff in Headquarters.

Overview

The aquatic CEMAF protocols require several different data collection methodologies throughout the field season, and this document organizes the protocols for these methodologies into discrete sections depending on the type of methodology. A given visit to the site may require implementing protocols from different sections of this document. Sites are ordered from lowest in the subwatershed (Site 1) to highest (Site 3). Site 1 requires more data collection methodologies throughout the field season than Sites 2 or 3.

Staff install data collection equipment in March or April and no later than May 1st at all sites with the goal of documenting the spring recession to base flow conditions and having a standardized index period from May through September to track trends. The installation date will vary by water year and watershed, but staff should install equipment as soon as safely possible. Drier conditions will call for an earlier installation, while wetter conditions may necessitate a later installation. At the time of installation, survey crews establish a vertical benchmark (VBM) and perform an auto level survey to determine pool stage. During early summer (or later in high water years), Instream Flow Program (IFP) staff may conduct surveys of the channel morphology following the Habitat Retention Method (HRM) and Wetted Perimeter Method (WPM) at priority watersheds and as resources allow. Unless high flows significantly alter the channel, HRM and WPM are performed once per subwatershed, whereas all other methods are performed annually.

Staff will conduct an aquatic bioassessment survey in May - June at each Site 1 following the State Water Resources Control Board (SWRCB) Surface Water Ambient Monitoring Program (SWAMP) protocol for bioassessment of benthic macroinvertebrates (BMI). The SWAMP protocol allows for these surveys to be conducted as late as September but May and June are optimal to keep comparability between watersheds and water years as consistent as possible. Survey crews conduct snorkel surveys at Site 1, once in the early summer and once in the fall. Throughout the monitoring period (March-October), all sites are visited to download data, check for biofouling, collect stage of zero flow (SZF), discharge, and stage measurements. Three discharge measurements are the absolute minimum required to create a rating curve, but staff should aim to collect a minimum of five discharge measurements at each site before flow conditions transition into winter high flow, and the risk of equipment loss increases (usually in October). Additional discharge measurements beyond the minimum, create a better-fitting rating curve, a more accurate hydrograph, and can be helpful if other discharge measurements prove to be invalid.

The data collection (Figure 1) follows the schedule listed below; protocols follow in the order they are completed, and the gear lists can be found in appendices.

- Installation (March – April, no later than May 1st)
    - Deploy Pressure Transducers (PTs) and Dissolved Oxygen (DO) loggers
    - Install staff plates
    - Discharge
    - Auto level survey
- Site Visits
    - Discharge
    - Water surface elevation
    - DO field calibration
    - Logger maintenance
    - SZF / RCT measurements
- Bioassessment Visit (May – June)
    - Benthic macroinvertebrates (Site 1)
    - Physical Habitat Transect-Based Measurements (Site 1)
    - Hydrology and Water Quality
- Summer Snorkel (early July)
    - Collect fish counts and pool metrics, place flagging (Site 1)
    - Hydrology and Water Quality
- Fall Snorkel (September)
    - Collect fish counts and pool metrics, remove flagging (Site 1)
    - Hydrology and Water Quality
- Removal (October)
    - Remove all equipment including flagging, staff plates, PTs and DO loggers
    - Discharge
    - Auto level survey

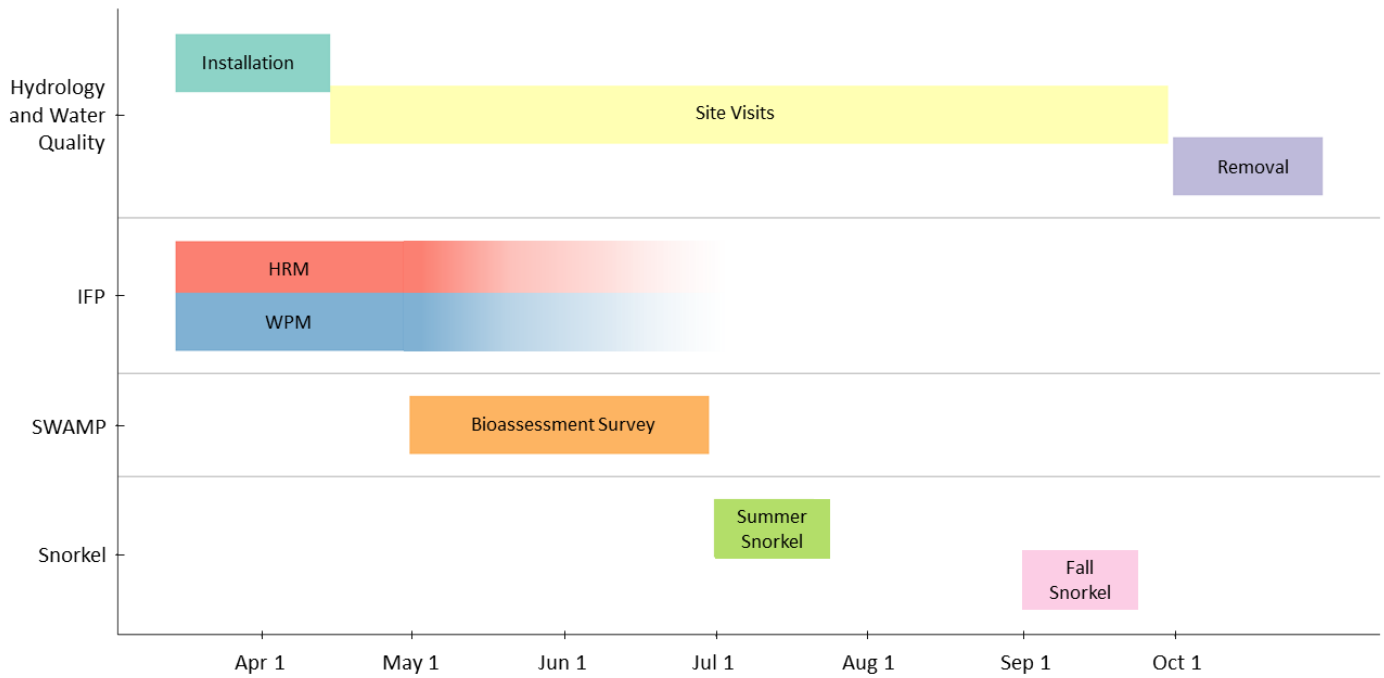


Figure 1. Approximate timeline of the monitoring efforts. The timing of these methods may shift from year to year depending on hydrologic conditions, however, it is important to keep timing as consistent as possible in order to produce the most comparable data.

Site Selection and Vetting

The initial sampling unit for the CEMAF is the Hydrologic Unit Code (HUC) 12 subwatershed (hereafter, watershed). From a management perspective, watersheds are often meaningful management units because they provide natural delineation features for aquatic species, and therefore a biologically relevant sampling scale for metrics such as aquatic species distribution and cumulative effects (Omernik et al. 2017). We use Balance Acceptance Sampling (BAS) to randomly select (with post-stratification) study watersheds, because it evenly distributes sampling effort geographically, is conceptually simpler than other spatially balanced designs, can be executed quickly, is freely available to download as an open-source R package, and allows for post-stratification, which is helpful for adjusting to frame imperfections common in environmental monitoring (Robertson et al. 2013, van Dam-Bates et al. 2018). Additionally, BAS allows for sampling with replacement, which is of practical importance to achieve the desired sample size when selected sample units cannot be observed (e.g., unsafe, physically, or legally inaccessible). The headquarters team maintains a master list of BAS-selected study watersheds and is available to help regional monitoring teams with desk-top and site-specific vetting and selection procedures.

Once watersheds are selected, use desktop methods to determine if a site will be sampleable based on characteristics that can be identified prior to the field season. The primary concerns are applicability of methods, accessibility, longevity, and safety.

For a site to be appropriate for field methods, it must have proper stream characteristics for a reach-length required by all methods. For Site 2 and Site 3, that length is short, but for Site 1 the reach must be 1-km for snorkeling, free of any major tributaries and should be wadable. A site may not be sampleable if high flows during the sampling period limit wadeability, or the site is part of a floodplain. Use ArcGIS with a stream layer to check for tributaries or other inputs or outputs. Use Google Earth to view the site during different seasons to check for flooding. Fire activity does not disqualify a site from consideration and is good to track to be sensitive to landowners, and to be aware of hazards like dead trees or altered roads. There are fire layers available in ArcGIS, and you can also use historic Google Earth imagery.

Staff should be able to safely drive to the site, park nearby, and walk to the site. Barriers might include lack of public roads, gates, fences, loose dogs, inhospitable landowners, steep terrain with no trails, and excessive poison oak or other thick vegetation. Typically, try to ensure the site is within about 1-mi of a parking location. Use Google Maps directions to check for the nearest public road access and Google Streetview to investigate parking options and access barriers. Public easements associated with bridges are good places to gain access to the stream.

Another consideration is longevity. The collection of data over several years is a challenge for long-term monitoring programs. Establishing a consistent baseline is needed to assess trends over time. Variability in stationary site locations can complicate interpretation, making it more difficult to understand relations between anthropogenic and natural ecosystem processes and cannabis cultivation levels. Keep site longevity in mind during the vetting process to reduce the likelihood of having to replace sites in the future. For example, if a particular neighborhood is resistant to CDFW presence or if you've had unfavorable run-ins with individuals, it is better to exhaust other options than choose a site that must be relocated later. Landowner access will be a significant challenge and monitoring teams must be committed to developing and maintaining the necessary relationships key to working with cooperative landowners. Access to private lands is a privilege provided to us through the generosity of landowners. To this end, we propose that regional teams consider landowner outreach plans that specifically include Resource Conservation Districts.

When it comes to safety, it is important to anticipate and avoid potential for human-caused danger. First, use Google Earth to check for nearby cannabis cultivation. If found, check the DCC active license layer to see if the grow is licensed. Staff should not cross or work directly adjacent to unlicensed cannabis grows. Other safety issues can be assessed through Google Streetview including hostile signage, encampments, and evidence of illegal activity.

If a site appears to be safe, accessible, and sampleable, use LandVision to determine the owner's first and last names, land use type, site address, assessor parcel number, and owner (mailing) address. This information can be out of date or mistyped, so be aware of potential errors. Vet any parcel you may seek access to, with regional permitting and fisheries staff before making contact. If a landowner already has a Lake or Streambed Alteration Agreement, or has already provided access for fisheries monitoring, it is important to minimize contact fatigue. It may be best that staff who have a pre-established relationship with the landowner request access for CEMAF activities.

Perform an in-person reconnaissance visit prior to sampling to ensure that the site is suitable for all sampling methods intended to be implemented at the site and that it can be safely accessed. Some things to consider for suitability include avoiding locations with visible beaver activity, high-traffic areas, and pool tail outs near recreational areas which are often dammed for "kiddie pools" in the summer months. All of these jeopardize the development of rating curves. Identify a pool that is a likely candidate for logger installation following the guidance in the *Installation* module *Logger Locations* section and record pool location and characteristics. For Site 1 locations, it is important to ensure there is enough access upstream and downstream to complete bioassessment and snorkel methods. If the site is ultimately determined to be suitable, you will eventually need a Temporary Entry Permit (Appendix B contains an example that has been approved by the Office of the General Counsel) signed by private landowners, although verbal permission is also okay. Using the Survey123 "Recon" form, collect information needed to populate Table 1 to develop simple location maps for a Reconnaissance Report (Figure 2, 3). If a site is not suitable for sampling due to access or other concerns, document that information in the "Recon" form and replace the site following the site-selection process, above.

Table 1. Template illustrating the primary information to collect during a site reconnaissance trip. Example data from the North Fork Navarro HUC 12.

Site Name/Number	NFNS1
Coordinates	123.5880256°W 39.1703091°N
Landowner Name (Contact)	Mendocino Redwood Company (David Smith)
Landowner Phone	(707) 555-5555
Landowner Email	
Preferred Contact Method	Email
Contact Directions/Point of Contact?	Email David three days prior to visiting.
Gate Combination or Key Required	Not needed for Site 1 (combo needed for Site 3)
Agreement Type	License Agreement
Agreement Dates	March 1, 2022 – October 31, 2022
Special Directions	All field staff must have a digital copy of a signed Release of Liability agreement signed and accessible to them when at these sites.
Notes	No wet weather travel: keep access gates closed and locked at all times.
Driving Directions	Follow coordinates to parking
Parking Directions/Coordinates	Parking is on a pullout along Flynn Creek Road. 39.169079, -123.586558
Access	Access stream from road and walk US ~ 50 m to where loggers are deployed in a deep (>1 m) scour pool on a meander bend with a LWD jam on RR (Fig 3).
Snorkel Reach Start	123.5884718°W 39.1706550°N
Snorkel Reach Stop	123.5966314°W 39.1805386°N
Snorkel Directions	Snorkel put-in is Site 1 and takeout is Site 2

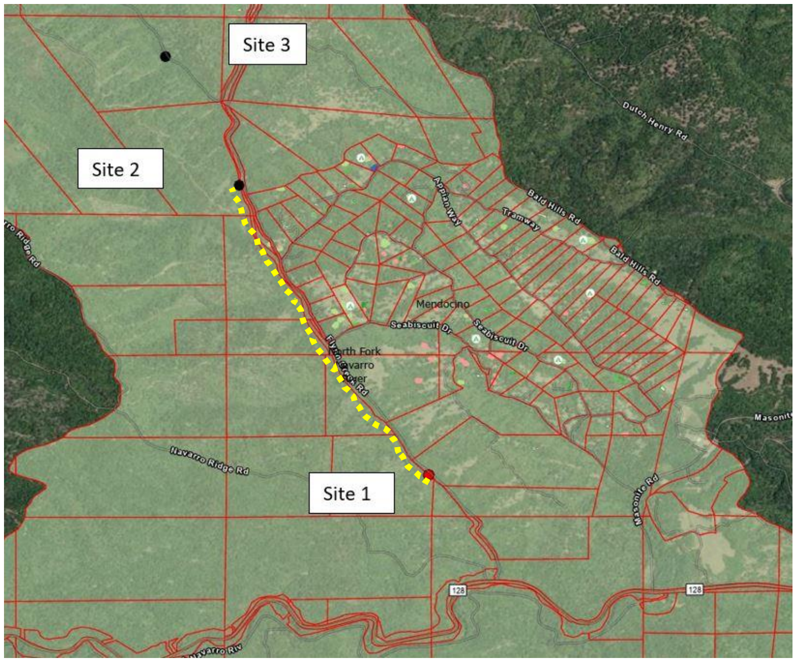


Figure 2. Site map showing locations of all three sites within the North Fork Navarro HUC 12. Snorkel reach is highlighted in yellow and parcels are shown in dark orange.

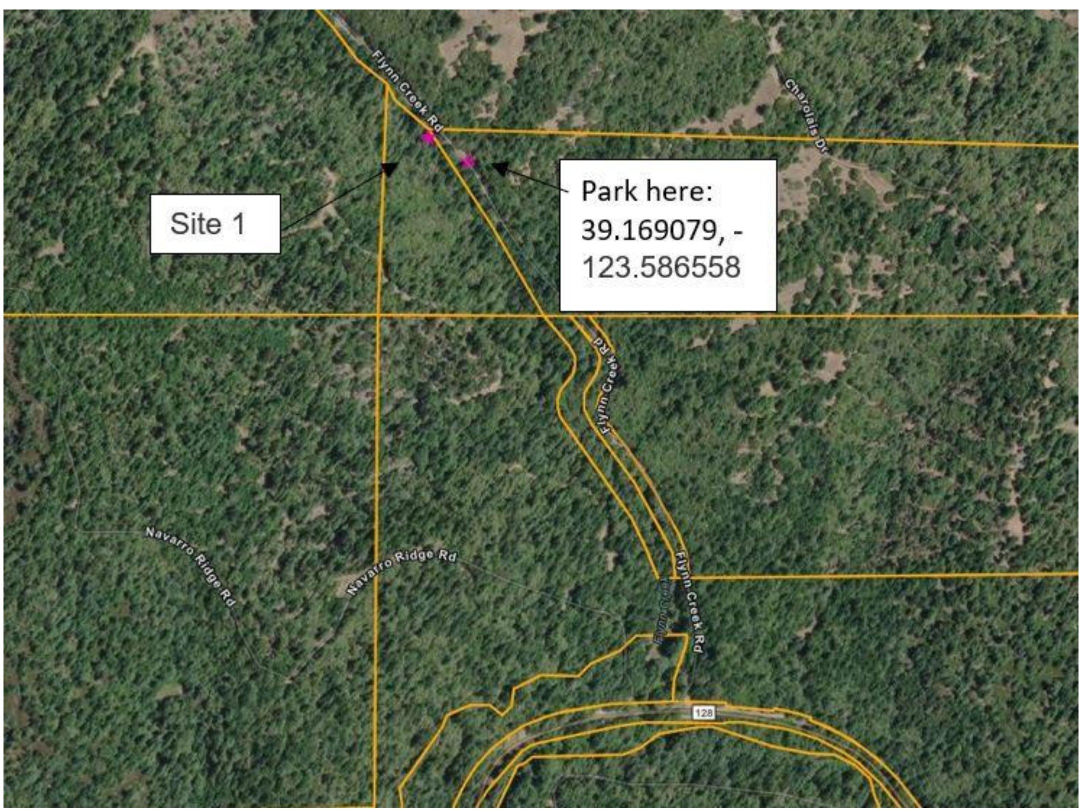


Figure 3. Site 1 location map. Parking coordinates and location are shown relative to the site. Parcels are shown in orange.

Decontamination

It is critical that staff are prepared to take all necessary measures to prevent the inadvertent spread of invasive species and pathogens (including parasites, bacteria, and viruses) by following decontamination measures. Invasive species are one of the primary threats to California's biodiversity (California Biodiversity Initiative 2018) and pose significant risks to the conservation and sustainability of native species and their habitat. Human activity in both terrestrial and aquatic environments is the primary avenue for the spread of non-native, invasive species, and pathogens. Aquatic ecosystems are even more vulnerable to the exchange or introduction of non-native species (Sala et al. 2000). To help ensure that monitoring activities do not have a negative impact on species or habitats, field crews should:

- Avoid moving any organic material from one location to another.
- Use boot brushes to remove soil, seeds, small organisms, or other organic materials from footwear upon leaving and before entering vehicles for each site visit.
- Avoid using felt-soled waders.
- Decontaminate all field equipment including but not limited to, wading, snorkeling, and sampling equipment (water quality probes, nets, buckets, stadia rods, flowmeters, loggers) before carrying to or from sites.
- Work from upstream to downstream when visiting multiple sites in a watershed.

CDFW has an aquatic invasive species decontamination protocol, mandatory for all personnel authorized to work in aquatic habitats. Staff should follow this protocol, prioritize methods that are least resource intensive and most importantly, practice vigilance to reduce chance introductions. Having two-three sets of personal and sampling gear, on trips to more than one watershed, saves time, reduces exposure to disinfectants, and allows other methods to be used (freezing, drying).

View the entire aquatic invasive species decontamination protocol document online (PDF).

Hydrology and Water Quality

Background

As part of the *Hydrology and Water Quality* module, Dissolved Oxygen (DO) loggers and Pressure Transducers (PTs) are used to continuously monitor dissolved oxygen, stream discharge (flow), and stream temperature throughout the field season. Information on site condition, logger placement, and other data needed to process logger data are collected during surveys defined as "installation", "site visit", and "removal". Staff should ensure the gear is functioning properly and regularly perform quality assurance measures.

Dissolved Oxygen Loggers

Most aquatic biota are reliant on sufficient concentrations of DO for survival. In salmonids, reduced levels of DO can impair growth and swimming performance, increase predation vulnerability, reduce food conversion efficiency and can be fatal after prolonged exposure (Bjornn and Reiser 1991). Dissolved oxygen has a direct relationship to fish health and is associated with streamflow and other physiochemical habitat characteristics. Water withdrawals for cannabis cultivation and other human land uses can directly impact surface flow and DO levels. Consequently, DO timeseries analysis was selected as a response metric to assess potential impacts from cannabis cultivation and other biotic and abiotic drivers.

Onset HOBO® U-26-001 DO loggers monitor the DO concentrations in the water at the sites over the study period. One DO logger is deployed at all aquatic sites to record DO concentration and temperature in 15-min intervals during the gaging period (typically March - October). During the gaging period, the Onset HOBO® Waterproof Shuttle Data Transporter (U-DTW-1) is used to offload the DO logger data during site visits. Use this data to perform time series analysis linking surface flow levels to DO throughout the gaging period.

Pressure Transducers

Understanding stream flow in aquatic systems is of fundamental importance since it is a primary driver of physiochemical conditions that affects everything from stream temperature, DO, sedimentation, the concentration of potential pollutants in the water and the distribution, expansion and contraction of lotic habitats (Poff et al. 1997, Stanley et al. 1997). Flow magnitude is positively correlated with DO levels and water availability, and negatively correlated with stream temperature (Boulton and Lake 1990, Magoulick and Kobza 2003, Falke et al. 2010).

The CEMAF uses HOBO U20L-01 Pressure Transducers (PTs) in conjunction with discharge (flow) measurements to quantify the magnitude, timing, and duration of instream flow and understand how flow may be impacted by surface water diversions or natural variability. Five PTs are installed in each subwatershed. Two PTs are installed at each lower most site and one PT at each upper site. These PTs will record absolute pressure and temperature in 15-min intervals during the gaging period (typically March - October). A fifth PT is deployed in the riparian area (barologger) adjacent to study reaches to compensate for atmospheric pressure in the calculation of water stage. The barologger is deployed within the elevation and distance requirements for the atmospheric pressure readings at all sites. HOBO software calculates water pressure by subtracting atmospheric pressure from absolute pressure. Water pressure is converted to water stage (or depth) by using differential leveling via an auto level survey linking the elevation of the PT to an arbitrary reference elevation (i.e., a vertical benchmark) for each PT. Pair water stage data with at least five field measurements of discharge to generate stage-discharge rating curves for each stream reach.

Flow Meters

The CEMAF uses the HACH FH950 flow meter (or similar) to collect discharge measurements. A discharge measurement is the volume of water, usually expressed in cubic ft per second (cfs), moving down a waterway per unit of time. It can be determined by measuring the average velocity of water in the cross section of a stream, and the area of water in that same cross section. These periodic measurements of water quantity are used in conjunction with the continuous record of stage from the PTs to quantify the magnitude, timing, and duration of instream flow and understand how flow may be impacted by surface water diversions or natural variability.

Collect discharge at each site a minimum of five times throughout the field season (during site installation, snorkel surveys, bioassessment, and site removal). Site visits specifically to collect an additional discharge measurement throughout the season may decrease uncertainty when creating a rating curve and allow for discarding flow measurements that might have issues.

Auto Levels

Elevations collected from auto levels are used in conjunction with pressure transducer readings to generate rating curves and hydrographs. Auto levels are used to measure the elevation of the water surface, staff plate, pressure transducer, and the stream bottom relative to a fixed vertical benchmark (or, reference). Auto level surveys that employ differential leveling techniques are used to collect water surface elevation levels (WSELs) and to check whether the elevation of a PT remains constant over the gaging period.

The CEMAF uses a Nikon AP-8 Auto Automatic Level and an Engineer's fiberglass level (25-ft and graduated to 1/10-ft and 1/100-ft) to complete auto level surveys during installation and removal of sites.

Quality Assurance

Dissolved Oxygen Loggers

Quality assurance measures for use of DO loggers include proper handling, calibration, and maintenance, checking for adequate battery voltage, correct installation, and maintenance of the HOBO shuttle.

- Loggers can be damaged by mechanical shock so ensure they are not dropped or subjected to shock by using proper packaging when transporting loggers to and from the field, or for servicing.
- Check and record the voltage of each logger prior to field season to ensure that battery voltage is above 3.2 volts. Return any logger that records a "bad battery" event to Onset for battery replacement.
- Calibrate the logger before deploying it or after replacing a sensor cap, using the 3-step calibration procedure and sodium sulfite that is not expired (it has a short shelf-life).
- After replacing and calibrating a new sensor cap, allow at least 24 hours and check for calibration drift. Connect the DO logger to HOBOware and use 'Device Status' to see current readings while in the saturated storage/calibration sleeve. If readings deviate more than 1.5% from the 100% standard, perform a 1-point calibration to correct.
- Fully submerge loggers (using anti-fouling guards) with the sensor face oriented vertically, out of direct sunlight and in perforated stilling wells to minimize temperature changes unrelated to water temperature and ensure unrestricted flow.
- To compensate for drift, use a stabilized and calibrated YSI meter or titration to collect field verification readings at the beginning and the end of deployment, and anytime loggers are removed for cleaning or downloading. The verification readings should be taken within ±5 minutes of the first and last readings of a deployment.
- Check for biofouling at each site visit and only clean the sensor cap or the body of the logger according to manufacturer's instructions.
- If algae or aquatic vegetation has grown on or near the stilling well, remove the growth as much as possible to prevent impedance of flow and localized effects on DO from photosynthesis and respiration.

- Before driving to a new site, plot the offloaded DO data in HOBOware and perform an initial QC check. If crews suspect the logger is experiencing erroneous readings or failure, the DO logger is replaced with a calibrated and initialized backup.
- Clean and store the logger at the end of each season according to manufacturer's instructions.
- Keep a maintenance log that includes dates and initials for calibrations.
- Conduct training for field staff on the use of the HOBO shuttle. It is imperative that data offload is performed correctly to ensure that redeployed loggers are recording data.
- Regularly assess the shuttle battery health. If batteries are replaced, then the shuttle will need to be relaunched using HOBOware software.
- Always launch and sync your shuttle through HOBOware on the day that you are offloading data from a logger deployed in the field.
- Don't store batteries in the shuttle at the end of field season.

Pressure Transducers

Quality assurance measures for PTs include proper handling and maintenance, checking for adequate battery voltage, correct installation, and the use of another HOBO U20L-01 PT as a barologger to compensate for barometric variations that can improve accuracy.

- The PTs should not be subjected to shock since they can fall out of calibrated accuracy if dropped. Take care in transporting them to and from the field, or for servicing.
- Check and record each PTs voltage prior to field season to ensure that battery voltage is above 3.3 volts.
- Deploy PTs in a stilling well with no-stretch wire to protect them from movement, vibration, debris, wave action, or being buried by silt. Avoid sudden temperature changes to minimize the rate of temperature fluctuations and allow the logger at least 20-min to reach full temperature equilibrium before recording the reference level.
- High amounts of nutrients, plant matter, or bacteria in freshwater systems *may* necessitate periodically checking for biofouling since biological growth on the face of the sensor or inside the nose cone will affect accuracy.
- Deploy a barologger (HOBO U20L-01) to compensate for atmospheric pressure and improve accuracy.
- Clean and store the logger at the end of each season according to manufacturer's instructions.
- Keep a maintenance log that includes dates and initials for calibrations.

Flow Meters

The instream flow practitioner must consider many factors, and the combined impact of these factors, to obtain high-quality discharge measurements. Quality assurance measures that affect the accuracy of discharge measurements, suggested by USGS (Rantz 1982; Turnipseed and Sauer 2010) include:

- Ensure transects have uniformity of depths, composition, and uniformity of the streambed (e.g., silt, gravel, cobble, detritus), without the presence of bridge pilings or other obstructions, and the ability to accurately measure depth.
- Avoid very slow or very high velocity, turbulence, or factors that could affect the vertical distribution of velocity (e.g. ice, wind, eddies, boulders, algal mats, etc.), and the method used to measure velocity (i.e., one-point, two-point, or three-point method).
- Stations at least 0.25-ft apart. The goal is to have cells that are roughly equal along the cross section. A site that is relatively uniform in depth and velocity can help the surveyor achieve similar cell velocities across a transect (Figure 4). It may be difficult to find a transect that is perfectly uniform. In these circumstances, concentrate the velocity measurements (i.e., decrease cell width) in areas with the most variation in depth and velocity.
- Use a minimum of 20 stations per cross section, where each cell has no more than 10% of the total discharge (ideally, less than 5%). Using fewer cells may reduce the accuracy of the discharge measurement. Take the first and last wetted measurements as near to each bank as possible.
- Avoid rapidly changing stage and utilize a temporary staff gage to determine if flow conditions change during data collection. If the stage is changing during data collection, wait for conditions to stabilize before retaking discharge.
- Avoid windy conditions that can change the vertical distributions of velocities and may make it difficult to determine the angle of the current. Wind can also produce waves that complicate depth readings. The effect of wind on the velocity profile lessens as depths and stream velocities increase.
- Always follow proper care and maintenance instructions for the HACH FH950 (or similar) to achieve the most accurate readings:
    - Take precautions before each field event to ensure that the sensor, sensor cable, and velocity meter are in good working condition and that there is no damage to any component. The FH950 sensor has four electrodes, three on the front and one on the left side towards the rear of the sensor. General practice is to not touch the front or

sides of the FH950 sensor since foreign substances such as oils or sunscreen can be transferred to the sensor. Foreign substances can change the conductivity of the sensor electrodes and cause inaccurate or noisy velocity readings. Only handle the back of the sensor.

- Clean the sensor before use if the meter has been used in muddy water, staff believe the sensor electrodes have been covered by a foreign substance, or if the meter readings become unexpectedly noisy. To remove any coatings from the sensor electrodes, ensure that the sensor is disconnected, wash the sensor using dish soap and water or isopropyl alcohol, then gently wipe with a clean cloth (Hach 2018).
- Charge the FH950 battery before each field day. Bring an extra rechargeable battery pack into the field in case the meter's battery stops operating. Replacement of the battery pack requires a Phillips head screwdriver. If you have access to an additional flow meter, bring it as a backup.

Figure 4. Example of a uniform stream channel selected for a flow survey.

Auto Levels

Quality assurance measures that affect the accuracy of measurements from auto level surveys include proper handling of precision instruments, ensuring good condition of equipment and regular calibration checks:

- Annual review of all protocols.
- Regular and periodic completion of two-peg calibration tests and servicing of instruments as necessary.
- Regular examination of stadia rods to ensure that their bottom surface is free of damage or debris, and that stadia rod buttons are in good working order.
- Avoiding stadia rod measurements above 16-ft as it becomes difficult to hold plumb.

Installation

Overview

An installation visit requires multiple procedures in addition to the equipment installation. Logger housings and loggers should be prepared prior to deployment. Once in the field, workflow should go as follows:

- Select suitable installation site
- Install vertical benchmark (VBM)
- Install in-stream PT
- Install DO logger
- Install staff plate
- Install PT barologger (one per 15-km/10-mi radius and 2,000-ft elevation)
- Perform auto level survey
- Take water quality measurements with handheld YSI meter
- Document canopy cover and pool geology
- Take discharge measurement

Pre-field Preparation

Office Tasks for Auto Level

Several months in advance of field work, and before the removal of sites, conduct a two-peg calibration test that checks the accuracy of the auto level by measuring the height differential between two pegs.

Step 1. Drive two pieces of rebar into the ground (A-peg and B-peg) 30-m apart at a reasonably level location. If you can’t drive rebar into the ground, mark the spots with tape, chalk, or a Sharpie.

Step 2. Set up the auto level halfway between A-peg and B-peg.

Step 3. Level stadia rod atop A-peg and shoot the elevation (A1); repeat at B-peg to obtain B1 elevation.

Step 4. Keeping the auto level in line with the pegs, move it behind the A-peg or B-peg about 2-m. Level the instrument and reshoot the elevation (A2 and B2) at each peg.

Step 5. Subtract point A measurements from each other and subtract point B measurements from each other.

$$B2 = (A2-A1) + B1$$

It is highly unusual that the auto level is perfectly calibrated, therefore small differences can be expected. If the height differential is not close, you may perform the test a couple of times to rule out the chance of bad or inaccurate readings. If the absolute value of the height differential is greater than 0.01-ft, the auto level needs adjustment (Kenney 2010).

Office Tasks for PT Loggers

Step 1. Construct or purchase PVC logger housing for each PT. Housings protect the PTs from wave action, physical damage, and are perforated near the PT which allows for the water surface elevation inside the housing to match the outside stream level. Make perforations all around the PVC using a 0.5-in size drill bit.

a. Use 1.5-in diameter perforated PVC pipe and caps, cut to 4-7-ft (long housings) or about 16-in (short housings) in length depending on site conditions. The primary determinant of whether to use a long or short housing is based on the sediment of the pool bed and the difficulty of installing T-posts. Typically, longer housing is recommended because they are more secure, but a short housing may be needed if the sediment makes installing T-posts impossible. For the shorter housing to be an alternative, the pool must be less than 3-ft deep. Consider spray painting the housings and caps to camouflage.

b. Shorter (16-in) perforated housings can be purchased from Onset (HOBO®-U2x) or constructed. The PT is affixed to the cap of the 16-in housing with two or more zip-ties to prevent movement. The 16-in PT housing can be installed oriented horizontally between two pieces of rebar, or vertically (preferred) attached to one piece of rebar. Drive rebar deep enough into the substrate to leave the exposed end stable. If using the vertical orientation, affix the housing so that the PT has the screw-off cap with the hole in it to attach a lanyard, pointing towards the sky. Only use two pieces of rebar to orient the housing horizontally if the substrate is unstable or bedrock and one piece of rebar alone is not stable enough (i.e., easily moves side to side when pushed). It is imperative that the PT will not move during deployment.

c. Longer, 4-7-ft housings, are built to hang a PT inside the well from a padlock clasp using a metal cable attached through a loop on the top of the PT and 1-2-in above the bottom of the housing. Perforate the bottom 14-16-in of the long housing around the diameter of the housing.

d. If you already know what length housing you will install at the site, use a permanent marker to write the PT's serial number on a visible location on the outside of the housing. If not, this step can be completed in the field.

Step 2. Launching the PT

a. Prior to deploying the PTs, connect each PT to a computer and use HOBOware® software (requires a software license key) to launch the PT. This is described in the manufacturer's user manual (HOBO® U20L Water Level Logger (U20L-0x) Manual).

b. Refer to manual for instructions describing how to attach the coupler (Coupler 2-C) to the HOBO® Waterproof Shuttle and the PT logger. Be sure to firmly press the lever/tab on the coupler when connecting the logger to the shuttle. The indicator will flash green upon successful connection.

c. While each PT is connected to HOBOware, record the following information in a spreadsheet: Serial #, Battery State, Memory Used, Last Launched Date, Deployment Number, Logging Interval (every 15 min), Current Status, Absolute Pressure, Temperature, Battery Voltage. This information can be critical during analysis for troubleshooting any data discrepancies between PTs deployed in the same pool.

Office Tasks for DO Loggers

Step 1. Refer to the manual for sensor cap (U26-RDOB-1) and protective guard or anti-fouling guard (U26-Guard-2) installation instructions. Configure logger.

Step 2. Ensure that HOBOware® Pro (version 3.3.1 or newer) is downloaded onto the computer used for launching the loggers.

Step 3. Install new batteries in the HOBO® Waterproof Shuttle and plug into the computer, making sure to synchronize the shuttle time with the computer time.

Step 4. Refer to manual for instructions describing how to attach the coupler (Coupler 2-C) to the HOBO® Waterproof Shuttle and the DO logger. Be sure to firmly press the lever/tab on the coupler when connecting the logger to the shuttle. The indicator will flash green upon successful connection.

Step 5. Refer to the HOBO® manual for the three-step calibration procedures, which is recommended when loggers will be in water with DO levels of 4mg/L or less.

a. Make sure the logger, sensor cap, fresh water, and sodium sulfite are at room temperature before calibration.

b. Install a new sensor cap (U26-RDOB-1) on the HOBO® U26-001 DO logger according to installation instructions. Ensure that O-rings on the optical DO sensor are in good condition, apply lubricant to the O-rings, and clean the lens on the sensor per the instructions provided by HOBO®. The anti-fouling guard will hold the sensor cap in place.

c. You can use a calibrated YSI Pro2030 DO/Conductivity meter (or similar) to provide the barometric pressure reading necessary for 100% saturation lab calibration. Calibrate the YSI meter prior to this step by standing outside and referencing the corrected barometric pressure from a local weather station. Then bring the YSI meter inside the office for DO logger calibration.

d. For the 0% saturation lab calibration with sodium sulfite, make sure there are no bubbles in the solution (tap container) before beginning.

e. Be sure to obtain the gain (100% saturation) and offset (0% saturation) values before sending the calibration to the logger. When carrying out this step, look for consistent gain and offset values before accepting the adjustments.

f. Set the logging interval for 15-min.

Step 6. While each DO logger is connected to HOBOware®, record the following information in a spreadsheet: Serial #, Site ID (e.g., Stream name - DO1), Battery State, Memory Used, Last Launched Date, Deployment Number and Location, Logging Interval, Current Status, Gain and Offset Calibration Values, Barometric Pressure used in calibration.

Step 7. Construct PVC housing for each DO logger. Housings protect the DO loggers from wave action and damage. Perforate the PVC with 15-20 1/2-in holes to allow unrestricted water flow around the sensor cap (Figure 5).

Figure 5. Dissolved oxygen logger with anti-fouling guard covering the sensor cap. Cable is attached to the cap of the logger. Also shown is the perforated bottom of a camouflaged housing.

a. Housings for the DO loggers are constructed out of 2-in diameter PVC or ABS pipe cut to 16-in or 3-ft in length with two 2-in caps. If public vandalism is a concern and peak flow is low, use housing units affixed to greater than 3-ft long 3/8-in rebar to hide the loggers. If using rebar, consider adding an additional paracord or small diameter rope tether from the housing to a root-wad or other anchor point in the channel. For either housing option, consider spray painting the pipe and caps for camouflage.

b. Housings are built to hang a DO logger inside the well from a padlock clasp using a metal cable. Loggers should be hung about 1-2-in above the perforated bottom of the logger housing (Figure 6). It is only necessary to perforate the bottom 14-16-in of the housing.

Step 8. Ensure that the DO logger is actively logging by waiting 15-min after initialization and checking that it is recording.

a. The HOBO® U26-001 DO logger has a removable cap that protects the optical communications window. You can confirm logger operation by looking at the LED in the communications window. When the logger is logging, the LED blinks once every four seconds. The LED also blinks when the logger is recording a sample. When the logger is awaiting a start because it is configured to start "At Interval," "On Date/Time," or "Using Coupler," the LED blinks once every eight seconds until logging begins.

Figure 6. Camouflaged housings with caps and padlocks with holes drilled through the top. The DO loggers are hung with cable inside the housings and attached to padlock clasps for easy retrieval.

The sensor cap expires seven months to the day after it has been initialized. Initialization occurs automatically when the cap is installed while the logger is recording. To see when the sensor cap expires after being initialized, check the 'Status' in HOBOware® for the expiration date. Make sure the gaging period is less than seven months or plan to install new sensor caps and recalibrate during the field season if the gaging period is greater than seven months. The sensor caps have a shelf life of two years from the manufacturer's date (regardless of if they have been used); check the "Install By" date printed on the canister and use the oldest caps first.

Unless calibrating the logger or offloading data, do not leave the sensors connected to the shuttle. When connected to the HOBO® shuttle the DO logger is 'awake' and consumes more power than when it is disconnected and considered 'asleep'. Leaving the logger attached to the shuttle can also reduce battery life and will require earlier servicing of the logger.

Logger Locations

Candidate pools for logger installation should have been identified during site selection and vetting. Re-evaluate these pools prior to logger installation to optimize the quality of data collected. Walk a section of stream centered around the targeted site location that is approximately 20x the average bankfull width and include multiple pool/riffle sequences. The selected pool should be the closest pool to the targeted site location that may also be refugia later in the season (don't select a pool that would be among the first to dry), has similar geologic and hydrologic features as nearby pools, and avoids the following possible disqualifiers to the greatest extent possible. Avoid pools with beaver activity and pools close to recreational areas or high-traffic trails to reduce risk of vandalism, theft, and disruption to the pool's hydrologic control. Do not move the logger pool upstream or downstream of a tributary relative to the targeted site identified with desktop methods unless more detailed desktop analyses have shown the move does not substantially influence the site's drainage area.

The DO loggers are installed as close to the deepest location that can be accessed at the time of installation, provided the location meets all other requirements. The deepest points in pools may not be representative of the entire pool as DO and temperature stratification occurs when flow approaches 0-cfs. Despite this, it is more important to ensure loggers stay wetted as long as possible in the field season. The PT loggers should only be installed in locations where the water surface above the loggers is still or smooth (i.e., not in the thalweg) and the streambed below the loggers is stable (i.e., not likely to experience significant scour or deposition over the gaging period). The accuracy of a stage-discharge relation relies on a stable longitudinal and lateral streambed profile between the PT and the downstream hydraulic control (Rantz 1982). Installing PTs following the above criteria maximizes the likelihood that PTs remain submerged during low flow periods, reduces frequent fluctuations in the water level recorded by each PT, reduces the likelihood of changes to the pool's bed elevation, which improves the accuracy of the stage-discharge relation.

The selected pool should be near a quality flow site for discharge measurements, free of inputs or diversions between the discharge transect and the pool. The USGS (Rantz 1982; Turnipseed and Sauer 2010) and FH950 user manual (Hach 2018) recommend that cross sections with the following characteristics be chosen whenever possible:

- The cross section is in a channel that is reasonably straight with flow perpendicular to the cross section.
- The streambed along the cross section is stable and free of large rocks, aquatic vegetation, undercut banks, or other physical obstructions that create eddies, slack water, or turbulence that could influence velocity measurements.
- The channel form along the cross section is roughly parabolic, trapezoidal, or rectangular in shape and is as uniform as possible (i.e., no pronounced thalweg).
- The water surface is smooth with steady, uniform, non-varying flow conditions along the cross section. No more than 10% (ideally no more than 5%) of the total flow can be in any one cell, defined as the distance between two adjacent vertical measurement points (referred to as stations) on the cross section.
- The cross section will ideally be close to a site of interest (e.g., gaging station, bed elevation profile) if the goal is to develop a relation between the field discharge measurement and data from the site of interest. This will help avoid the impacts of inflows from intervening drainage areas or diversions between the cross section and site of interest.
- The wetted length of the cross section is wide enough to take velocity measurements at a minimum of 20 stations (using the FH950, the minimum allowable distance between stations is 0.25-ft).

- The cross section is not immediately downstream of sharp bends or vertical drops that would negatively impact velocity measurements by unevenly distributing flow along the cross section.
- It is acceptable to modify the channel by moving rocks or other debris but allow flow conditions to stabilize before collecting measurements.

Install two instream PTs at each Site 1 and one PT at Site 2 and Site 3 in as deep of a location within the pool as is accessible without topping your waders. The second instream PT at Site 1 is a back-up in case the primary is damaged or lost and both PTs should be deployed in the same pool.

Install the DO logger in the same pools as the PT(s). Place the DO logger in or near the deepest location in the pool that is also in a well-mixed area both vertically within the pool and in a streamwise direction (not in a non-flowing backwater area). Unless representative of stream conditions throughout the reach (i.e., minimal canopy cover), avoid a location where local temperatures in the pool may be impacted by direct sun exposure for long periods of the day, to minimize temperature changes unrelated to water temperature. Try to install the logger in as close to a vertical position as possible per manufacturer's recommendation.

Install Vertical Benchmark

Differential leveling requires a VBM established as an arbitrary reference elevation at each site. A VBM must be established on stable, immovable features (e.g., tree root greater than 3-in, large/established branch, large wood jam, boulder, etc.) within sight of the pool where the PT is deployed. Since VBMs are intended to provide a continuous record of elevation changes and vertical control for future years, preservation of the VBM is vital. During the installation visit, hammer a lag bolt into the tree root or branch, leaving the bolt head and 0.5 - 0.75-in of the bolt exposed for the stadia rod to balance on. Label the VBM with flagging. Ensure that the stadia rod can be placed vertically on the VBM without obstruction and that the VBM is visible from the stream.

Scout locations to set up the auto level and tripod and ensure that the VBM and each PT are visible from this location. Ensure that the horizontal line of sight from the auto level is above the VBM. If the VBM is above the auto level line of sight, you cannot collect the elevation of the VBM.

Install Pressure Transducer

Step 1. Once a suitable location within a pool is identified for PT deployment, determine whether you will use a 4-7 ft or a 16-in housing, attach the PTs inside the housings as described in Office Tasks 3, and use permanent black marker to label the housings with the PT serial number. Longer housing is preferred for stability and allows for the PT to be placed deeper in the water column.

Step 2. Drive two T-posts (preferable) or one piece of 5/8-in rebar (30-36-in long) into the streambed and/or bank using a post pounder or mallet. Drive the T-posts more than 2-ft deep, or until vertically and horizontally stable when grasped from the top and moved vigorously. If using 16-in housing, pound the rebar into the bed with mallet to a depth where the rebar feels stable vertically and horizontally. This is usually at least a third the total length of the rebar.

Step 3. If using 4–7-ft housings, affix the housing to the T-posts using hose clamps. Affix the housing at an angle between 45 - 70° to make it easier to access from the bank (Figure 7). The bottom of the housing should be one boot-height (about 2-in, Figure 8) above the streambed and the top of the housing should be accessible.

Step 4. Use the lag bolt at the base of the housing to rest stadia rod on while taking depth measurements. If using a 16-in housing, affix the housing vertically or horizontally to rebar with at least one hose-clamp and a zip-tie (Figure 9).

Step 5. Fill in all applicable fields in the Survey123 installation form on tablet.

Step 6. Document the installation with a photo that shows relative position of PT housing(s) in pool using the Survey123 installation form.

Once deployed, it is imperative that the instream PT remain at the reference level, or height under water, for the duration of the gaging period. This ensures an accurate relation between measured flow and recorded depth of the PT below the water surface.

It is not recommended to move an instream PT unless there is a specific reason to do so (e.g., extreme biofouling, data download, or poor initial deployment). Any vertical or horizontal movement, would change the reference depth of the PT and require a new auto level survey to obtain a new reference elevation (See *Auto Level Survey* section under the *Site Visit* module for protocol and details.). If a PT must be removed, be very careful to return the PT to the same level within the housing, as well as to the same level within the stream. The use of a cable to attach the logger to the cap of the housing allows for the logger to be returned to the same level.


Figure 7. Six-ft PT housing installation.


Figure 8. Perforated housing: perforations circumvent PVC (reprinted with permission: Cowan 2018).

Figure 9. Pressure transducer with 16-in HOBO® housing installation affixed to rebar. Photo taken at end of gaging season (October). PT should be fully submerged during installation.

Install Dissolved Oxygen Logger

Step 1. Determine if the location warrants a longer 3-ft housing or a shorter 16-in housing. Longer housings are preferred for stability, deeper placement in the water column, and ease of access for downloads and biofouling checks. The short housing should be used only if it is impossible to secure T-posts to the streambed (e.g. impenetrable bedrock with no fissures to drive T-posts into).

Step 2. Install one DO logger per reach in the same pool as the PT(s) and in the same general area as the PT(s). If using the shorter DO housing, affix it to the same T-post as the PT.

Step 3. If using T-posts for the PT logger, affix the DO logger housing to the T-post (Figure 10). If it is not possible to use the streambed, the bank is a less preferred option so long as landowner permission is secured.

Step 4. Affix the housing to the T-posts using hose clamps. Establish the housing at a 90° angle and make it as close to vertical as possible. The bottom of the housing should be one boot-width (about 2-in) above the streambed and the top of the housing should be accessible without needing a ladder.

Figure 10. A 3-4-ft housing with DO logger inside is attached to a T-post next to staff plate (right side of photo). The 6-8-ft PT housing is affixed diagonally across both T-posts in the pool.

Step 5. If using a short housing, pound rebar into the streambed with a mallet and affix housing vertically to rebar with at least one hose-clamps and a zip-tie (Figure 11).

Step 6. Use a Sharpie to write the DO logger's serial number on a visible location on the outside of the logger housing, and if theft is not a concern, use flagging with the serial number, or a unique identifier associated with the logger.

Step 7. Take and record four 17-point readings 0.3-m above the DO logger: a) facing upstream, b) facing downstream, c) facing the left bank, d) facing the right bank. The observer should revolve around the densiometer (i.e., the densitometer pivots around a point) over the center point of the transect (as opposed to the densiometer revolving around the observer). See the *Stream Shading (Densiometer Readings)* section in the *Physical Habitat Transect-Based Measurements* module for details.

Figure 11. A 16-in PVC housing affixed to rebar. This photo was taken at retrieval during baseflow conditions. Housing should be fully under water at deployment.

Refer to the DO logger manual referenced in this document for more details about calibration, maintenance, and use of the DO loggers. The manufacturer, Onset, also has instructional videos and technical phone support. Do not hesitate to call the company if you have technical issues.

Install Seasonal Staff Plate

This protocol for installing a staff plate is largely based on the *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson, 1994). A staff plate is a scale (usually enameled steel, marked in tenths of ft, placed in the stream to show the elevation of the water surface. It is calibrated by referencing the numbered height on the plate to the surveyed elevation of the water surface and its associated flow at the time of installation.

A plot of stage against discharge is known as a rating curve. The staff plate is used to develop the rating curve by relating measured stream flow to water surface elevation above the PT logger. The rating curve is developed after numerous visits to the site to observe stage and measure stream flow.

Procedure For Installing a Staff Plate:

Step 1. Install the staff plate in the selected pool, making sure the lower end of the plate is within the channel at low flow. In other words, be sure that the staff plate extends deeper than the hydrologic control elevation so that if the pool disconnects, the staff plate will still be in the water. Also ensure the staff plate is high enough that any potential increase in stage from late season storms would not overtop the plate. Avoid installing the plate in the path of high-velocity currents or floating debris. Position the plate to be readable from the zero end of the cross section or another location accessible during high flows. (Use binoculars in difficult cases, if necessary.)

Step 2. Drive a steel T-post, fence post, or pipe vertically into the streambed and use heavy-duty zip-ties or hose claps to secure the staff plate to the post. The staff plate can be attached to the same post that the loggers are mounted to. In streambeds where boulders make this impossible, look for a vertical face on a large boulder or tree, drill holes, and attach the plate with expansion bolts or screws.

Step 3. Ensure that the staff plate is securely installed. This information will be used to determine if there was any movement of the staff plate during the monitoring period.

It is very important to ensure that the staff plate and post is securely mounted and will not move for the duration of the field season, even during moderate flow events (Figure 12). With all CEMAF methods, it is best to ensure that the landowner is okay with how the equipment is mounted in the stream.

Figure 12. Example of staff plate affixed securely to T-post.

Install Barologger

Step 1. Use a 16-in housing to protect the barologger, and affix with hose-clamps or zip-ties to a tree root, limb, or base of dense shrub. Install a barologger in the riparian area adjacent to the stream reach to record air pressure and air temperature every 15-min. Deploy in a location that does not receive direct sunlight (e.g., underneath a tree root or dense overhanging vegetation).

Step 2. If vandalism is not a concern, attach ample flagging to nearby vegetation. If vandalism is a concern, be sure the logger is not visible to the public.

Step 3. Document the installation with photos and record the compass bearing and distance from the VBM to the barologger to assist field crews with finding the logger during removal.

Barometric pressure is typically consistent across a limited, low relief region. If multiple monitoring reaches are located within a 15-km/10-mi radius and 2,000-ft elevation of a centrally located barologger, then one barologger can be used to compensate all sites in that area.

Collect Survey Data

Fill in all other applicable fields on the Survey123 installation form. The form is arranged in the order that steps should be completed. Ensure that all data fields are filled out. If it is not possible to complete any field, enter –9999 to indicate the value was intentionally not collected. If the pool is disconnected enter 0 instead of -9999, as 0 is the proper field measurement for discharge in this instance.

Auto Level Survey

Auto level surveys collect the elevation of the streambed and the water surface and are based on CDFW's Standard Operation Procedure (SOP) for Streambed and Water Surface Elevation Data Collection in California (CDFW 2013). Elevations recorded to the nearest 0.01-ft are suitable for developing rating curves, however in general, the magnification of optical levels is about 30 times and allows for readings as precise as 0.001-ft up to about 150-ft. This can be dependent on the distance of the rod to the level, and on environmental conditions such as the absence of heat waves (Kenney 2010) but measurements to the nearest 0.001-ft are also acceptable.

Step 1. Set-up tripod firmly into the ground by depressing foot plates into the ground, adjust the height of the tripod legs so that the base is as level as possible; affix auto level using the threaded tripod screw but do not use excessive force since it could damage the base plate and head plate (Figure 13). Level the instrument by raising or lowering the leveling screws to center the bubble within the circular level. The bubble will usually be nearer to one side, indicating that side of the auto level is higher. To center the bubble, turn the leveling screw on the lower side of the level clockwise to raise that side of the level, while turning the leveling screw on the higher side of the level counterclockwise, to lower it (Figure 14). When the instrument is level, the bubble should stay centered when rotated through 90° turns. *All leveling screws should only be tightened with finger pressure to prevent damage to the screws, base or tripod head.* Ensure that the VBM and PT pool is visible from tripod location and the VBM is lower than auto level line of sight (Figure 15).

For more detailed instructions on setting up equipment prior to performing an auto level survey, you may refer to this instructional video.

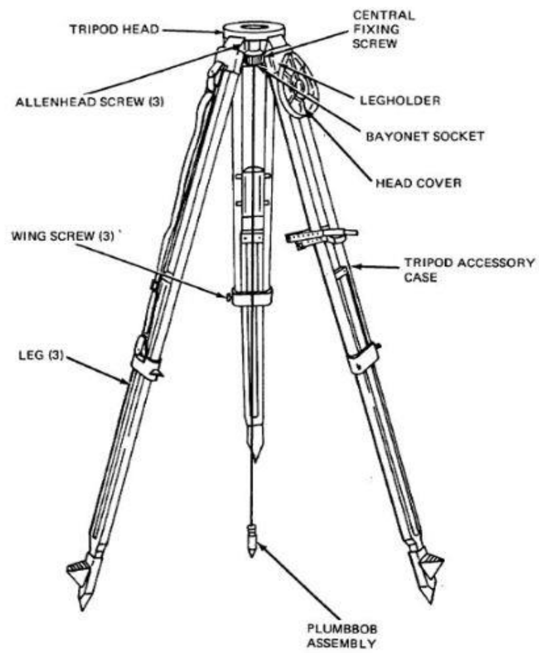


Figure 13. Diagram of a surveyor's tripod (reprinted from California State Parks, 2019).

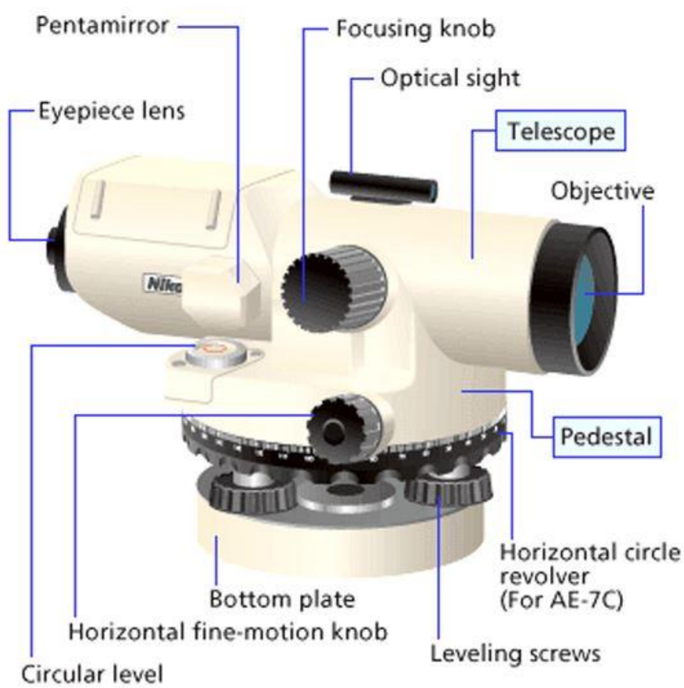


Figure 14. Diagram of the various components of an auto level (reprinted from California State Parks, 2019).

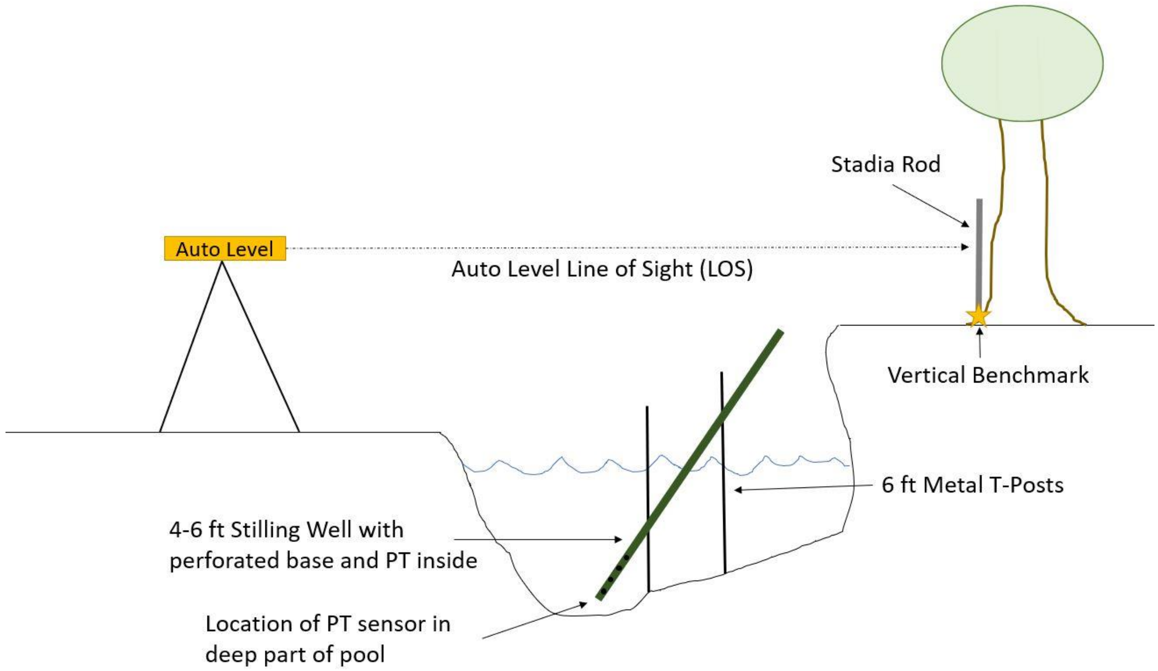


Figure 15. Ensure that the VBM and PT pool are visible from the location of the auto level and that the VBM is lower than auto level line of sight.

It is critical to perform an accurate auto level survey to be able to create a stage-discharge rating curve. Common survey mistakes include: misreading the stadia rod (e.g., reading 3.54 instead of 3.45, see Figure 16) sighting with the incorrect cross hairs (Figure 17), stadia rod not being vertical or extended properly between sections, or failing to properly level the auto level. Environmental factors including wind, precipitation, and dense vegetation can make taking accurate readings more difficult and should be dealt with carefully. Vegetation can be trimmed to improve the visibility of the markings. Small errors in SZF and WSEL elevations can strongly influence the accuracy of the hydrograph, so take time to make these measurements properly.

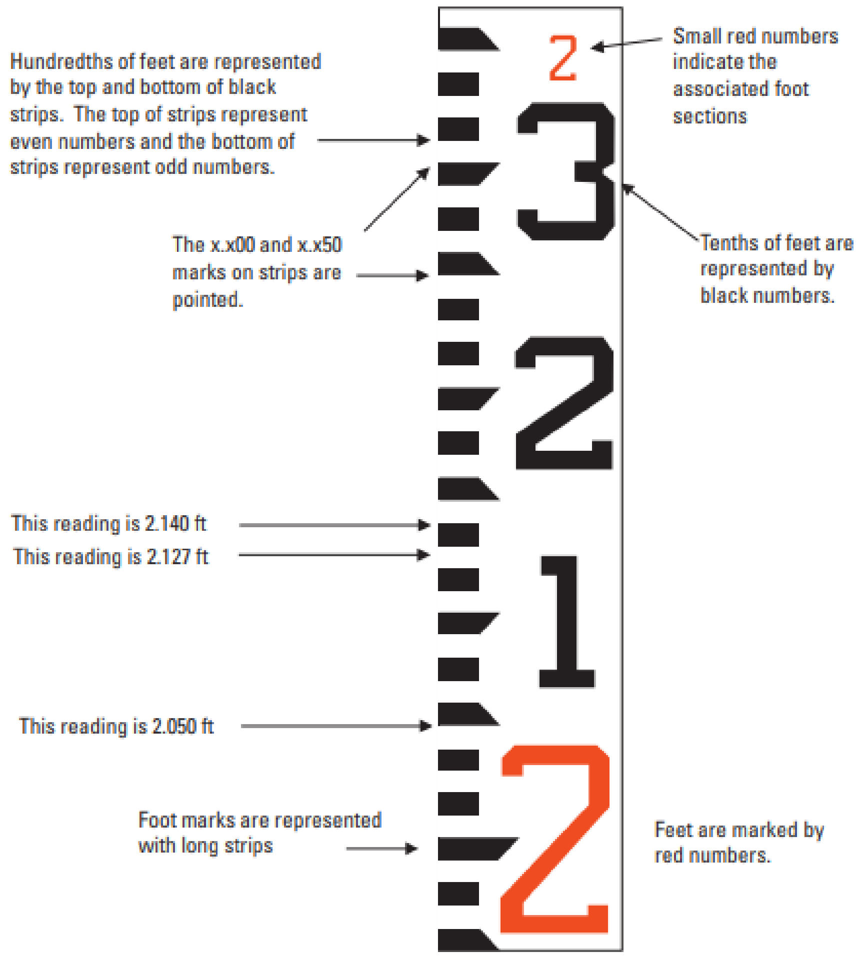


Figure 16. Staff plates and stadia rods allow you to measure to the nearest thousandth of a foot. The depiction of a staff plate or stadia rod above indicates how to properly interpret measurements to the thousandths of ft (reprinted from U.S. Geological Survey, 2010).

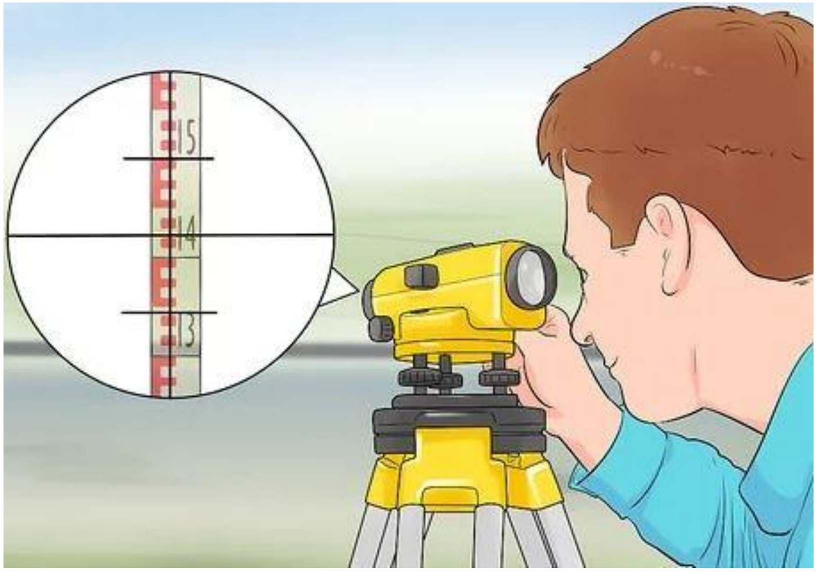


Figure 17. Example of how to use the auto level crosshairs to take a measurement on the stadia rod. Ensure that you use the middle crosshair when taking a reading. For example, in this image, the reading would be 14.2 ft (reprinted from WikiHow article by Kamran, 2024).

Step 2. Survey and record the elevation of VBM to nearest 0.01-ft.

Step 3. Record elevation at staff plates to the nearest 0.01-ft.

Step 4. Collect PT elevation. Place the stadia rod on the lag bolt at the bottom of the PT housing.

Step 5. Collect elevation at staff plates to the nearest 0.01-ft.

Step 6. Collect the elevation of the pool directly under the stilling well.

Step 7. Collect the elevation of the maximum depth in the pool.

Step 8. Collect the WSEL. The WSEL measurements can be compared to water stage (or level) measurements from the PT taken on the same date and time. If there is a discrepancy between the two values, the WSEL measurements are used to adjust the PT measurements after the gaging period. Collect the WSEL in the same pool as the PT in a location with no surface turbulence (i.e., flatwater) as close to the PT as possible. Hold the stadia rod level, away from your body and slowly touch the bottom of the stadia rod to the surface of the water several times, forming a meniscus when the rod touches the water (Figure 18). Say “touch” to alert the auto level operator to the exact time the base of the stadia rod forms a meniscus in the water’s surface. The auto level operator records the elevation most consistently observed when the base of the stadia rod forms a meniscus. Another option is to set the base of the stadia rod at the edge of the pool and adjacent to the PT logger so that the stadia rod is resting on the substrate at the WSEL.

Figure 18. Stadia rod forming a meniscus on water's surface (reprinted from CDFW, 2013).

Step 9. Close the survey by reoccupying the VBM. If the VBM start elevation and VBM stop elevation are within ± 0.01-ft, then the survey is accurate. If not, it is likely the auto level shifted during the survey. Redo steps 3 through 7 until ± 0.01-ft tolerance is met.

Step 10. Record ending depth from the staff plate and time. The start depth and ending depth should be within ± 0.01-ft of each other. If depth changes more than this during the auto level survey, then the flow level is changing too rapidly to perform an accurate survey and you must wait until the flow level stabilizes. If depths are ± 0.01-ft pre- and post-survey, then you can conclude the survey.

Pool Characteristics

Step 1. Collect distance from the DO logger to the pool head by following the thalweg (not necessarily a straight line).

Step 2. Use a YSI meter to collect DO concentration, DO saturation, specific conductance, and water temperature in the logger pool.

Note: Be sure to follow the manufacturer's instructions on calibration and operation. These measurements should only be taken as close as possible to the DO logger and only after the DO logger is stabilized and logging. If using the YSI Pro2030 DO/Conductivity meter (or similar), power the instrument on and wait approximately 5 to 15-min for the storage chamber to become completely saturated and to allow the sensor to stabilize.

Step 3. Record pool geology metrics during installation by visually assessing the percentage of each rock type present in the pool. For this survey, use the same classifications described in the bioassessment methods (Document the installation with photos in the Survey123 from. These photos can be used for data reports and to reference at the end of the field season for troubleshooting purposes. Include both banks in the photo.

Table 2: Substrate size categories used for assessing pool geology.

Size Class Code	Size Class Description	Intermediate Axis Common Size Reference	Size Class Range
RS	bedrock, smooth	larger than a car	> 4 m
RR	bedrock, rough	larger than a car	> 4 m
RC[21]	concrete/ asphalt	larger than a car	> 4 m
XB	boulder, large	meter stick to car	1 - 4 m
SB	boulder, small	basketball to meter stick	250 mm - 1 m
CB	cobble	tennis ball to basketball	64 - 250 mm
GC	gravel, coarse	marble to tennis ball	16 - 64 mm
GF	gravel, fine	ladybug to marble	2 - 16 mm
SA	sand	gritty to ladybug	0.06 - 2 mm
FN	fines	not gritty	< 0.06 mm
HP	hardpan (consolidated fines)		< 0.06 mm
WD	wood		
OT	other		

Discharge Measurement

The protocol herein is largely based on the CDFW Instream Flow Program (IFP) (CDFW 2020) and draws from other sources for low-flow measurements.

Calibration of the FH950

Calibrate the FH950 each day before data collection begins by performing a zero adjustment. Keep a copy of the manual readily available in the field.

Step 1. Suspend the sensor in a non-metallic bucket with water at least 6-in deep. To suspend the sensor, the meter cable can be clamped or otherwise secured to a piece of rebar placed over the bucket. Leave at least 3-in between the sensor and the sides and bottom of the bucket.

Note: Avoid touching the electrodes on the sensor.

Step 2. Wait until the water in the bucket is completely still before proceeding to Step 3.

Step 3. When the water is still, power on the FH950. From the Main Menu screen on the FH950, select **Setup**, then select **Velocity Calibration**.

Step 4. Allow the meter to complete one velocity cycle (the default is 10-seconds and cannot be changed) If the meter reads 0.00-ft per second (ft/s), select **OK**. If the water is still and the meter does not read 0.00-ft/s, wait for the reading to stabilize, and select **Zero Velocity**, then select **OK**. The zero stability of this instrument is +/- 0.05-ft/s (Hach 2018). If a velocity of greater than +/- 0.05-ft/s is read, repeat the zero adjust process starting with Step 2. Consider cleaning the sensor electrodes (disposable isopropyl pads) or ensuring the water inside the bucket is completely stable before repeating the process.

Connecting the FH950 to the Top-setting Wading Rod

Before collecting discharge, attach the FH950 to the top-setting wading rod as follows:

Step 1. Place the mounting hole of the FH950 sensor over the mounting shaft on the bottom end of the sliding top-setting rod.

Step 2. Hand-tighten the thumb screw clockwise to secure the sensor onto the mounting shaft. Do not overtighten the thumb screw.

Note: The FH950's thumb screw can detach from the sensor body; bring extra thumb screws into the field.

Determining Cell Depth and Width

The FH950 measures velocity and is used in conjunction with the top-setting wading rod to estimate site-specific discharge measurements. The depth that the FH950 sensor is set at for each individual measurement along the cross section is based on water depth at that station. The fixed, hexagonal portion of the top-setting wading rod measures depth and has graduations of 0.10-ft. Double graduation marks represent increments of 0.50-ft, and triple graduation marks represent increments of 1.00-ft (Figure 19) The hexagonal rod scale is read to the nearest 0.05-ft by visually estimating between the 0.10-ft graduation increments.

This is particularly important when measuring shallow depths. **The minimum operable water depth for the FH950 sensor is 0.15-ft, which is the depth at which the sensor is fully submerged.**

Figure 19. Hexagonal portion of the top-setting wading rod measures depth and has graduations of 0.10-ft.

The vernier setting scale on the handle of the top-setting wading rod is used in conjunction with the sliding setting rod to position the sensor at the correct depth to measure velocity. The vernier scale has graduation marks of 0.10-ft and the graduation marks on the setting rod represent increments of 1.00-ft (Figure 20).

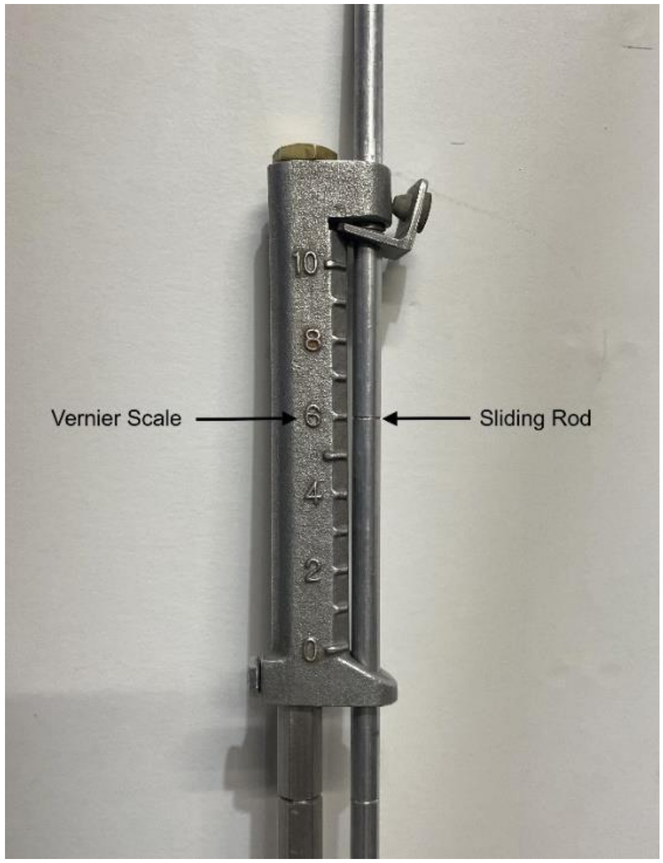


Figure 20. Vernier scale and sliding rod aligned for measuring flow at 0.6-ft depth.

When the foot scale on the setting rod and vernier scale are aligned to match the water depth observed on the hexagonal rod, the sensor is automatically set to six-tenths depth (0.6 depth) from the water surface. In accordance with USGS (Turnipseed and Sauer 2010) protocol:

For depths measuring 0.15 to 2.45-ft, one measurement is taken at 0.6 depth from the water surface. This is referred to as the one-point method. Set the sensor at 0.6 depth by lining up the foot scale on the setting rod with the vernier scale on the top-setting wading rod handle. For example, if the depth is 0.90-ft, line up the 0 on the setting rod foot scale with the 9 on the vernier scale of the wading rod handle. In this example, the sensor will automatically be set to measure velocity at a depth of 0.36-ft.

For depths greater than or equal to 2.50-ft, depth measurements are taken at two-tenths depth (0.2 depth) and eight-tenths depth (0.8 depth) from the water surface, then averaged. This is referred to as the two-point method (Figure 21).

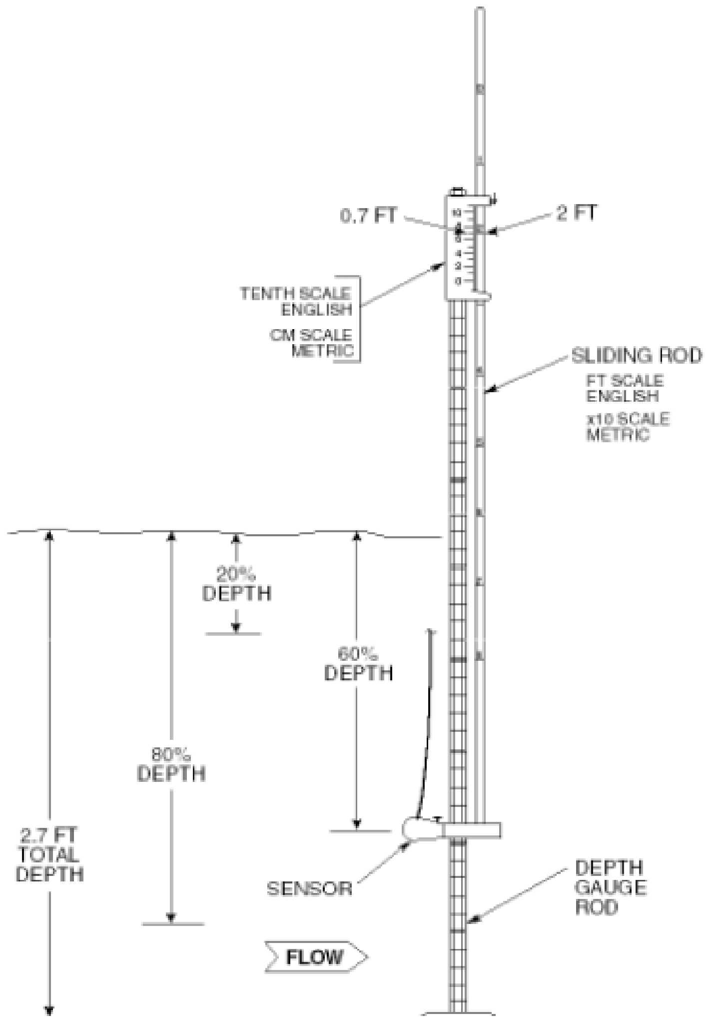


Figure 21. Diagram showing velocity measurement locations at 0.2 (20%), 0.6 (60%) and 0.8 (80%) depth within a channel, and how these are measured using a wading rod and current meter (Nolan and Shields, 2000).

For example, if the depth is 2.50-ft, set the wading rod as follows:

- To measure at 0.2 depth from the water surface, double the depth observed on the hexagonal rod (i.e., 2.50-ft x 2 = 5.00-ft) and set the scale to 5.00-ft by aligning the “5” on the setting rod foot scale with the “0” on the vernier scale of the wading rod handle. This will automatically set the sensor to measure velocity at a depth of 2.00-ft.
- To measure at 0.8 depth, divide the depth by two (i.e., 2.50-ft / 2 = 1.25-ft) and set the scale to 1.25-ft by aligning the “1” on the setting rod foot scale halfway between “2” and “3” on the vernier scale of the wading

rod handle. This will automatically set the sensor to measure velocity at a depth of 0.50-ft.

- If the two-point method produces a non-standard or inverted-velocity profile, take an additional velocity measurement at 0.6 depth. This is referred to as the three-point method. A non-standard velocity profile is one in which the velocity at the 0.8 depth is greater than that at the 0.2 depth, or in which the velocity at the 0.2 depth is greater than twice that of the 0.8 depth (Turnipseed and Sauer 2010). The velocity at 0.6 depth is then averaged along with the average velocities of the 0.2 and 0.8 depths to determine the velocity at that station along the cross section.

A minimum of 20 vertical cell measurements (or stations) are required for each discharge cross section (exception below). The cross section must have no more than 10% (ideally less than 5%) of the total discharge occurring in any one cell or between any two stations along the cross section.

As a rough guide, the distance between each station can be determined by the length of the cross section, where the maximum distance between each station would be the length of the cross section divided by 20 (to account for the minimum number of required cell measurements). Equal distances between stations can be maintained if the depth and velocity at each station is relatively uniform and the discharge is evenly distributed across the stream (Rantz 1982). Shorter distances between stations may be necessary if the depth or velocity varies along the cross section. Due to the width of the sensor, and to avoid overlapping velocity profiles in adjacent cells, the distance between stations can be no less than 0.25-ft.

Often, along the edges of a transect, the velocity will be slow or not moving. When the flow meter detects a velocity measurement of zero, record that value and move to the next station.

Special Considerations for Small Channels and Low Flow

Low flows are important to measure accurately to understand abiotic conditions and their effects on aquatic biota. Baseflows are often a period when aquatic ecosystems are at their most vulnerable state. The CEMAF provides guidance that can be followed when it is not possible to find a suitable transect at least 5-ft wide due to extreme low flow conditions. Special considerations for measuring discharge in small channels and during low flow is based on international standards (British Standard, 2007), guidance from other members of the local flow monitoring community, and direct experience working during the driest three-year period of California's instrumented record (Medellin-Azuara et al.). These unprecedented stream conditions truncated the field season due to accelerated drying of streambeds, and narrowed the wetted stream width, which made following existing protocols impossible.

The IFP discharge SOP requires transects to be at least 5-ft wide to encompass 20 cells spaced 0.25-ft apart. This standard is based upon the original USGS *procedure for conventional current-meter measurement of discharge* (Rantz 1982) that stipulates that no cell should contain more than 10% of the total discharge and ideally no cell should contain more than 5% of the total discharge. The author admits the 5% target is seldom achieved when collecting 25-30 verticals. If no suitable transect can be found that allows for 20 cells, the CEMAF protocol allows discharge measurements to be collected using the maximum number of cells that can fit in the selected transect (British Standard, 2007). To determine the maximum number of cells that can fit within a small channel transect, use the published minimum width requirements of the specific flow meter (HACH FH950 = 0.25-ft). *All effort should be made to walk the stream reach and look for suitable transects, before deviating from the 20-cell minimum.*

When it is necessary to collect fewer than 20 cells, take multiple discharge measurements to validate measurement accuracy. Take the first discharge measurement with the maximum number of cells possible. Take the second measurement along the same transect with the same number of cells as the first but start on the opposite stream edge. If the difference between the two measurements is greater than 10% (abs [discharge 1 – discharge 2]/discharge 1 x 100), collect a third discharge measurement. Record all flow measurements in Survey123. The first discharge measurement recorded that is within 10% of another is the discharge measurement that will be used.

Good site selection is crucial for capturing accurate discharge measurements, especially when there are fewer cells. This is because each cell will contain proportionally more weight relative to the total discharge, when compared to the traditional 20-cell-minimum method. Here are some important considerations to keep in mind when measuring flow in small channels:

- It is essential to find a transect that has uniformity of depths, streambed, and velocities.
- Avoid or modify transects to reduce eddies and non-linear flow paths. This includes moving cobbles and other objects that can increase flow roughness from the area immediately upstream and downstream of the transect.
- Use caution when modifying a transect so as not to affect the hydraulic control. If flow is measured after modifying the hydraulic control, the

measurement could be biased high while the pool drains and reaches a new equilibrium.

- If possible, avoid transects where most of the cells are too slow for the flow meter to detect velocity (i.e., deeper, slow-moving pools). Locate the transects in locations where most of the channel meets the minimum depth requirement of the flow meter (HACH FH950 = 0.15-ft) and where flow is detectable by the sensor.
- When zero-velocity is measured by the flow meter at a specific cell, record the zero value. Do not continue to move the cell until there is a non-zero value.

Surveying Staff Gage

If the discharge site is not located near the staff plate, a temporary staff gage (small piece of rebar with measuring tape affixed) is used to determine if the stream discharge has fluctuated during the field visit, which might be caused by precipitation events or upstream water use. Before beginning any data collection, use a mallet to install a staff gage in the pool where it will be secure and undisturbed for the duration of the site visit. Ensure that the staff gage is completely vertical and record the water level when you start your discharge collection. At the end of the discharge collection, record the water level from the staff gage for a second time. If the water level has changed by more than 0.01-ft, it will be necessary to perform all measurements again. Note that if the water level is changing rapidly due to recent precipitation, it may not be the most optimal time to complete a site visit.

Discharge Cross Section Setup

Step 1. Identify a suitable cross section (or transect) perpendicular to the stream flow. Mark the cross section with a headpin (HP) on the left bank (looking upstream) and a tailpin (TP) on the right bank. Rebar can be used for this purpose but sticks or rocks can also be used so long as they are stable and not likely to shift during measurements. Install the HP and TP into the streambank beyond the wetted edge of the water.

Step 2. Take a reading from the staff plate, or if the staff plate is not close enough to the transect to easily check, from the temporary staff gage into the substrate near the stream's edge.

Step 3. Once the HP and TP are installed on the streambank, stretch a measuring tape from HP to TP and ensure that the tape is taut. Make sure to have the zero side of the tape measure start on the HP.

Step 4. If the cross section has been modified in any way to provide more reliable velocity measurements, allow the flow conditions to stabilize before beginning. Once velocity measurements have begun, do not alter the cross section.

Step 5. After the measuring tape is installed, photograph the cross section from the upstream and then the downstream direction, being sure to include the survey measuring tape in the image. Photographs are helpful for documenting and comparing wetted cross section widths and channel conditions between measurements, validating discharge, and publishing in reports.

Data Collection Using the Hach FH950

Step 1. Populate the datasheet or Survey123 form header information, including the stream name, site information, FH950 unit ID number, data evaluator full name, data recorder full name, and photo range.

Step 2. Record the staff plate or temporary staff gage water surface height in the "Gage Start" field of the datasheet and record the start time. ***Recording the start time is very important for the creation of the rating curves.***

Step 3. If the discharge measurement is being repeated at an established cross section, clearly note on the datasheet any changes to the stream channel in the area around the cross section. Changes to the stream channel between measurements (e.g., due to downstream migration of woody debris or sediment) can impact the hydraulics of the stream and affect the stage-discharge relation.

Step 4. Record the total HP to TP distance in the appropriate field on the datasheet. Next, record the distances from the HP to the wetted edges of the stream at the left bank wetted edge (LBWE) and the right bank wetted edge (RBWE), looking upstream.

Step 5. Press the FH950 power button to turn on the unit.

Step 6. From the Main Menu screen, select **Profiler**. Then enter the evaluator's name and select **OK**. Next, select **Stream** and enter the stream name or reach that is being measured, then select **OK**. The next screen will prompt the user to enter the stage reference; enter "100" and select **OK**.

Step 7. Starting on the left bank looking upstream, the first station for the discharge measurement is the LBWE. From the Profiler Menu screen, select **Edge/Obstruction**, then select **Left**. This will automatically set the depth and velocity to zero. Next, enter the distance to the station by selecting **Dist. to Vertical**; enter the distance between the HP and the LBWE and select **OK**. Then select **Next** at the bottom of the screen to move onto the second station.

Step 8. At the first wetted measurement station, select **Edge/Obstruction**, then select **Open Water**. Next, select **Dist. to Vertical** and enter the distance between the measurement station and the HP, then select **OK**. Record the distance in the appropriate field on the datasheet.

Note: The first and last wetted measurements must be taken as close as possible to the LBWE and RBWE, respectively, due to the use of the mid-section calculation method (see *Discharge Calculations*).

Step 9. Always stand at least 1.50-ft from the sensor to avoid interfering with velocity measurements (Rantz 1982). At each station, place the top-setting wading rod onto the streambed, check that it is plumb, and record the depth from the hexagonal rod in the appropriate field on the datasheet.

Step 10. Select **Set Depth** from the Profiler Menu and enter in the stream depth at the station being measured, then select **OK**. Adjust the vernier scale on the top-setting wading rod to the proper depth as described in the section titled *Connecting the FH950 to the Top-setting Wading Rod*.

Note: Use of the vernier scale on the top-setting wading rod automatically adjusts the sensor to the correct measurement depth. If the vernier scale does not perfectly match on both sides of the top-setting wading rod, use the same side throughout data collection for consistency.

Step 11. From the Profiler Menu screen, select **Measure Velocity**. Ensure that the FH950 sensor is facing directly into the flow at the station, and that there is no debris impeding or obstructing the sensor from detecting flow at that station.

a. If the depth of the stream is less than 2.50-ft, select **One Point**, then select 0.6. The FH950 will then display the depth at which to set the sensor. Properly adjusting the top-setting wading rod using the vernier scale will automatically set the sensor to the correct depth. Next, select **Capture**, and wait for the fixed period averaging (FPA) time to elapse, then select **OK**. Fixed Period Averaging averages data over a user-selectable period (1 to 480 seconds) which should be set to 20-30 seconds for CEMAF. Lastly, select **Main**. The FH950 will then return to the Profiler Menu screen for that station. Select **Next** to continue to the next station.

b. If the depth of the stream is greater than or equal to 2.50-ft:

    i. Select **Two Point**, then select **0.2**. Ensure that the vernier scale on the top-setting rod is adjusted to the proper depth. This measurement will represent the velocity at 0.2 depth from the water surface. Next, select **Capture**, and wait for the FPA time to elapse, then select **OK**.

ii. Next, select **0.8**. Ensure that the vernier scale on the top-setting rod is adjusted to the proper depth. This measurement will represent the velocity at 0.8 depth from the water surface. Next, select **Capture**, and wait for the FPA time to elapse, then select **OK**. Lastly, select **Main**. The FH950 will then return to the Profiler Menu screen for that station. Select **Next** to continue to the next station.

Note: Because the sensor needs to be oriented directly into the flow at the station, it may not face directly upstream.

Step 12. Record the velocity measurement to the nearest 0.01-ft/s in the appropriate field on the datasheet.

Step 13. Repeat steps 9 through 12 until the RBWE is reached.

Step 14. Once the RBWE is reached, select **Edge/Obstruction** on the Profiler Menu, and select **Right**. This will automatically set the depth and velocity to zero. Next, select **Dist. to Vertical** and enter the distance between the HP and the RBWE, then select **OK**. Record the RBWE in the appropriate field on the datasheet.

Step 15. Check the channel summary to ensure that each cell along the cross section has a partial discharge of less than 10% of the total discharge (ideally, less than 5%). From the Profiler Menu, select **Channel Summary**. The total cross section discharge will be shown in a box at the top of the screen and a bar graph will be shown at the bottom of the screen. Select the **Cont**. (i.e., Continue) box at the bottom of the screen to toggle the bar graph between the depth, velocity, and percent discharge of cells along the cross section. If any changes need to be made (e.g., because the top-setting wading rod was not adjusted properly or a cell had a partial discharge of 10% or greater), such as adding stations, checking entries, or retaking velocity measurements, follow the directions provided in the note below.

Step 16. Calculate discharge from the data on the datasheet. This may be done by the recorder during data collection if the recorder can still focus on accurate recording. Otherwise, it should be done after data collection but prior to the next step of saving the data file and turning off the instrument. Calculating discharge from the datasheet, provides an opportunity to review FH950 station entries (e.g., the station depth or the distance to vertical may have been entered incorrectly) or to take additional measurements if errors are found (e.g., if the partial discharge of a cell is greater than or equal to 10%).

Discharge Calculations

Discharge is calculated using the width, depth, and velocity data from each station along the cross section. Do not round recorded depth and velocity measurements on the datasheet (e.g., if the velocity is 1.99, do not round to 2.0). Similarly, do not round the partial discharges for individual cells. Rounding may result in inaccurate total discharge values. The total discharge can be rounded after all partial discharges have been summed.

Use the mid-section method to calculate the cell width. This method assumes that the average velocity at each station is representative of the average cell velocity (Turnipseed and Sauer 2010). In accordance with the mid-section method, the width of a cell is calculated as half of the change in distance from the preceding station plus half of the change in distance to the next station (Figure 22). This is equivalent to half the distance between adjacent stations, rather than simply the distance from the preceding station.

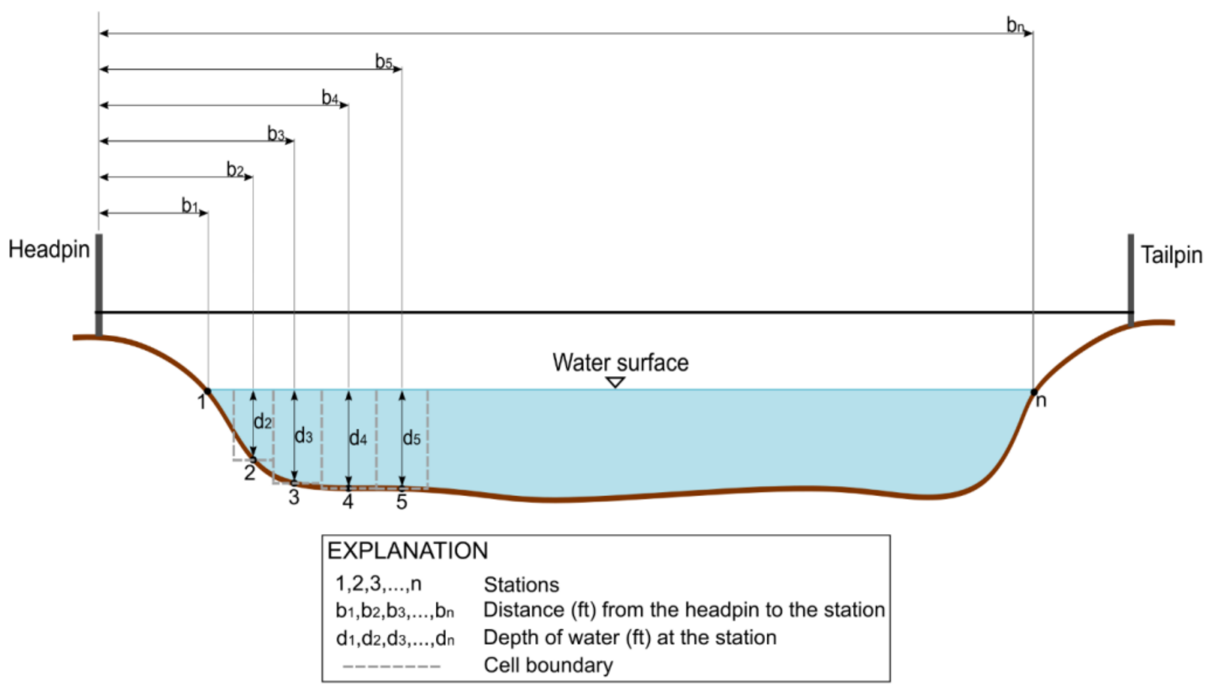


Figure 22. Cross section showing vertical measurement cells and the distances used to determine cell width using the mid-section method. Headpin, tailpin, and measuring tape are indicated over the cross section. Figure adapted from Turnipseed and Sauer (2010).

Equation 1: Cell Width

In Figure 22, the width of the first cell (Station 2) would be:

$$Width_2 = \frac{(Distance_2 - Distance_1) + (Distance_3 - Distance_2)}{2}$$

or

$$Width_2 = \frac{(Distance_3 - Distance_1)}{2}$$

$$Width_2 = \frac{(b_2 - b_1) + (b_3 - b_2)}{2} = \frac{(b_3 - b_1)}{2}$$

Where:

b = distance from HP to measurement station (ft)

Equation 2: Partial Discharge of a Cell

The partial discharge of each cell is determined by multiplying the width, depth, and velocity:

$$q = w * d * v$$

Where:

q = partial discharge of cell (cfs)

w = cell width (ft)

d = station depth (ft)

v = average station velocity (ft/s)

For example, if the cell width is 1.00-ft, the station depth is 1.20-ft, and the velocity is 1.30-ft/s, the partial discharge of the cell would be calculated as follows:

Partial discharge = 1.00-ft x 1.20-ft x 1.30-ft/s = 1.56 cfs

Note: If two velocities were taken at a station (at a depth greater than or equal to 2.50-ft), use the average velocity.

Equation 3: Total Discharge of a Cross Section

The total discharge of a cross section can then be estimated by summing each cell's partial discharge value:

$$Q = q_1 + q_2 + q_3 + \cdots q_n$$

Where:

Q = total discharge of cross section (cfs)

q_1 = partial discharge of the first cell (cfs)

q_2 = partial discharge of the second cell (cfs)

q_3 = partial discharge of the third cell (cfs)

n = total number of cells in cross section

Note: Partial discharge calculations resulting in negative values must be included in the sum (i.e., subtracted).

Equation 4: Check for Exceedance of 10% of the Total Discharge

To check what percent of the total cross section discharge is in the cell with the largest partial discharge value, use the following equation. This calculation is used to check if the discharge in any one cell exceeds 10%.

$$\text{Maximum cell discharge \%} = \frac{q_{largest}}{Q} * 100$$

Where:

$q_{largest}$ = largest partial discharge found in any one cell (cfs)

Q = total discharge of cross section (cfs)

Step 17. If stations need to be added or deleted, options for **Prev.**, **Next**, **Ins.**, and **Del.** appear at the bottom of the Profiler Menu screen. Use **Prev.** (i.e., Previous) and **Next** to navigate to the station where you would like to insert (i.e., **Ins**.) or delete (i.e., **Del**.) a station. For example, to insert a new station between Stations 3 and 4, select **Prev.** until the Profiler Menu display screen shows information for Station 3, and then select **Ins**. The new station will be named Station 4 and subsequent stations will be renamed sequentially. To delete Station 3, navigate to that station and select **Del**., then select **Yes** to confirm, and lastly select **OK** to return to the Profiler Menu. If the Channel Summary reports an unexpectedly large partial discharge, check the Depth and Distance to Vertical entries by navigating to the station(s) of concern using **Prev**. and **Next** and editing as necessary by referring to the field datasheet. To retake a velocity reading, select **Measure Velocity** at the station of concern.

Step 18. If cell values are 10% or less, select **Save Data** and **Exit** and name the file. The FH950 only allows for eight characters in the file name. Lastly, select **OK**. The file naming convention is HUC initials + site number (example: '1', not '01') + date in MMDD format. Lower Pescadero Site 3 on 06/27/22 would be LPC30627.

Step 19. After data collection is complete, check the staff plate or temporary staff gage to ensure that flow conditions did not change by more than 0.01-ft. Review the datasheet(s) to ensure completeness prior to removal of survey equipment.

Step 20. A staff member who was not the primary data recorder must thoroughly review all datasheets or electronic data forms before leaving the field site and complete the final section in the Survey123 form. Ensure that all data fields are filled out. If it is not possible to complete any field, enter –9999 to indicate the value was intentionally not collected.

Data Quality and Management

Upload field data to AGOL

Once staff have Wi-Fi service, upload Survey123 field data to AGOL as soon as possible after each field day. To upload the Survey123 field data, log into ArcGIS online through the Survey123 application on the tablet using a CDFW username and password that is part of the CEMAF aquatic group. Navigate to the CEMAF Hydrology and Water Quality Monitoring survey and click the Outbox button. The Outbox will indicate the number of surveys that need to be uploaded (Figure 23). Use the Send button in the lower right-hand corner to upload to the AGOL cloud (Figure 24).

QC Field Data

As soon as possible after each field survey, the field crews review the uploaded data together and use a separate QC spreadsheet to record any corrections to the data, without modifying the raw data. The raw data is later downloaded from AGOL, and an R script is used to process the raw data with the QC spreadsheet to create a clean, final dataset. This section explains the process field crews use to upload and QC the Suvey123 data.

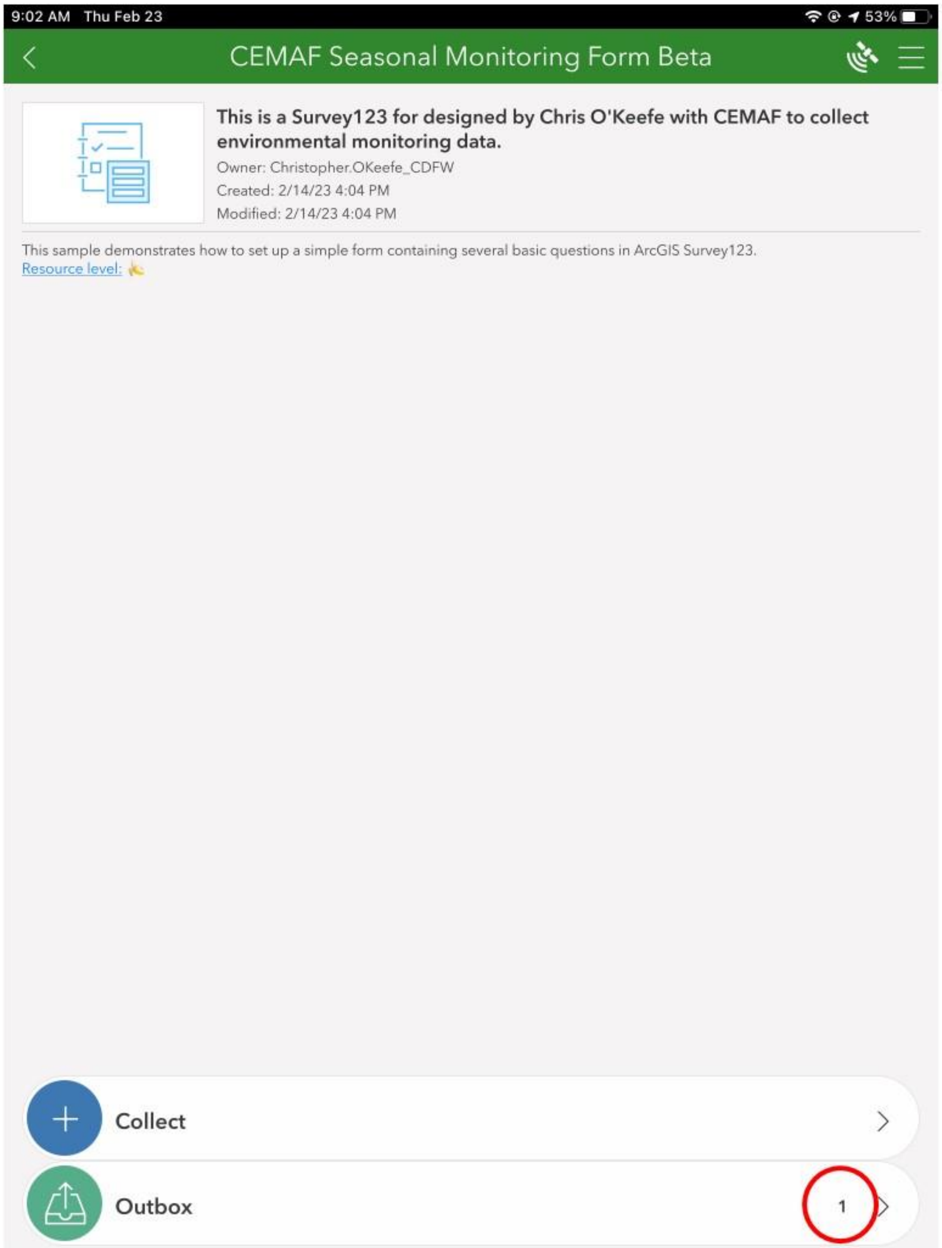


Figure 23. Screenshot of the CEMAF Hydrology and Water Quality Monitoring survey (formerly named and seen here as "Seasonal Monitoring Form Beta" navigation page. Note that there is one survey that is in the outbox that needs to be sent.

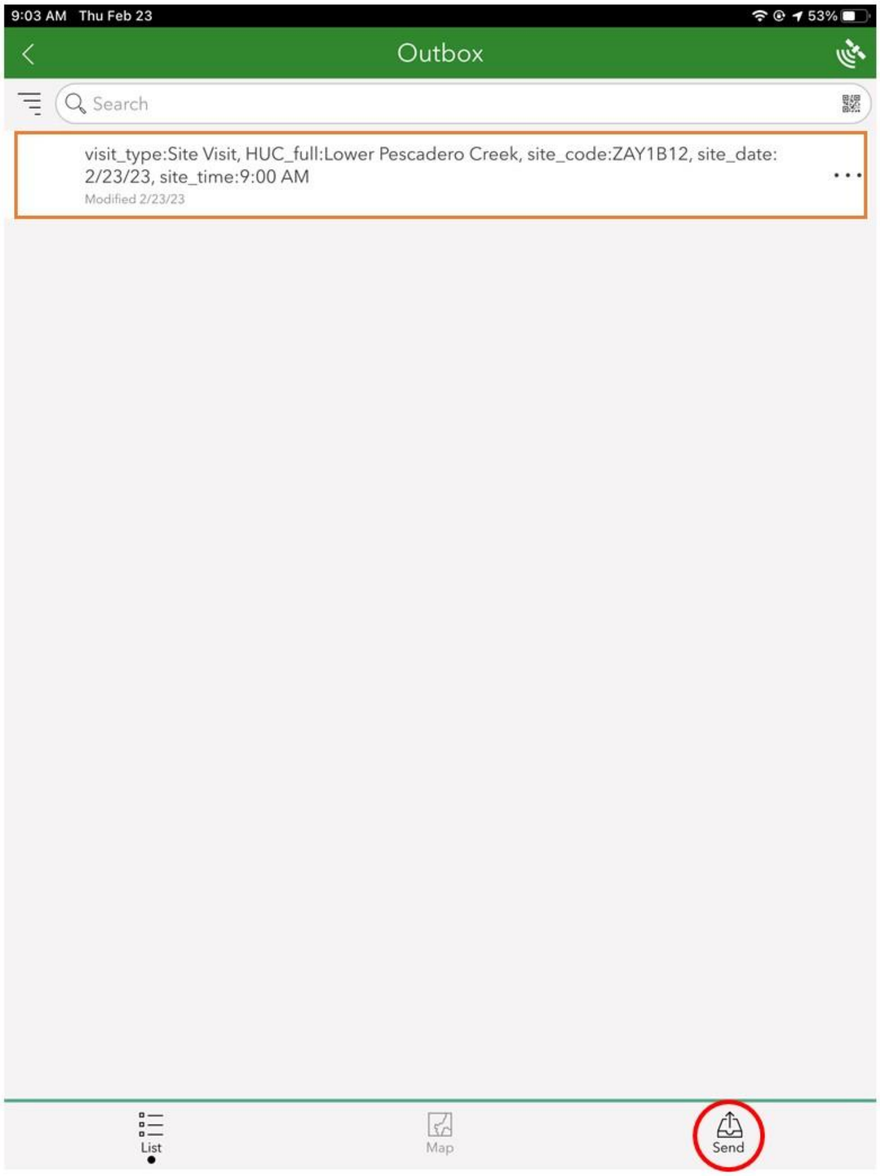


Figure 24. Screenshot of the CEMAF Hydrology and Water Quality survey Outbox page. Note that there is one Site Visit that needs to be uploaded (highlighted by the orange rectangle). Use the "send" button to upload the survey to AGOL.

Open the AGOL web portal on a computer and navigate to the CEMAF QC Web Map. Ensure the data was uploaded from the tablet before beginning this process. A CDFW AGOL username and password will be needed to access the web map.

Once logged in, open the Layers on the left side of the screen, and select the three dots on the CEMAF Hydrology and Water Quality Form to display the table (Figure 25).

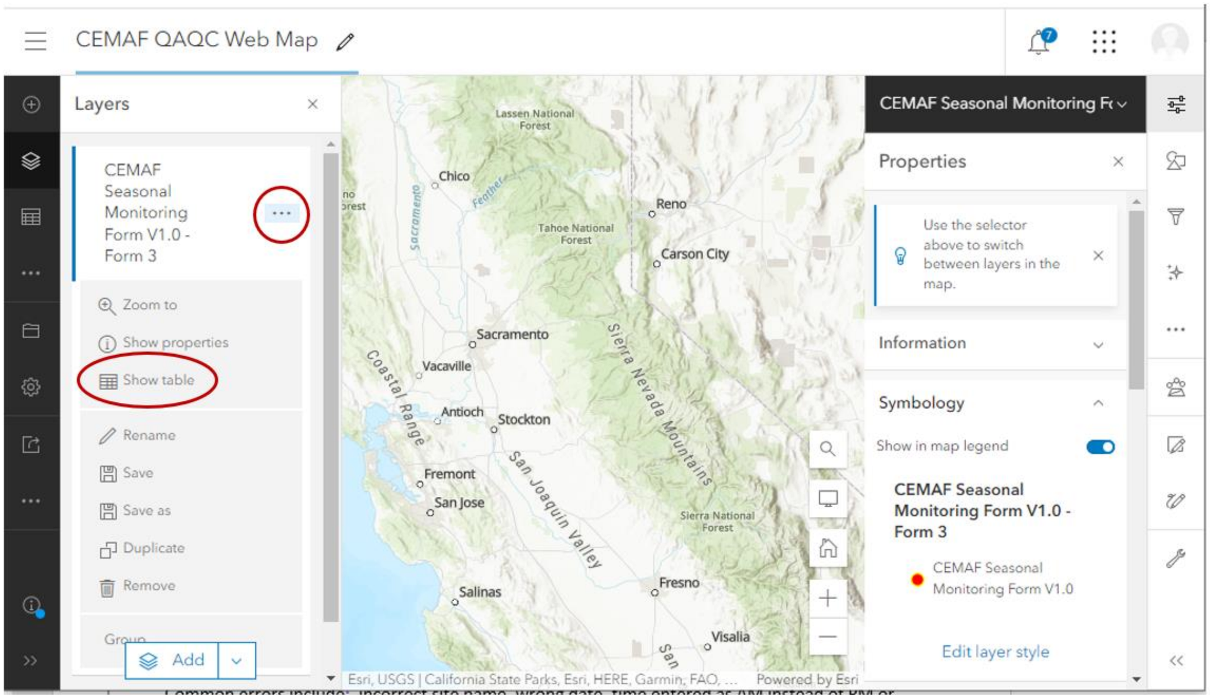


Figure 25. Screenshot of the CEMAF QAQC Web Map on AGOL. This image shows how to view the data table for the Seasonal Monitoring Form.

Next, select the settings wheel at the top of the table and check the box to the left of GlobalID to make that field visible (Figure 26).

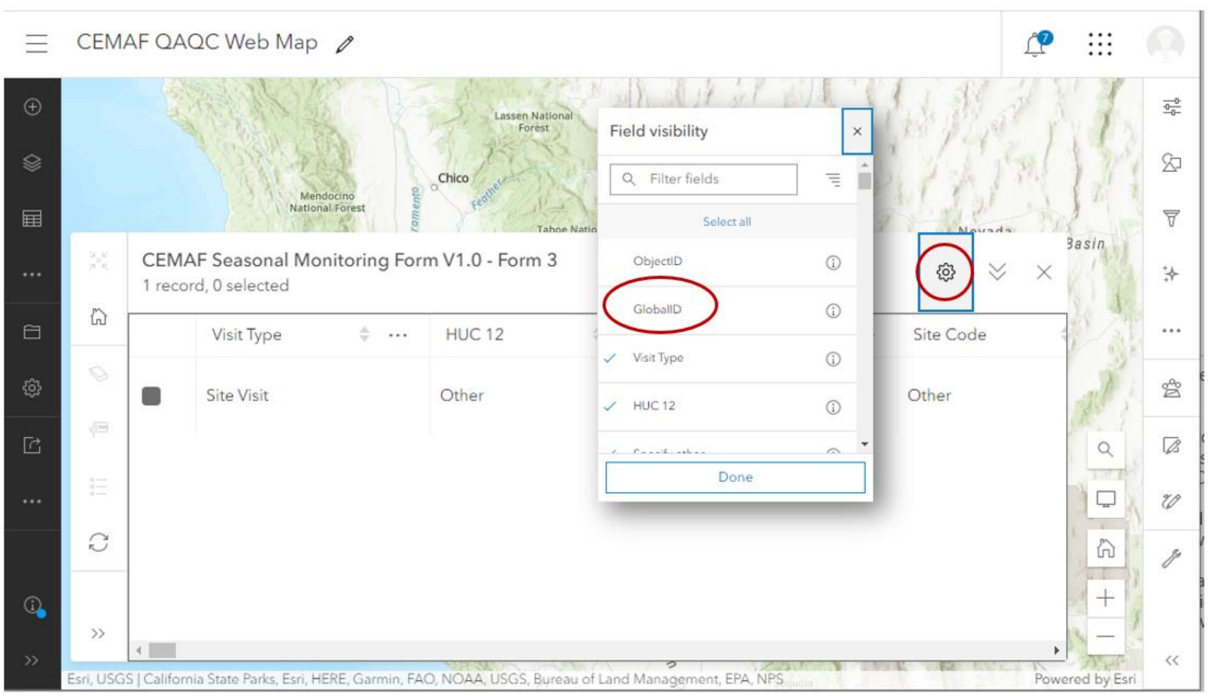
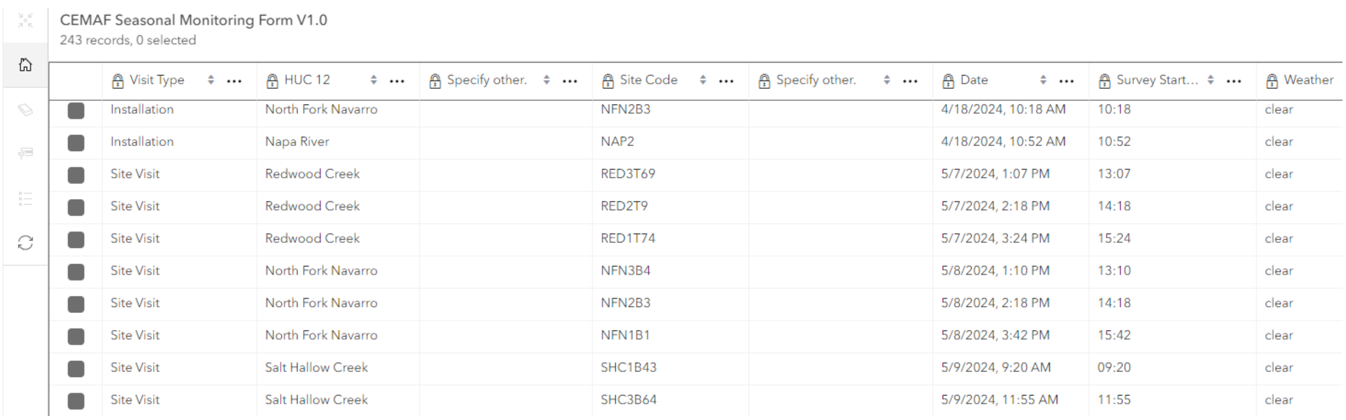


Figure 26. Screenshot of the Seasonal Monitoring Form data table in AGOL. This image shows how to change the visibility setting for fields (i.e., GlobalID).

Look through the CEMAF Hydrology and Water Quality table to identify errors or typos (Figure 27) that may have been missed during the field QC of the data form. Use the Excel QC spreadsheet described in the next section to make updates to the form.

Note: It is important to remember not to make any changes directly to the Survey123 data.



CEMAF Seasonal Monitoring Form V1.0
243 records, 0 selected

Visit Type	HUC 12	Specify other.	Site Code	Specify other.	Date	Survey Start...	Weather
Installation	North Fork Navarro		NFN2B3		4/18/2024, 10:18 AM	10:18	clear
Installation	Napa River		NAP2		4/18/2024, 10:52 AM	10:52	clear
Site Visit	Redwood Creek		RED3T69		5/7/2024, 1:07 PM	13:07	clear
Site Visit	Redwood Creek		RED2T9		5/7/2024, 2:18 PM	14:18	clear
Site Visit	Redwood Creek		RED1T74		5/7/2024, 3:24 PM	15:24	clear
Site Visit	North Fork Navarro		NFN3B4		5/8/2024, 1:10 PM	13:10	clear
Site Visit	North Fork Navarro		NFN2B3		5/8/2024, 2:18 PM	14:18	clear
Site Visit	North Fork Navarro		NFN1B1		5/8/2024, 3:42 PM	15:42	clear
Site Visit	Salt Hallow Creek		SHC1B43		5/9/2024, 9:20 AM	09:20	clear
Site Visit	Salt Hallow Creek		SHC3B64		5/9/2024, 11:55 AM	11:55	clear

Figure 27. Screenshot of the Hydrology and Water Quality data table in AGOL.

Open the Excel QC spreadsheet located on the CDFW Microsoft Cloud (i.e., Teams, Sharepoint), here:

> *(Microsoft Teams) California Department of Fish and Wildlife\Wildlife Cannabis Monitoring Program - Documents\Data and Analysis\Seasonal Monitoring\Survey123\QC Forms\YYYY_CEMAF Seasonal Monitoring Form**
>
> ** YYYY = year*

The QC spreadsheet is used to document any changes that are made to the data after leaving the field. Any field populated in this spreadsheet will be used to replace incorrect data during data-processing (Figure 28). All errors that are identified for a survey are entered in the same row in the spreadsheet. For each row, fill in the first five columns with the survey date, site code, your name, the unique GlobalID for the specific survey from the AGOL web map, and a clear explanation of the changes to be made. If no corrections need to be made, surveyors will still populate the first 5 columns, add 'none' to the corrections column, and leave all the other fields blank. The columns highlighted in green represent every data entry field in the Survey123 form. For all changes to be made, enter the correction in the appropriate column (the cell will turn yellow).

	A	B	C	D	E	F	G	H	I	J
1	Survey Date	Site Code	GlobalID QC	Your Name	Corrections	ObjectID	GlobalID	Visit Type	HUC 12	Specify other.
2	4/9/2024	STV3B3	676afe07-46a4-449b-	Joan Smith	Added densiomiter measurements that were taken on 04-10-2024					
3	4/9/2024	STV2B10	6d0a4a41-81ed-4d64-	Joan Smith	Change DO serial number to 20820186					
4	4/9/2024	STV1B1	ecccf54f-8560-427b-8	Joan Smith	Change DO serial number to 20820197					
5	4/10/2024	RED1T74	760f7533-9f38-486b-	Joan Smith	HUC 12 should have been Redwood. Site Code should have been RED1T74				Redwood Creek	
6	4/10/2024	ZAY2B1	a5a63192-0c5f-420b-	Joan Smith	None					
7	4/10/2024	ZAY1B12	bcfe70ea-c946-428e-	Joan Smith	None					
8	4/11/2024	LPC3B1	bf5df3fe-2670-4b7a-b	Joan Smith	None					
9	4/11/2024	LPC2B4	d337b6aa-9127-4a40-	Joan Smith	None					
10	4/11/2024	LPC1B2	84e4e35e-50d5-4406-	Joan Smith	None					
11	4/8/2024	USR2B1	4153d33d-7ccd-48fa-	Joan Smith	None					
12	4/8/2024	USR3B19	e13f8d75-6ce0-41d6-	Joan Smith	None					
13	4/8/2024	USR1B1	1bc07075-424d-43ae-	Joan Smith	None					
14	4/9/2024	MIL3B3	c79050bc-4897-4cb9-	Joan Smith	None					
15	4/9/2024	MIL2B2	2bf975c0-69a2-46b4-	Joan Smith	None					
16	4/9/2024	MIL1B1	d202f8d7-e641-45e9-	Joan Smith	None					
17	4/10/2024	SHC3B64	34b66213-e905-4334	Joan Smith	None					
18	4/10/2024	SHC2B1	44063eb6-ecec-4592-	Joan Smith	None					
19	4/10/2024	SHC1B43	6c58a379-5683-466c-	Joan Smith	None					
20	4/16/2024	RED1T74	09242f70-0f85-4748-	Joan Smith	None					
21	4/16/2024	RED2T9	8c76de44-b7c8-4efe-	Joan Smith	None					

Figure 28. Screenshot of the QC spreadsheet. Columns A-E are populated for every survey; columns F-EN are used only to make corrections to the data and are left blank if no corrections are needed.

Check the data very closely at the end of every day, or as soon as feasible. Common errors include incorrect site name, wrong date, time entered as AM instead of PM or vice versa, and typos (particularly decimals). Obvious typos can be identified if values exceed reasonable ranges (ex, vbm_elevation = 428 instead of 4.28) or if there are unexpectedly large differences between current and previously entered data. If a required data field was not collected, and instead filled with -9999, make sure there is a comment in the notes of that specific section describing why.

Data Processing

Data processing should be completed by CEMAF personnel that are responsible for data management and analysis. The data processing steps outlined here describe how to combine the raw AGOL data with the QC spreadsheet using an Rmd script, to produce a final, cleaned, dataset.

Clean the data: After recording all errors in the QC spreadsheet, work through the Survey123_AGOL_Query.Rmd file. This R script walks the user through several steps to ensure that edits made in the QC spreadsheet are applied to the data, and data from all types of site visits merge correctly. The output from this script is a data file that contains all Survey123 data collected during installation, site visits, and removal, with standardized names and format for all variables. The script can be run throughout the field season and updated as more data is collected. This step is not necessary after every survey.

Site Visit

Site visits should be made as frequently as feasible throughout the field season. They can be performed on their own, as part of a snorkel or bioassessment visit, or when high flows (unusual during baseflow conditions) may cause channel reforming. Minimally, they include collecting discharge and WSEL, but should also include cleaning and downloading DO loggers, and visually inspecting the PT housing to ensure the equipment has not dislodged.

Auto Level Survey

For site visits outside of installation and removal visits, record staff plate depth instead of using an auto level to survey all elevations. This simple measurement is all that is needed because the relative elevation of the staff plate is known, and all other elevation measurements can be calculated using the VBM and the water surface elevation. However, if you have reason to believe the streambed elevation, the staff plate, or logger elevations may have changed due to a storm event or other reasons, complete an Auto level survey as described in the *Auto Level Survey* section.

Document the staff plate elevation and start time at the beginning of the survey, complete all other elements associated with the site visit, then finish by recording the staff plate elevation and ending time. The start depth and ending depth should be ± 0.01-ft. If depth changes more than this during the survey, then the flow level is changing too rapidly to perform an accurate survey and you must wait until the flow level stabilizes.

Stage Zero Flow and Riffle Crest Thalweg

The SZF and RCT are the same geomorphic feature, but the two terms differentiate the feature locations relative to the pool of interest. The SZF is the hydraulic control at the downstream end of the PT pool, while the RCT is at the base of the upstream pool that is responsible for controlling the riffle flowing into the PT pool. They both refer to channel bed elevation at the lowest point in the hydraulic control that is responsible for 'backing up' the water and forming the pool. The SZF/RCT elevation is thought of as the point at which the last trickle of water would drain from the pool if the water upstream stopped (Figure 29). These elevations are critical for developing rating curves, defining the time of disconnection, and understanding how flow affects DO.

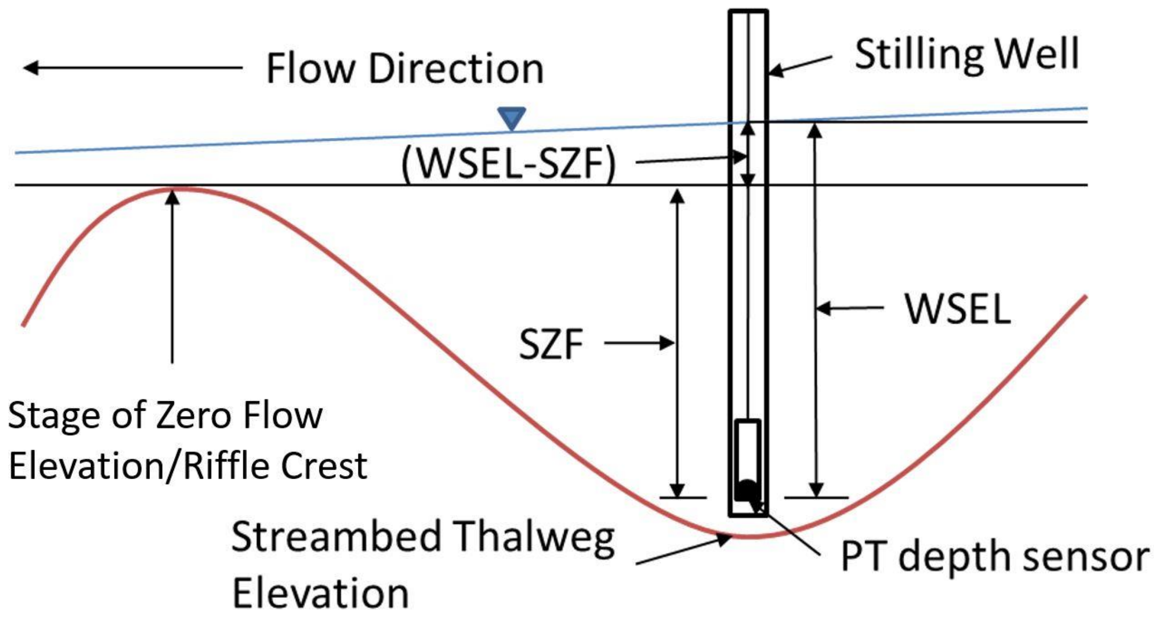


Figure 29. Stage of Zero Flow (SZF) diagram. The blue line represents the water surface (reprinted with permission and minor modification: Cowan, 2018).

The SZF is found by following the deepest flow pathway, the thalweg, downstream to a point where the thalweg elevation crests, before sloping downward into the next geomorphic unit (typically a riffle). Collect multiple depths in the longitudinal and lateral directions within the wetted channel until the greatest depth in the thalweg is located. Periods of high flow are sub-optimal to identify the exact SZF location. Surveyors should collect SZF/RCT data as close to the time of disconnection as possible during the field season. It is important to collect SZF/RCT when the stream conditions allow for more accurate identification of the zone of reliable RCT/SZF (Figures 30 and 31).

Step 1. Collect RCT and SZF depths using the stadia rod. To account for the way in which water piles up against the stadia rod, hold the stadia rod so the narrow edge faces the current, and take the measurement halfway across the stadia rod surface. If identifying the SZT is not yet possible, skip to the last step of recording the ending depth from the staff plate and closing the survey.

Step 2. Once the SZF is identified, monument the location by driving a short rebar post into the streambed. If the exact SZF location is not suitable for rebar, hang flagging nearby and write on the flagging with permanent marker to indicate the exact location. If the SZF location is in the wrong location later in the season, monument the "true" SZF and continue to document depth of both locations throughout the season.

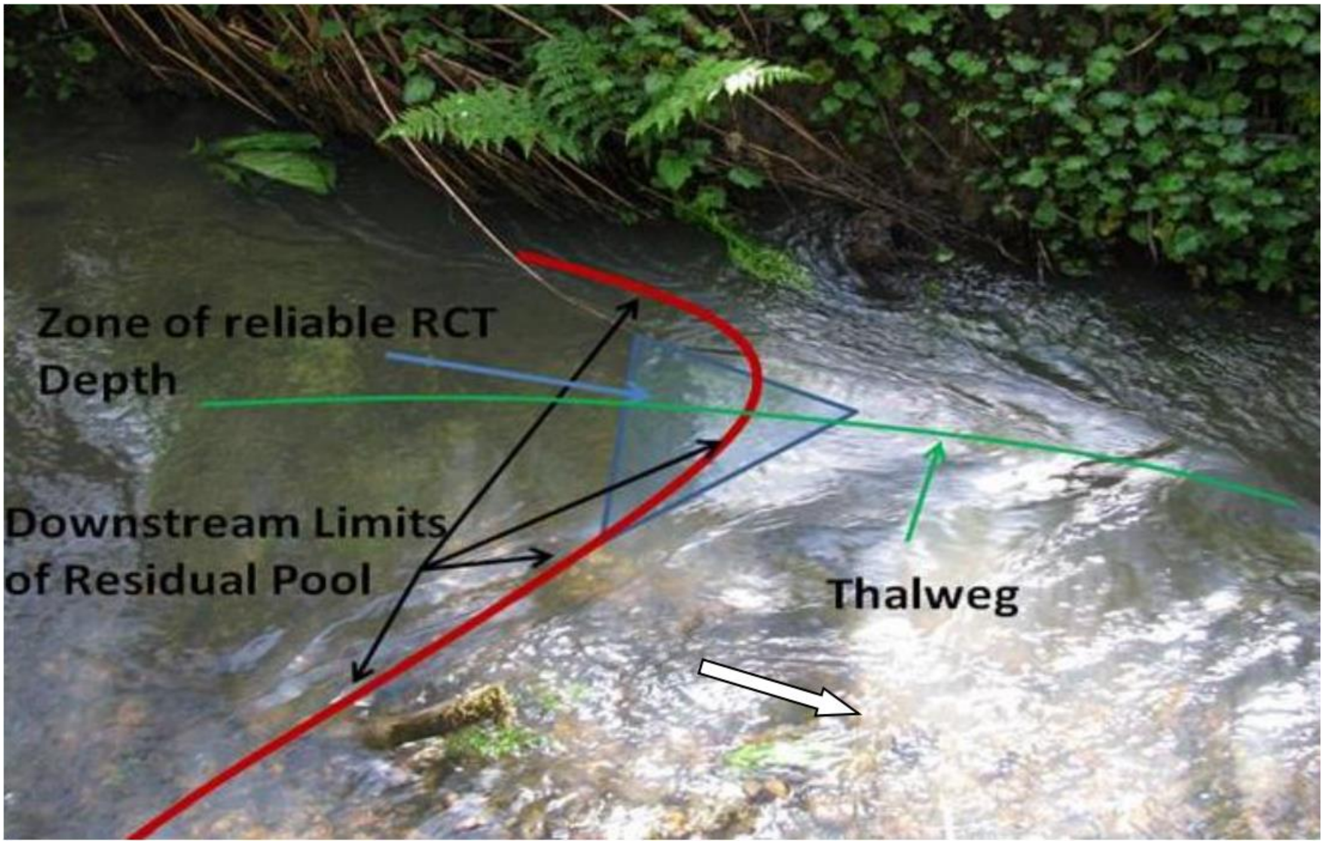


Figure 30. Riffle crest in small, confined stream where the RCT is easy to locate. (Reprinted from Rossi 2012).

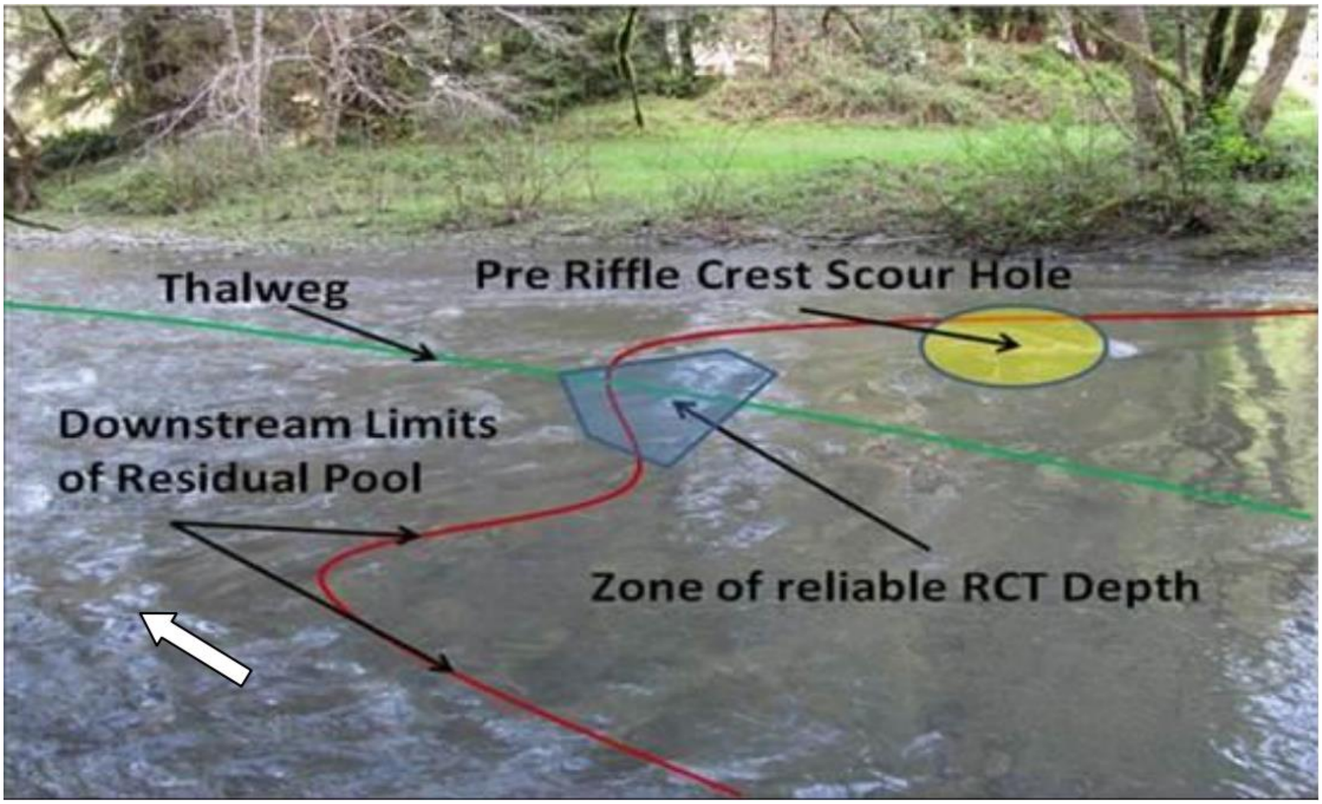


Figure 31. Riffle crest in a medium-sized stream where the RCT is less obvious. Although depth is greater in the scour hole on the right side of the channel, RCT should still be measured along the thalweg. (Reprinted from Rossi 2012).

Step 3. Take photos of SZF and RCT locations with the pool of interest in the background. For the SZF, stand downstream of the SZF location and take a photo facing upstream toward the pool. Ideally the photo will contain the SZF location, both stream banks, and the pool head. For RCT, stand upstream of the RCT location and take a photo facing downstream toward the pool, capturing both stream banks and the entire pool within the photo. All photos should be taken in landscape orientation.

Dissolved Oxygen Field Calibration and Data Offload

Biofouling is the accumulation of living organic materials such as algae, microorganisms, small animals, and/or plants on DO loggers within a wetted environment (Figure 32). Biofouling of the sensor caps over the gaging period can result in erroneous data collection (e.g., logger drift) or prevent the ability to collect data at all. Use anti-fouling guards on all DO loggers and collect DO and temperature with the YSI meter during every visit to validate continuous logger readings. Logger drift can be corrected using HOBOware® but only if there are adequate field calibrations.

Be sure to have an extra launched logger that could be deployed if there are issues with a logger in the field. Prior to conducting a site visit, calibrate and launch one extra DO logger with a new initialized sensor cap and make sure it goes out with field crews during site visits. This backup logger should be transported in a way that reduces shock and stored in a rubber boot with a wetted sponge to prevent the sensor cap from drying out.

During each site visit, use the YSI meter to conduct a field calibration. Take readings next to the DO logger and use them to account for logger drift by taking one measurement before and after removing the DO logger from the housing for cleaning and downloading.

Conduct training for field staff in the use of the HOBO shuttle. It is imperative that data offload is performed correctly to ensure that redeployed loggers are recording data.

Notes on use of HOBO shuttle when offloading data and relaunching loggers in the field:

- Always launch and sync your shuttle through HOBOware on the day that you are offloading data from a logger deployed in the field. Plug the shuttle in and open the software on a laptop. Go to the device menu up top and then hit launch and the manage shuttle screen comes up. Hit the sync shuttle button and make sure the clock matches and says in sync.
- Onset recommends replacing the batteries in the shuttles at least once per month, but this might depend on the frequency of use.
- Always remove the batteries from your shuttle prior to placing the equipment into storage at the end of field season.

Step 1. Before removing the probe from the boot, turn on the handheld YSI meter and wait at least 5-min for the polarographic sensor to ‘warm-up.’ The sponge in the boot must be damp. After the YSI meter has warmed up, calibrate the meter before removing the probe from the boot.

Step 2. Place the probe in the water directly next to the DO logger. Because the dissolved oxygen sensor of the YSI meter actively consumes oxygen, the user must move the logger through the water column (jigging up and down or swirling) at a rate of at least 6-inches/second until the readings stabilize and will not go any higher/lower.

Step 3. Record the time and DO in mg/L and percent saturation, as well as temperature, and specific conductance.

Step 4. Remove the DO logger from the logger housing.

Step 5. Follow the manufacturers' user manual to readout the data from the DO logger using the HOBO® Waterproof Shuttle with Coupler 2-C.

a. Insert the DO logger into the coupler so that the alignment bump on the coupler and the corresponding bump on the logger are aligned.

b. Briefly press the coupler lever firmly (press hard enough that the lever bends) to begin data offload.

c. Readout should begin immediately. The amber LED on the shuttle blinks continuously while readout and relaunch are in progress. Do not remove the logger while the amber LED blinks.

d. After readout but while still connected, the shuttle relaunches the logger with the same settings you used during calibration (i.e., every 15-min).

e. When the relaunch is complete the green LED blinks for 15-min or until you briefly press the shuttle lever to stop the green LED. If the red LED blinks instead, there was an error, and the logger may have stopped recording. To troubleshoot, try reconnecting to the shuttle again. If you are unable to troubleshoot the problem in the field, bring the logger back to the office and contact Onset. It is best practice to have a back-up, initialized, calibrated, and launched DO logger with you in case you need to redeploy and remove a non-functioning DO logger for any reason during the gaging period. Follow the data collection procedures for removing a logger in the field (i.e., record time, date, etc.).

Step 6. Inspect the logger for biofouling or sediment encroachment (Figure 32). Remove the anti-fouling guard and inspect the sensor cap but leave the sensor cap on. Be careful not to touch the sensor cap with dirty hands. If biofouling is present, it can be removed by wetting the logger and/or housing with stream water and gently wiping until clean with a soft bristle toothbrush or sponge. Store cleaning equipment in a container with 70% ethanol for disinfection between streams to prevent introduction of non-native species. Thoroughly rinse cleaning equipment in the stream to remove all alcohol before cleaning the logger.

Step 7. Look for signs of sediment or fine gravel inside the wire of the biofouling guard and the housing. If this is an issue, clean the logger and move the logger housing to an appropriate depth to mitigate the impacts of sediment encroachment.

Step 8. Replace the DO logger in the logger housing.

Step 9. Collect another set of calibration measurements with the YSI meter.

Step 10. Have a staff member other than the initial data recorder check the data forms for completion and accuracy. Ensure that all data fields are filled out. If it is not possible to complete any field, enter –9999 to indicate the value was intentionally not collected.

Step 11. Visualize the DO data as soon as possible after downloading. Ideally, this will be back at the car before leaving the site or at the end of the field day. During this process, the data files can be saved to the laptop's desktop and synced to the appropriate cloud storage location later. Inspect plot of DO data for indications the logger is not recording correctly. This includes DO rapidly dropping to and staying at 0 or missing data between the deployment and download dates. Some pools with a large amount of algae, decomposing organic matter, or hot and stagnant water can have low DO levels, and are also locations where the loggers might be more likely to experience significant drift. If it is hard to tell if the logger is recording reasonable values, compare readings with the YSI meter at the same date and time. If the logger is malfunctioning, replace it with a different unit as soon as possible.

If the HOBO Waterproof Shuttle batteries are removed while in the field, the shuttle will need to be relaunched using HOBOware software. Failure to do so will prevent the shuttle from properly relaunching the logger.

Figure 32. Example of moderate biofouling accumulated on a DO logger.

Discharge

Discharge collections spaced out evenly through the monitoring season, say every 3-5 weeks, can be a great approach for capturing the variation in flow magnitude and creating a hydrograph, especially in 'normal' water years. In low water years, disconnection can occur earlier, and field crews may need to increase the frequency of discharge collections or decrease the time between visits, to collect enough measurements for a rating curve. To help pinpoint disconnection timing in intermittent streams and increase certainty for flow estimates, it is important to collect a discharge measurement during late baseflow season, as close as possible to the time of disconnection. Often baseflow conditions can be limiting for many species, so it is helpful to have more precise flow estimates during that period.

Collect discharge measurements as close as possible to flow transect selected during installation, according to *Discharge Measurement* section. Note, as flows change throughout the monitoring period, the initial transect may become suboptimal due to uneven flow velocities or depths. If this happens, find a nearby transect that is better suited for measuring flow. Be sure that the new transect and the logger do not have any diversions or inputs in between that might change the amount of flow measured.

Data Quality and Management

Follow the same steps described for uploading and data processing procedures outlined in the *Data Quality and Management* section of the *Installation* module.

Additionally, once in the office offload DO data files (.hobo) from the HOBO® Shuttle to the CEMAF data storage platform using the HOBOware® Pro software. During offload, the .hobo data files will be automatically named with the logger's serial number. At this point, the data is 'raw' and requires processing in HOBOware® to export data in a usable .csv format.

Removal

Office

Before leaving the office for site removal, be sure to review site reconnaissance material and photos from install, especially the barologger and VBM location. Load any useful documents, photographs, and maps onto the iPad.

Auto Level Survey

Perform a water surface elevation survey using an auto level. See *Auto Level Survey* section under the *Site Visit* module for protocol and details.

Discharge Measurement

Take a discharge measurement at a nearby transect. See section on *Discharge Measurement* under the *Installation* module for protocol and details.

Dissolved Oxygen Field Calibration and Data Offload

Use a YSI meter to take DO measurements next to the DO logger. See *Dissolved Oxygen Field Calibration and Data Offload* section of the *Site Visit* module for protocol and details. If water levels drop below the data loggers, the DO logger should be removed from the field because exposure to air can damage the sensor cap. Staff can also remove the PT to reduce the risk of theft or vandalism in high traffic areas if the chance of the logger becoming rewetted is minimal.

Equipment Removal

Step 1. Complete all field measurements before removing any loggers. This includes discharge, DO spot-check, and auto level survey.

Step 2. Have a staff member other than the initial data recorder check the forms for completion and accuracy. Ensure that all data fields are filled out. If it is not possible to complete any field, enter –9999 to indicate the value was intentionally not collected.

Step 3. Remove all loggers, rebar and T-posts and note time in the survey form. Remove loggers from housing and transport loggers using proper packaging to ensure they are not dropped or subject to shock while traveling from field. If staff plan to return the following year to the same pool, the VBM can be left in place.

Step 4. Remove the barologger, consulting photos and site map to locate if necessary.

Step 5. Remove any trash and flagging before leaving the site.

DO and PT Logger Maintenance

At the end of the field season, clean the body of the PT and DO loggers and the anti-fouling cap for the DO loggers by gently scrubbing with a plastic bristle brush or nylon dish scrubber. Use Alconox® to remove grease and soak in vinegar to remove mineral deposits. Rinse the loggers with distilled water. The manual provides more detailed instructions. Store the DO loggers in the calibration boot with a wetted sponge.

Data Quality and Management

Follow the same steps described for uploading and data processing procedures outlined in the *Data Quality and Management* section of the *Installation* module.

Additionally, offload the remaining DO and PT data files (.hobo) from the HOBO® Shuttle to the CEMAF data storage platform using the HOBOware® Pro software. During offload, the .hobo data files will be automatically named with the logger's serial number. At this point, the data is 'raw' and requires processing in HOBOware® to export data in a usable .csv format. The PT file contains uncompensated absolute pressure that will need to be compensated with the barometric PT data and further processed to convert the pressure readings to water stage (or water depth).

Bioassessment Survey

Background

The Framework includes the collection of benthic macroinvertebrates (BMIs) from the lower most site at each HUC 12, using the SWRCB's SWAMP protocols for the Reach-wide Benthos methodology. This protocol, *Standard Operating Procedures for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat* (2016), can be found online on the SWAMP website. The procedures are recognized by the US Environmental Protection Agency (EPA) as California's standard bioassessment procedures and are designed to support general assessment of the ecological condition of wadable streams and rivers based on the composition of the benthic macroinvertebrate and benthic algal assemblages. The CEMAF uses a multi-metric score based on community composition (the California Stream Condition Index) to make inferences about stream conditions. The procedures also produce standardized measurements of instream and riparian habitat to support interpretation of the biological data (Ode et al. 2016). The bioassessment protocol is divided into several modules that need to be completed in a particular order to avoid compromising data collection.

Quality Assurance

Quality assurance measures for field sampling of bioassessment methods include training, auditing, and care and maintenance of equipment:

- Annual review of SWAMP Bioassessment protocol; ensure any new modifications to the protocol can be properly implemented. Establish consistent sampling procedures across crews and years to ensure comparability over time and space. Assemble crew members for a pre-season calibration and training to review sampling procedures and perform several transects on a shortened reach together. Crews can ask questions and present concerns during a group discussion. Then, with minimal interaction, conduct a few more transects recording data on sample data sheets so that crews can share the results and identify any discrepancies or concerns arising from the mock sampling. An annual pre-season calibration and training can also be requested of College of Bioassessment staff.

- Request an audit, from staff at the SWRCB's College of Bioassessment. Audits are conducted at field sites; once or twice (beginning and mid-season) for each crew.

- Ensure all necessary field equipment, supplies and consumables are in good condition
- Regularly check the D-frame kick net for holes caused by rocks, to ensure no loss of organisms. Always take a spare net to the field. Keep a maintenance log that includes dates and initials for calibration of pH pen and YSI meter.

In addition to the quality assurance measures outlined above, there are additional resources that can be utilized to ensure that your team is up to date on current information:

- Stay informed about future trainings, advancements, changes, or updates to the standard operating procedures by signing up to the SWAMP Water Quality Monitoring email list (Lysis).
- Attend the annual California Aquatic Bioassessment Workgroup meeting to stay updated on current activities and analyses being conducted by the bioassessment community.

Scope and Applicability

This protocol may be used in both perennial and non-perennial streams if sampling conditions are met. A reach is considered "sampleable" if at least half of the reach has a wetted width of at least 0.3-m (the width of a D-frame net) and there are no more than three transects that are completely dry within the monitoring reach at the time of assessment. If more than three transects are completely dry, then the stream reach should not be sampled for biota; however, the reach may be shifted to reduce the number of dry transects. The start point (transect A) should not be shifted more than 300-m from the intended start. The wadeability limitation is determined by the practical ability to safely obtain a consistent sample of the benthic community from a reach. In general, a reach is considered wadeable if it is less than 1m deep for at least half the length of the reach.

Surveys may be carried out from May through September, depending upon the region (Figure 33) when streams are at or near base flow (i.e., not influenced by storm runoff) since sudden flow increases can displace benthic organisms from the stream bottom and dramatically alter local community composition. Wait at least two, and preferably three, weeks after any storm event that has generated enough stream power to mobilize cobbles and sand/silt capable of scouring stream substrates to allow time for benthic fauna and algae to recolonize scoured surfaces. Ultimately, the time of delay from a scouring event to the acceptable window for sampling will depend on environmental setting and time of year. Consult with the SWAMP Bioassessment Coordinator in questionable cases.

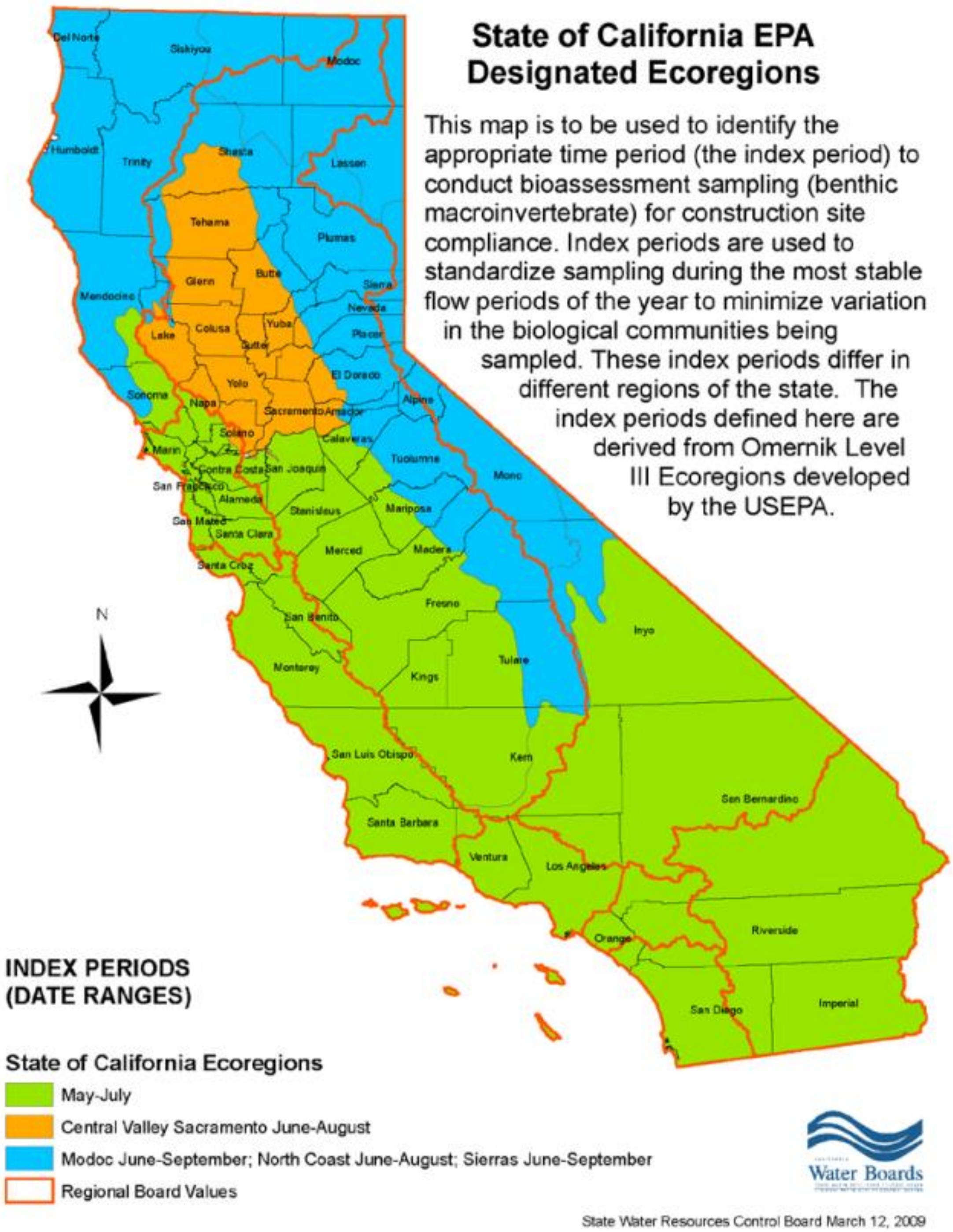


Figure 33. A map of California showing index periods for aquatic bioassessment.

Notable Field Conditions

As mentioned above, ideally, a stream reach should not be sampled for bioassessment if mobilized bed materials has potentially disrupted benthic communities. If a suspected recent scour has occurred, mark "Yes" in the Notable Field Conditions field of the bioassessment field form that says, "Site is affected by recent scouring event". High-flow/scour indicators that can be assessed to make the determination include:

1) Lack of slime/color coating on the streambed (this may be inferred by a high frequency [i.e., near 100%] of microalgal cover scores of "0").
2) Lack of macroalgal mats, or if present, mats displaced, as indicated by being "unnaturally" bunched up against fixed objects within the stream (like tree roots, large boulders) away from centroid of flow.
3) Non-rigid instream vegetation (e.g., emergent macrophytes like cattails and tules) bent over or lying down within the stream.
4) Absence of leaves and other detritus in pools, despite riparian cover.

Following the sampling visit, under "Field Notes/Comments" on the field sheet, field crews or the project manager can add the size of, and actual time since, storms or discharge releases.

Reach Delineation

Before biotic sample and physical habitat (PHab) data collection can begin, the monitoring reach must be identified and delineated, information about reach location and condition is to be documented, water chemistry parameters are to be recorded. A set of field forms for recording information about monitoring sites, biotic samples, and associated water chemistry and PHab data is available on the SWAMP website.

Field crews must designate someone (other than the field recorder) to review the forms for completeness and legibility. If parameters cannot be measured for some reason, "NR" (i.e., "Not Recorded") should be entered in the corresponding field. It is imperative to confirm throughout the data collection effort at each site that all necessary data have been recorded on the field forms correctly by doublechecking values and confirming spoken values with field partner(s).

Note: Unlike other protocols implemented by CEMAF, this protocol requires that "left bank" and "right bank" are designated looking **downstream**.

Step 1. Upon arrival at the site, fill out the "Reach Documentation" section of the field forms. Record the Station Code that is provided by the SWAMP. Record the geographic coordinates of the downstream end (Transect A) of the reach (in decimal degrees to at least five decimal places) with a Global Positioning System (GPS) receiver and record the datum setting (preferably NAD83) of the unit. Target coordinates need to be determined before the field sampling. Sampling locations can be moved up or downstream as much as 300-m from the target location for reasons such as avoiding obstacles, mitigating issues regarding safety or permission to access, and to ensure adequate transect connectivity, as long as the shifted transect does not contain any inputs, outputs or structures such as bridge abutments.

Step 2. To delineate the monitoring reach, first scout it to ensure it is of adequate length for sampling biota. The length to use depends upon the average "wetted width" of the stream reach. The "wetted channel" is the zone that is inundated with water, and "wetted width" is the distance between the sides of the channel at the point where substrates are no longer surrounded by surface water. If the average wetted width ≤ 10-m, delineate a 150-m reach for sampling. If the average wetted width > 10-m, delineate a 250-m reach. When delineating the reach, stay out of the channel as much as possible to avoid disturbing the stream bottom, which could compromise the water and biotic samples, and PHab data, that will subsequently be collected. Starting at one end of the reach, walk along the stream bank, taking large steps (for most adults, a large step is roughly equal to 1-m) and count the steps until reaching 150-m (or 250-m for larger streams). This will give a rough idea about the location of the ends of the sampling reach. Scout for any features that should be excluded (e.g., tributaries, "end-of-pipe" outfalls feeding into the channel, bridge crossings, major changes between natural and artificial channel structures, waterfalls, and impoundments). If any such features are within the target sampling location, the start of the reach can be shifted up to 300-m. If there is still not enough room to accommodate a full 150-m reach or 250-m reach entirely upstream or downstream of the feature(s), then the reach may be shortened (to as little as 100-m) to exclude them. Record on the datasheet under "Actual Reach Length" the length of the reach that has been delineated.

Step 3. Use markers (e.g., wire-stemmed flags) to indicate locations of transects and inter-transects. The standard sampling layout consists of 11 "main" transects (A-K) interspersed with 10 "inter-transects", all of which are arranged perpendicularly to the primary direction of stream flow and placed at equal distances from one to the next (Figure 34) The first flag should be installed at water's edge on one bank at the downstream limit of the sampling reach to indicate the first main transect ("A"). The positions of the remaining transects and inter-transects are then established by heading upstream along the bank and using the transect tape or stadia rod to measure off successive segments of 7.5-m (if sampling reach is 150-m), or 12.5-m (if it is 250-m). Although it is usually easiest to establish transect positions from the banks (this also prevents disturbance to the stream channel), this can result in uneven spacing of transects in complex stream reaches. To avoid this, estimate transect positions by projecting from the mid-channel to the banks. Refer to Figure 34 for a visual clarification of proper transect alignment relative to the stream's direction of flow. For monitoring reaches of non-standard length (i.e., < 150-m; see Step 2 above), divide the total length of the reach by 20 to derive the distance between the adjacent main, and inter- transects. Alternating between two different flag colors (e.g., orange, and yellow, or blue), to demarcate main- vs. inter-transects is recommended, as well as writing the transect/inter-transects names on the flags.

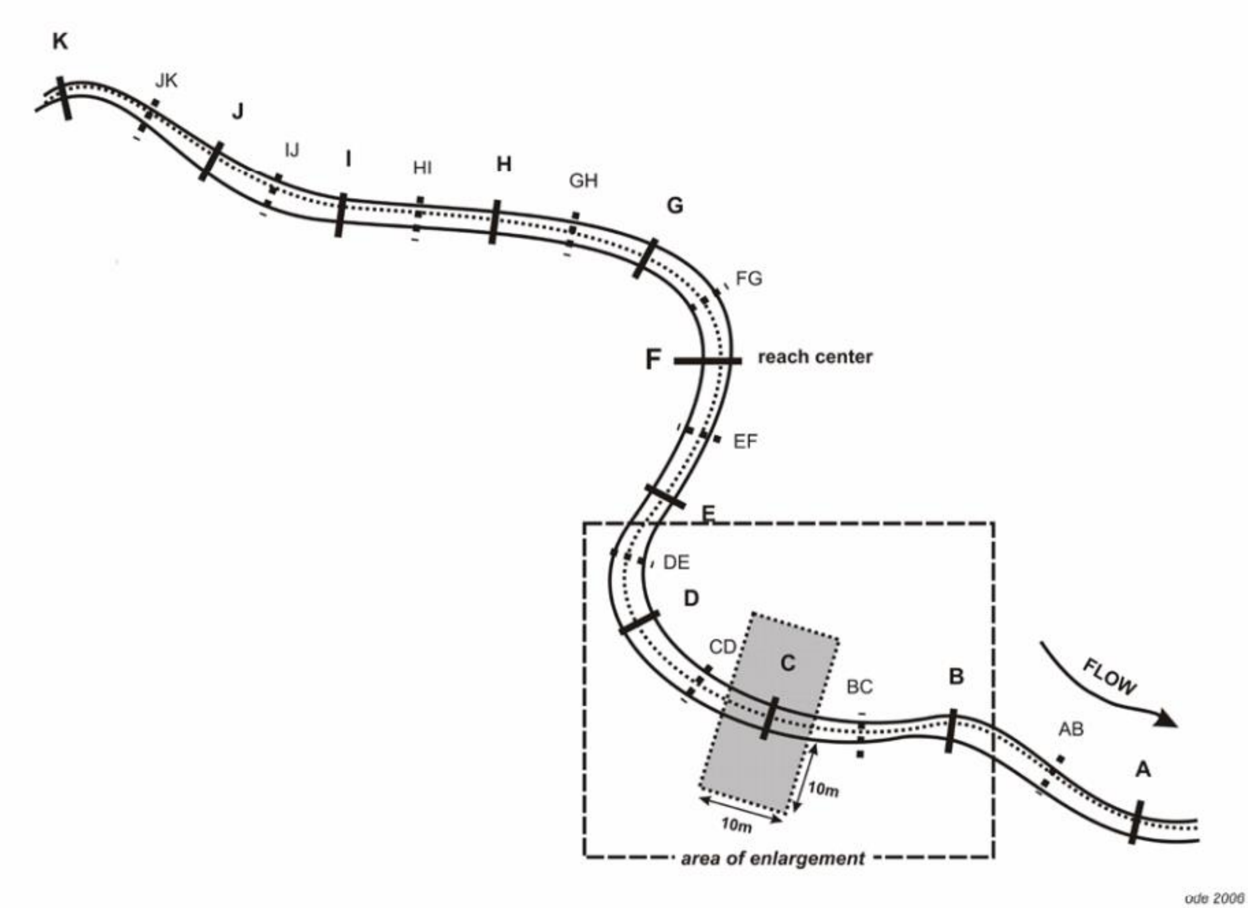


Figure 34. Reach layout geometry for physical habitat (PHab) and biotic sampling showing positions of 11 main transects (A-K) and the 10 inter-transects (AB-JK).

Step 4. Under "Notable Field Conditions", record evidence of recent flooding, fire, or other disturbances that might influence bioassessment samples, such as scour, for which specific guidance is provided in the section above. These are subjective determinations, so use whatever cues are available to make the call. If unaware of recent fire or rainfall events, select the "no" option on the form. Also, to the best of your ability, record the dominant land use and land cover in the area surrounding the reach (i.e., evaluate land cover within 50-m of either side of the stream reach). You can optionally use a scaled aerial photograph of the site and vicinity as an aid. Finally, mark whether the sampling reach occurs within an engineered channel. Engineered channels include streams that have been straightened or armored (with riprap, rocks, grout, concrete, or earthen levees) on the banks, streambed, or floodplain of the channel. Partially armored channels (e.g., armored only at bridge abutments) are "engineered".

Water Chemistry

Be sure to sample water in such a way that it does not interfere with subsequent biotic sampling and PHab data collection, but also in such a way that water samples are not compromised by other sampling activities upstream (e.g., by suspension of matter from the stream bottom into the water column, and the consequent introduction of this matter into the water chemistry samples). To do this, sample water chemistry just downstream of Transect A, the same general location as where the GPS coordinates were taken, prior to stepping in the water anywhere upstream. If, for whatever reason, measurements are not taken at Transect A before biotic sampling in the reach has begun, they should be taken immediately upstream of Transect K (the most undisturbed transect), and this change of sampling location should be noted on the field sheet.

- Calibrate the YSI Pro2030 DO/Conductivity meter (or similar) following user manual directions.
- Using the vial provided in the alkalinity test kit, collect a sample of water. Follow the directions in the test kit to titrate the sample to determine the alkalinity (mg/L).
- Use the pH pen to measure pH.
- Once calibrated, use the YSI meter to collect:
    - Water temperature (°C)
    - Specific conductivity (µS/cm)
    - Dissolved oxygen (mg/L and % saturation)

Biotic Community Sampling

Once the transects have been laid out and water sampling is complete, the biotic samples (BMIs) can be collected. On a transect-by-transect basis, any biotic sampling should occur before physical habitat data are collected.

The Reachwide Benthos (RWB) Method for Biotic Sample Collection

The RWB procedure followed by CEMAF employs an objective method for selecting subsampling locations that is built upon the layout of the 11 main transects that will be also used for physical habitat measurements. This method can be used to sample any wadeable stream reach, since it does not target specific habitats. Because sampling locations are defined by the transect layout, the position of individual sub-samples may fall in a variety of habitat types including:

1) Erosional (aka, transport) where habitats in the stream that are dominated by fast-moving water, such as riffles, where stream power is more likely to facilitate erosion (suspension) of loose benthic material than deposition. Examples of "erosional" substrates include cobbles and boulders.
2) Depositional where habitats in the stream that are dominated by slow-moving water, such as pools, where deposition of materials from the water column is more likely to occur than erosion (or (re)suspension) of bed materials. Examples of "depositional" substrates include silt and sand.) habitats.

For the RWB method, the sub-sampling position alternates between left, center, and right portions of the main transects, as one proceeds upstream from one transect to the next. These sampling locations are defined as the points at 25% (left") 50% ("center") and 75% ("right") across the wetted width in most systems. **The left and right sides of the stream are determined when facing downstream**.

Note: Employ a modified version of the RWB method, called the Margin Center-Margin (MCM) method when all three of the following stream conditions are met: 1) very low slope (generally < ~ 0.3%); 2) uniform sandy/fine-substrate; and 3) stable habitat at stream margins. The MCM protocol modification is to collect subsamples at 0%, 50%, and 100% of wetted width instead of 25%, 50%, and 75%, to ensure collection of biota from marginal habitats. There is no hard rule for using the MCM variation, but in general it should be reserved for reaches where the bulk of the streambed consists of unstable habitat (e.g., shifting sands), and the only stable microhabitats (e.g., macrophytes, algae) are restricted to the margins and would otherwise be missed. The type of sampling method used (RWB, MCM, or TRC) should be circled on the field sheet under "collection method".

The recommended method for collecting duplicate biotic samples is at adjacent positions along the sampling transects according to the scheme depicted in Figure 35 (the duplicates are shown in light grey, with dashed-line outlines). Both samples should be collected at each transect before moving on to the next transect.

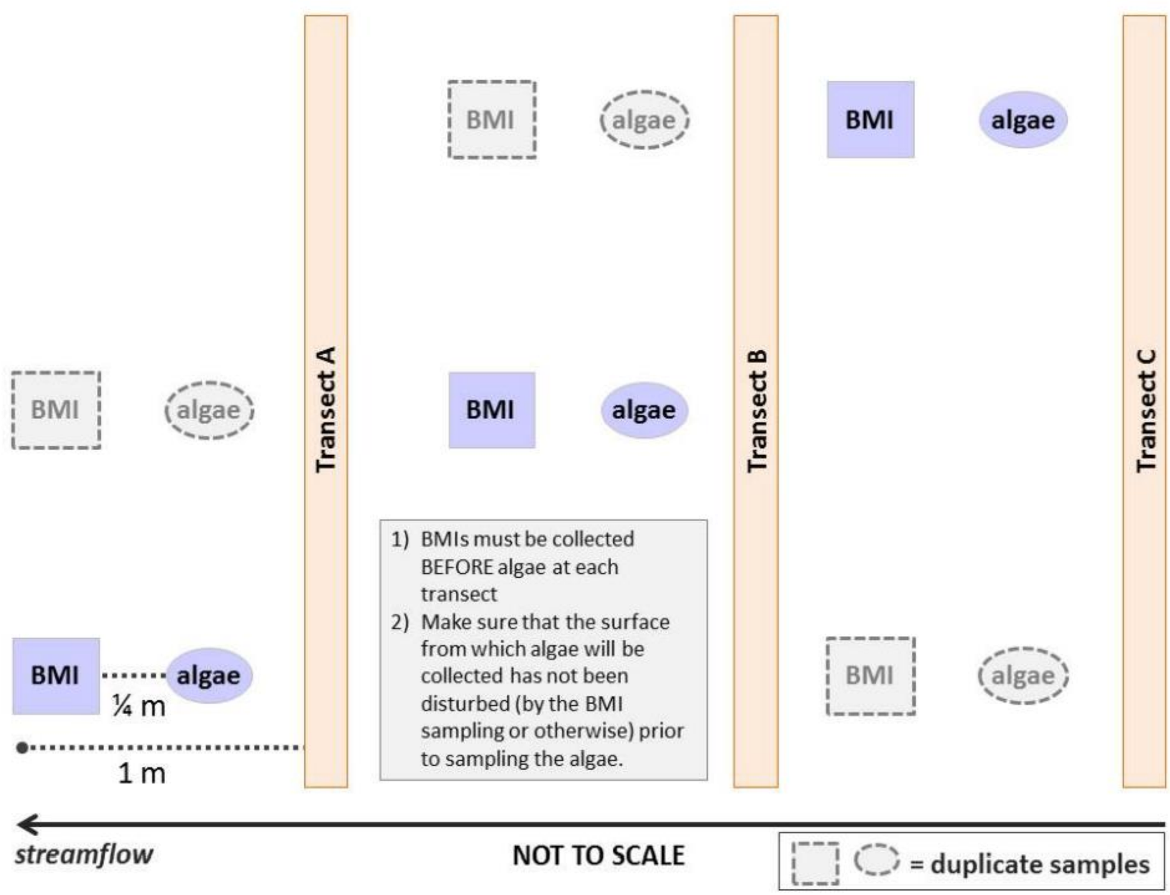


Figure 35. Sampling array for collection of BMIs, algae, and duplicate samples (outlined with dashed lines) for each assemblage. Figure reproduced from SWAMP SOP for the Collection of Field. Note that CEMAF does not collect algae at this time. For convenience, only Transects A through C of the sampling reach are shown, but the same pattern of placement should be rotated across all 11 transects.

Sampling Procedure for BMIs

Step 1. Starting with the downstream transect (Transect A), identify a point that is 25% of the stream width from the left bank when facing downstream. If it is not possible to collect a sample at the designated point because of deep water, obstacles, or unsafe conditions, adjust the sampling spot while keeping the point as close as possible to the designated position. Always be as objective as possible when identifying the sampling spot; resist the urge to sample the "best looking" or most convenient area of the streambed.

Step 2. Once the sampling spot is identified, place the 500-µm D-frame net in the water 1 m downstream of the target transect. To avoid affecting subsequent PHab data collection, do not sample directly on the transect. Position the net so its mouth is perpendicular to, and facing into, the flow of the water. If there is sufficient current in the area at the sampling spot to fully extend the net, use the normal D-net collection technique (as described in steps 3-6 below) to collect the sub-sample.

Step 3. Holding the net in position on the substrate, visually define a square shape (a “sampling plot”) on the stream bottom upstream of the net opening, approximately one net-width wide and one net-width long. Because standard D-nets are 12-in wide, the area within this plot is 1 ft^2 (0.09 m^2). Restrict sampling within that area.

Step 4. Working backward from the upstream edge of the sampling plot, check the sampling plot for heavy organisms such as mussels, caddis cases, and snails. Remove these organisms from the substrate by hand and place them into the net. Carefully pick up and rub stones directly in front of the net to remove attached animals. Pick up and clean all the rocks larger than a golf ball within the sampling plot such that all the organisms attached to them are washed downstream into the net. Set these rocks outside the sampling plot after they have been cleaned. Large rocks that protrude less than halfway into the sampling area should be pushed aside. If the substrate is consolidated, bedrock, or comprised of large, heavy rocks, kick and dislodge the substrate (with the ft) to displace BMIs into the net. If a rock cannot be removed from the stream bottom, rub it with your hands or feet (concentrating on cracks or indentations), thereby loosening any attached insects. While disturbing the plot, let the water current carry all loosened material into the net. Do not use a brush to dislodge organisms from substrates.

Step 5. Once the coarser substrates have been removed from the sampling plot, dig through the remaining underlying material with fingers or a digging tool (e.g., rebar or an abalone iron) to a depth of about 10-cm (less in sandy streams), where gravels and finer particles are often dominant. Thoroughly manipulate the substrates in the plot to encourage flow to dislodge any resistant organisms.

Note: the sampler may spend as much time as necessary to inspect and clean larger substrates but should take a standard time of 30-seconds for the digging portion of this step. To the extent practical, reduce the amount of sand particles in the net, as they damage organisms and degrade taxonomic data quality.

For slack-water habitats, vigorously kick the remaining finer substrate within the plot using the feet while dragging the net repeatedly through the disturbed area just above the bottom. Keep moving the net so that the organisms trapped in the net will not escape. Continue kicking the substrate and moving the net for 30-seconds. For vegetation-choked sampling points, sweep the net through the vegetation within a 1-ft^2 (0.09-m^2) plot for 30-seconds. After 30-seconds, remove the net from the water with a quick, upward motion to wash the organisms to the bottom of the net.

Step 6. Let the water run clear before carefully lifting the net. Dip the lower portion of net in the stream several times to remove fine sediments and to concentrate organisms into the end of the net, while being careful to prevent water or foreign material from entering the mouth of the net. Be particularly careful to avoid "backflow" situations, in which collected material restricts flow through the net and the resulting turbulent flow causes collected material to escape the net; this is a major potential source of loss of BMIs during sampling.

Step 7. Move on to the next transect to repeat the sampling process across all 11 main transects. The sampling position within each transect is alternated between the left, center, and right positions along a transect (25%, 50%, and 75% of wetted width, respectively, for standard RWB, or 0%, 50%, and 100% if using the MCM collection method), then cycling through the same order repeatedly while moving upstream from transect to transect. Ultimately, you will collect from the left and center four times each, and the right three times. Care should be taken in transporting samples between reaches.

Step 8. Fill and label sample jars by affixing Rite-in-the-Rain paper to the outside of the jar with clear tape and inserting a duplicate label inside the jar.

Step 9. Once all BMI subsamples have been collected and composited, transfer the composited sample to one or more 500-mL wide-mouth plastic sample jar, preferably one with straight edges. Never fill a jar more than halfway with sampled material; use as many jars as necessary to prevent this. Samples with a lot of organic material (e.g., plants, algae, leaf litter) tend to contain a lot of water that may inhibit sample preservation. Gently squeeze out as much water as possible (through the mesh of the D-frame net) before placing the sample in the jar, to prevent diluting the alcohol too much. Approach this task gingerly, so as not to damage invertebrates during this process. Invert the contents of the D-frame net into the sample jar. Perform this operation over a large, white tray to avoid loss of any sampled material and make recovery of spilled organisms easier. If possible, remove the larger twigs and rocks by hand after carefully inspecting for clinging organisms. Use forceps to remove any organisms clinging to the net and place these in the sample jar. All samples should be completely transferred to the sample jar without elutriation. If the samples contain a lot of fine particles, confirm that the sampling procedure is being executed correctly (i.e., use care to disturb the substrate as gently as possible and avoid kicking). Samples with an abundance of sand or organic material should be processed expeditiously at the lab, as specimens in these samples can degrade quickly. Therefore, the presence of these kinds of samples should be communicated to the taxonomy lab as soon as possible and they should not be stored for a long time before delivering to the taxonomy lab for processing.

Step 10. Place a date/locality label, filled out in pencil, in the jar and completely fill the jar with 95% ethanol (if not prefilled). The target concentration of ethanol is 70-80%, but 95% ethanol is used in the field to compensate for dilution from water in the sample. Final concentration of ethanol can be confirmed in the laboratory upon receipt of samples. To ensure proper preservation of BMIs, gently rotate jars that contain mostly mud or sand so that the ethanol is well distributed. Affix a second waterproof label on the outside of the jar. It is recommended that the label for the outside of the jar be printed with a laser printer (with alcohol-proof toner); otherwise, fill the label out by hand in pencil (Figure 36). Tape the label with transparent tape. Make sure all samples have both internal and external labels.

Contract/Billing Code:	
Project: CEMAF_2023	
Date: 06/08/23	**Time:**
Site Code: 114SRA005	**Sample ID:** 060823_114SRA005
Replicate#: 1	**Jar#:** 1 of 2
Stream Name: Upper Santa Rosa Creek	
County: Sonoma	**Collector:**
Sampling Method: RWB	

Figure 36. Example of a BMI jar label filled out with information from a bioassessment survey.

Step 11. After all sample collections have been obtained, transport all samples to CDFW's Aquatic Bioassessment Lab in Rancho Cordova, and use a Chain of Custody form (Appendix E1) to track the movement and handling of samples.

Physical Habitat Transect-based Measurements

After all biotic samples have been collected at a given transect, PHab data collection may begin. These data are designed to characterize a stream reach's physical habitat, knowledge about which can aid interpretation of the biotic data. In some cases, however, PHab data may be desired for a site assessment even when biotic/biomass samples are not being collected. The majority of PHab measurements in this SOP are gathered relative to the 11 main transects (Figure 34), and data for the PHab parameters described in this section are entered on transect- specific field sheets (and in the case of the "Pebble Count" data, also on the inter-transect field sheets). Physical habitat data collection starts at Transect A and proceeds working upstream along the monitoring reach.

Wetted Width and Bankfull Dimensions

Step 1. Measure the wetted width associated with the transect and record this (in meters) in the box at the top of the transect form. The wetted channel is the zone that is inundated with water and the wetted width is the distance between the sides of the channel at the point where substrates are no longer surrounded by surface water. The wetted width can include emergent, unvegetated sandbars or boulders in the middle of a channel, but should not include emergent, vegetated "islands" (defined as features that are not flooded during average year highwater events). When a transect crosses an island, subtract the width of the island from the distance between the wetted margins.

Step 2. Scout beyond the wetted channel along the stream reach to identify the location of the bankfull margins on either bank by looking for evidence of annual or semi-annual flood events. The bankfull channel is the zone of maximum water inundation in a normal-flow year (i.e., one to two-year flood events). Examples of evidence for bankfull location include topographic, vegetation, and geologic cues (changes in bank slope, changes from annual to perennial vegetation, changes in the size distribution of surface sediments, location of water stains on concrete and bedrock channels, etc.). Although it is tempting to use the position of drift material caught in vegetation to identify bankfull location, it only indicates the discharge height during extreme recent flow events and should not be used as an indicator by itself.

Step 3. Stretch a tape or stadia rod from bank to bank at the bankfull position along the transect. Record this distance (in meters) as a bankfull width at the top of the transect form. If using flexible tape, make sure the tape is taut before taking a reading.

Step 4. Record bankfull height (in meters) as the vertical distance between the water surface and the height of the bank at bankfull position. This can be done by standing at the wetted edge or transect center, holding a meter stick vertically from the water surface to the stretched tape to measure the height.

Step 5. Carry out the above steps at each of the 11 main transects.

Substrate Size, Depth, and Coarse Particulate Organic Matter (CPOM)

Particle size frequency distributions often provide information about instream habitat conditions that affect BMI distributions and may also reflect the stream's ability to accrue algal biomass. Changes in particle size distributions often accompany stream disturbances and may be a key source of stress to benthic organisms.

The Wolman "pebble count" technique (Wolman 1954) is a widely used and cost-effective method for estimating the particle-size distribution that produces data that correlate with costly, but more precise, bulk-sediment samples. The method described here records sizes of 105 particles in a reach: five particles, equidistant from one another, along each of the 11 main transects and 10 inter-transects. Depth refers to the depth of surface water in the stream at each of these points. Coarse particulate organic matter (CPOM; small particles of organic material, such as leaves/twigs, that are >1-mm in size, but no larger than 10-mm) is an indicator of the amount of allochthonous organic matter available at a site. Because CPOM is food resource for certain benthic macroinvertebrates, its abundance can provide information about the quality of the food web in a stream reach. Pebble count, depth, and CPOM are all measured in tandem at each of the 105 points along the sampling reach.

Step 1. At each transect (and inter-transect), use a stadia rod or tape measure to divide the wetted stream width by four to get the distance between the five points (Left, Left Center, Center, Right Center and Right) and locate the positions of these points along the transect. Once the positions are identified, lower a graduated rod (e.g., a waterproof meter stick) straight down though the water column to identify the particle located at the tip of the rod.

Step 2. Measure the depth from the water surface to the top of the particle with the graduated rod and record to the nearest cm.

Step 3. Record the presence or absence of CPOM within 1-cm from the edge of the rod.

Step 4. Remove the particle from the streambed and measure and record the length of its intermediate, or b-axis, to the nearest mm. The intermediate axis is neither the longest or the shortest of the three mutually perpendicular sides of each particle picked up. Actual measurements should always be recorded, whenever possible (i.e., for the fine gravel through large boulder-sized bed materials). If a direct measurement is impossible (e.g., the particle is deeply embedded or in a deep pool), an approximate size may be designated by assigning a particle size class listed in Table 3 based on visual estimation. Regardless of the method, all particles < 0.06-mm should be recorded as fines, and all particles between 0.06-mm and 2.0-mm recorded as sand. "Wood" applies to woody material, living or dead. "Hardpan" applies to consolidated fines, where individual particles cannot be easily separated or dispersed. Substrates (e.g., trash, macrophytes, live tree roots, and any other substrate not captured by the other available categories) that do not fall into any of the categories should be recorded as "other" (OT). Record particle measurement (or size class) on the transect sheet under "mm/size class" in the "Transect Substrates" portion of the form. If recording particle size class, use only the standard codes in Table 3 to record the information.

Table 3. Substrate size categories

Size Class Code	Size Class Description	Intermediate Axis Common Size Reference	Size Class Range
RS	bedrock, smooth	larger than a car	> 4 m
RR	bedrock, rough	larger than a car	> 4 m
RC[21]	concrete/ asphalt	larger than a car	> 4 m
XB	boulder, large	meter stick to car	1 - 4 m
SB	boulder, small	basketball to meter stick	250 mm - 1 m
CB	cobble	tennis ball to basketball	64 - 250 mm
GC	gravel, coarse	marble to tennis ball	16 - 64 mm
GF	gravel, fine	ladybug to marble	2 - 16 mm
SA	sand	gritty to ladybug	0.06 - 2 mm
FN	fines	not gritty	< 0.06 mm
HP	hardpan (consolidated fines)		< 0.06 mm
WD	wood		
OT	other		

Step 5. If the particle is cobble-sized (64 – 250-mm diameter), record to the nearest 5% the percent of the cobble surface that had been embedded by fine particles (< 2-mm diameter; see Cobble Embeddedness measurement procedure, below). Only continuous sections of concrete (e.g., concrete channel) should be coded as "RC". Concrete agglomerations smaller than 4-m should be treated as a single particle and measured accordingly.

Sometimes points with dry (not submerged or moist) substrates are encountered. To determine how to collect data at dry sampling points, it is necessary to first establish whether the dry area lies within the stream's active channel (i.e., therefore regularly inundated during storms), or on a stable island (i.e., therefore rarely, if ever, inundated). Stable islands are typically vegetated, often with woody shrubs or trees, and have heights near or exceeding bankfull height. Pebble counts should not be conducted on stable islands. If the transect spans a portion of the study reach in which the channel is bifurcated such that there are two channels with an intervening island, the entire transect should be placed across the dominant channel, and all five pebble count points should be located on that side.

If the point falls on a dry surface that is within the usual active channel (i.e., subject to regular disturbance by flows), then pebble count and primary-producer cover data from the dry point should be recorded as follows:

- score Depth as 0
- score Particle Size/Class and Embeddedness as described above for wet particles
- score all the algae variables (Microalgae, Macroalgae Attached, and Macroalgae Unattached), as well as Macrophytes and CPOM, as "D" for "dry"

Ordinarily, the transect would span the wetted width of the channel, but when no water is present at a given transect, evidence of the typical wetted extent of the active channel will need to be used to infer appropriate transect boundaries. Such indicators can include the transition from vegetated to unvegetated area (i.e., moving from banks toward the active channel), as well as the presence of dried algae, water stains, micro-topographic transitions, changes in substrate composition, soil cracks, and others.

Cobble Embeddedness

The degree to which fine particles fill interstitial spaces in the streambed has a significant impact on the ecology of benthic organisms and fish. Here embeddedness is the percent of the surface area (not volume) of cobble-sized particles (64 – 250-mm) that is buried by fines or sand particles (< 2.0-mm diameter). Embeddedness is determined for each cobble that is measured for particle size, up to a total of 25 cobbles. If < 25 cobbles are encountered during the pebble count, the remainder are "made up" by assessing cobbles that lie outside of the PHab data collection transects (see Step 3, below). In certain streams, it may not be possible to find 25 cobbles.

Step 1. Every time a cobble-sized particle is encountered during the pebble count, remove the cobble from the streambed and visually estimate the percentage of the cobble's surface area that had been buried by fine particles. If removal of the cobble is impossible, approximate embeddedness to the best extent possible. In the rare circumstances that multiple sample points land on the same cobble, do not take a second embeddedness measurement. Once embeddedness has been assessed for 25 cobbles, no more need be assessed.

Step 2. Record the embeddedness values for the first 25 cobble-sized particles encountered during the pebble count in the "% Cobble Embed" field in the "Transect Substrates" portion of the transect sheet.

Step 3. If 25 cobbles are not encountered during the pebble count by the time Transect K has been sampled, supplement the data by conducting a "random walk". It is preferable to wait until the rest of the PHab transect/inter-transect measures are complete so as not to trample unsampled transects during the random walk. Starting at a random point in the reach, follow a line from one bank to the other at a randomly chosen angle, recording embeddedness of any cobbles encountered (that were not previously recorded) along the way. Upon arriving at the other bank, reverse the process with a new randomly chosen angle. Spend a maximum of 10-min on the random walk, even if 25 cobbles have not been encountered by that time. Embeddedness for any cobbles encountered outside of the pebble count locations should be recorded in the "Additional Cobble Embeddedness" section of the field sheets.

Algal and Macrophyte Cover

Algal cover refers to the amount of algae in the stream reach, both in terms of 1) microalgal coatings ("slimy-ness") on stream substrates and 2) macroalgae (e.g., filaments, mats, globules). Algal cover is estimated by a point-intercept approach that entails collecting information about the presence/absence of both types of algae (as well as thickness, for the microalgae) at each of the five points along the transects associated with the pebble count. If the point corresponding to each pebble intercepts algae, then algae is recorded as "present" at that point.

Step 1. For each point along the pebble count, record information about algae as follows. For any film-like coating of algae (referred to as "Microalgae" on the datasheet) present on the surface of the substrate at that point, estimate the presence / thickness category according to the scheme in Table 4. For thicker microalgal layers, a small ruler can be used for measurement. For layers too thin to measure, use the indicators listed in the last column of Table 4. Note that these thickness codes refer only to microalgal film, not macroalgal mats. Be sure to collect microalgal thickness data from whatever substrate is topmost within the stream, and therefore most likely exposed to sunlight. Sometimes this substrate is not the actual pebble used in the pebble count, but rather a substrate type that occurs above the pebble, such as a thick mat of macroalgae that is above (and obscuring) the stream bottom. Microalgal species can grow as epiphytes upon macroalgal filaments and mats, coating them with a slimy, brown-tinted film.

Sometimes, due to the nature of the substrate, it can be difficult to discern whether a microalgal layer is present. For example, deposits of very fine sediments might obscure the diagnostic color of a microalgal layer, and the slipperiness of very fine silt may make tactile determination of microalgae impossible. If presence/absence of a microalgal layer cannot be determined with confidence, score microalgal thickness as "UD".

Table 4. Microalgae codes, thicknesses, and associated indicators.

Code	Thickness	Indicators
0	No microalgae present	The surface of the substrate is not at all slimy.
1	Present, but not visible	The surface of the substrate feels slimy, but the microalgal layer is too thin to be visible.
2	<1mm	Rubbing fingers on the substrate surface produces a brownish tint on them, and scraping the substrate leaves a visible trail, but the microalgal layer is too thin to measure.
3	1-5mm	
4	5-20mm	
5	>20mm	
UD	Cannot determine if a microalgal layer is present	(see explanation in text)
D	Dry point	

Step 2. In addition to recording the presence and thickness of microalgae on the surfaces of substrates, record the presence/absence of attached macroalgae in the water column, as well as unattached, floating macroalgal mats on the water's surface, corresponding to each pebble count sampling point. Do this by envisioning an imaginary line extending from the water's surface down to the stream bottom where the target pebble lies. If this line intercepts macroalgae, either floating on the water's surface, or somewhere within the water column, the appropriate algal class(es) should be recorded as "present". Attached macroalgal filaments have an obvious, current, physical connection to something (like a cobble, boulder, or a gravel bed) lying on the bottom of the stream, whereas for unattached macroalgae, there is no obvious physical connection with the streambed at the time of the assessment, and the algae is freely floating at or near the

water's surface. The data-collection point does not need to intercept attached algae at its point of attachment for it to be scored as "Attached"; all that is required is for the algae to be attached to the streambed somewhere, even if the attachment occurs far from the sample point. For each class of macroalgae (Attached and Unattached), mark "P" (for "present") if intercepted by the sampling point and "A" (for "absent") if not intercepted. Because pebble counts span the "wetted width" of each transect, pebbles at the margin positions will often be at least moist, and sometimes even submerged. As such, it is important to realize that algal cover can occur at the bank positions of the pebble count as well as intermediate positions across the stream. Algal cover should therefore be recorded at all five observation points along each transect. If any portion (above- or underwater) of a macrophyte is intercepted by the imaginary line associated with the pebble count point, mark "P" for "present" under "Macrophytes". Otherwise, mark "A" for absent. Macrophytes are defined as herbaceous, vascular plants rooted or floating within the stream's wetted channel, such as sedge, cattail, knotweed, Arundo donax (giant reed), watercress, water primrose, duckweed, etc. Our definition of aquatic macrophytes excludes trees, root mats, shrubs, mosses, and algae. This is the same as the definition of macrophytes used for Module J (Instream Habitat Complexity).

Bank Stability

The vulnerability of stream banks to erosion is often of interest in bioassessment because of its direct relationship with sedimentation. For each transect, record a visual assessment of bank vulnerability along an imaginary line between the wetted width and bankfull width of the stream channel. Note that sandbars are not considered part of the bank. Choose one of three vulnerability states: eroded (evidence of mass wasting), vulnerable (unprotected banks), or stable. All three states may be evident in a single reach at both natural and highly modified streams. The following indicators help describe the states:

- Eroded: Exposed tree roots, obvious bank slumps, fallen trees.
- Vulnerable: Sparse vegetation
- Stable: Bank armoring, robust vegetation, few exposed tree roots

Human Influence

The influence of human activities on stream biota is a central question in bioassessment analyses. Quantification of human activities is used to evaluate stress and to identify minimally disturbed reference sites. Reach-scale observations provide a crucial supplement to data provided by aerial imagery and GIS analysis. Anthropogenic features and activities associated with each main transect (for 5-m upstream and 5-m downstream from the transect, totaling a width of 10-m centered on the transect) are recorded in terms of zones based on how close they are to the wetted margins. The relative distance between the wetted and bankfull margins can complicate the assessment of human influence. If the wetted edge and the bankfull margin are at the same point, then land uses between the wetted edge and bankfull margin are not present, and that location cannot be scored. Conversely, in some streams, the bank and the wetted edge may be many meters apart. In that situation, the wetted edge should be used as a consistent point for defining the area. The area in which human influence is measured extends outward 50-m in both directions from the bank along the entire reach.

For each human disturbance feature/activity class, circle "Y" if it is present between the wetted margins; otherwise, circle "N", and then assess each side of the stream as follows: If the feature/activity is present between the wetted edge and bankfull margin, circle "B"; if it is within 10-m of the bank circle "C"; if it is within 50-m of the bank, circle "P"; otherwise, circle 0.

For each feature/activity, the most proximal category takes precedence and therefore is the distance at which that feature/activity should be scored. For example, if a feature/activity is observed within the channel, as well as on the banks, circle "Y" to denote the channel, and move on to scoring the next feature/activity class. Note that certain features (e.g., parks) are not applicable within the channel, and for these, "B" would represent the most proximal location possible.

Riparian Vegetation

Riparian vegetation has a strong influence on the composition of stream communities through its roles in directly and indirectly controlling the food base, moderating sediment inputs, and acting as a buffer between the stream channel and the surrounding environment. These methods provide a cursory survey of the condition of the riparian corridor. Observations are made in the same 10-m x 10-m riparian area, on either side of the wetted channel, used for assessing human influence "C" zone (Figure 37).

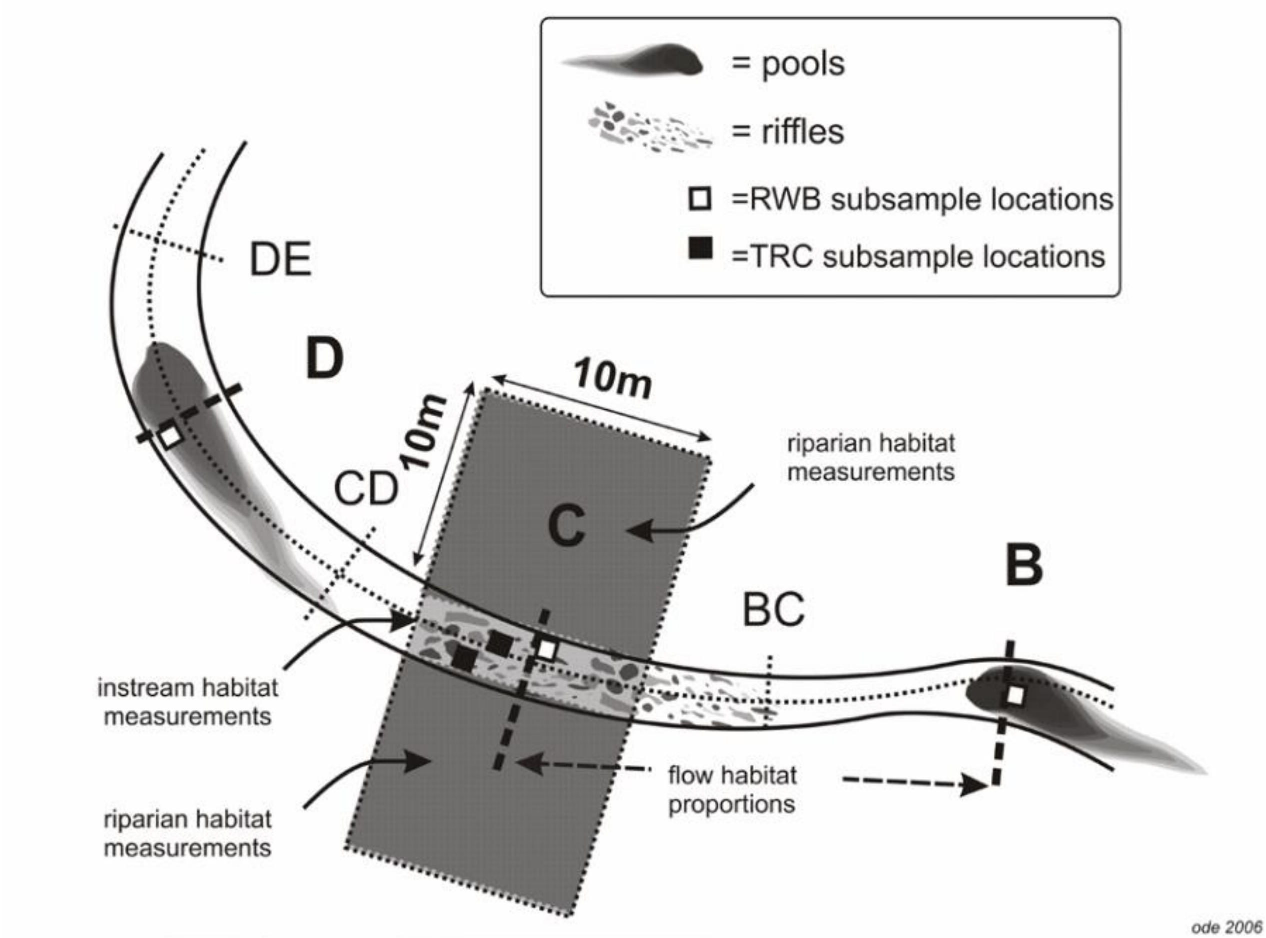


Figure 37. The section of the standard reach showing the appropriate positions for collecting riparian habitat and flow habitat proportion measurements. Also shown here is the human-influence zone corresponding to the area within 10m of the wetted width (i.e., zone "C").

Step 1. Mentally divide the riparian area into three elevation zones relative to the ground surface:

- Ground cover (< 0.5-m high)
- Lower canopy (0.5-m – 5-m)
- Upper canopy (> 5-m).

Within each zone, record the density of the following riparian classes:

- Upper Canopy: Trees and Saplings
- Lower Canopy: Woody Shrubs and Saplings
- Ground cover:
    a. Woody Ground Cover
    b. Herbaceous Ground Cover

c. Barren, Bare Soil and Duff (artificial banks, rip-rap, concrete, asphalt, etc. should be recorded as "barren").

An individual plant may contribute to multiple elevation zones. However, low-hanging canopy vegetation should not contribute to groundcover.

Step 2. Indicate the areal cover (i.e., shading) by each riparian vegetation class as either: 1) absent, 2) sparse (< 10%), 3) moderate (10-40%), 4) heavy (40-75%), or 5) very heavy (> 75%). Each of the elevation zones (upper canopy, lower canopy, and ground cover) should be evaluated independently of the others. All together, they do not need to total to 100%. However, the total for the three ground cover categories (Woody Ground Cover; Herbaceous Ground Cover; Barren, Bare Soil and Duff Ground Cover) should equal 100%.

Instream Habitat Complexity

The instream habitat complexity measure was developed to quantify fish concealment features in the stream channel, but it also provides valuable information about the general condition and complexity of the stream channel for other fauna. Concealment features include macroalgae, aquatic vegetation, boulders, woody debris (small and large), live tree roots, undercut banks, overhanging vegetation, and artificial structures. Estimates should include only those features that are found between the stream's wetted margins. Record the category best approximating percentage of areal cover of nine different instream (wetted channel) features within a zone 5-m upstream and 5-m downstream of the transect. Indicate the areal cover of each feature as either: 1) absent, 2) sparse (< 10%), 3) moderate (10-40%), 4) heavy (40-75%), or 5) very heavy (> 75%). Note that the sum of the percentages of the different features does not necessarily need to equal 100%.

Stream Shading (Densiometer Readings)

The amount of sunlight that can reach the stream is important because it influences stream temperature as well as primary productivity, which in turn affects food webs and constrains eutrophication. Using a convex spherical densiometer, stream shading is estimated in terms of the percent cover of objects (vegetation, buildings, etc.) that block sunlight. The method described uses the Strickler (1959) modification of a densiometer to correct for over-estimation of stream shading that occurs with unmodified readings. Taping off the lower left and right portions of the mirror emphasizes overhead structures over foreground structures (the main source of bias in stream shading measurements).

The densiometer is read by counting the number of line intersections on the mirror that are obscured by overhanging vegetation or other features that prevent sunlight from reaching the stream (Figure 38). All densiometer readings should be taken at 0.3-m above the water surface, and with the bubble on the densiometer leveled. The densiometer should be held just far enough from the squatting observer's body so that his/her forehead (or hat brim) is just barely obscured by the intersection of the two pieces of tape, when the densiometer is oriented so that the "V" of the tape is closest to the observer's face.

Take and record four 17-point readings from the center of each transect: a) facing upstream, b) facing downstream, c) facing the left bank, d) facing the right bank. The observer should revolve around the densiometer (i.e., the densitometer pivots around a point) over the center point of the transect (as opposed to the densiometer revolving around the observer).

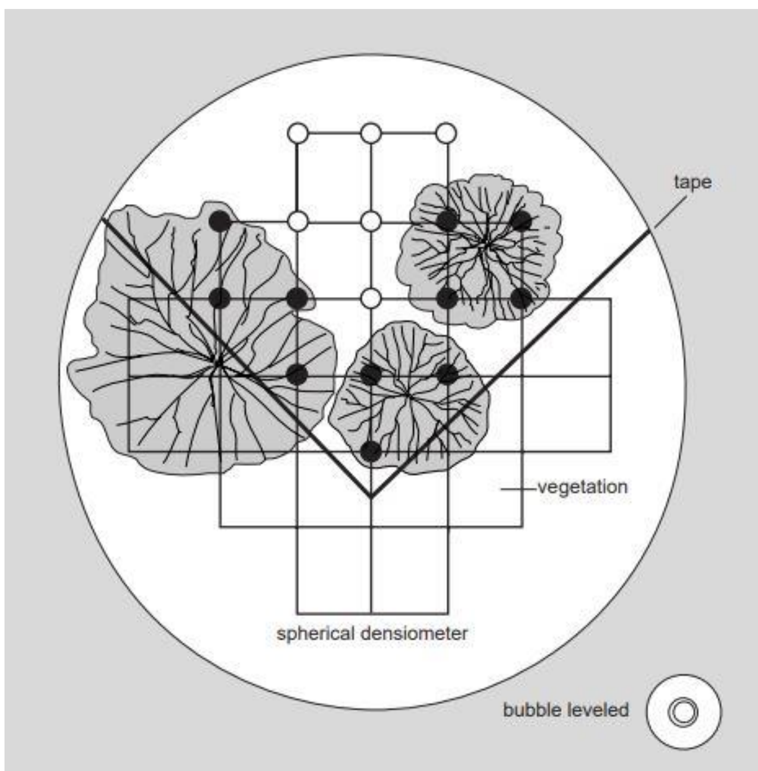


Figure 38. A concave spherical densiometer with bubble level, tape, and 17 points of observation. Closed circles represent line intersections counted in measurement of canopy closure (11 out of 17 points) (Reprinted from Fitzpatrick 1998)

For sites with a mean wetted width > 10-m, two additional readings must be taken: one at the left bank and one at the right, standing at the water's edge and facing away from the stream, toward the floodplain. These additional readings are useful in the case of larger streams and rivers, where the center of the channel does not provide adequate information about the degree to which shading is affecting the stream. For smaller streams, these additional two measures are recommended, but optional.

Slope and Sinuosity

The slope of a stream reach is one of the major stream classification variables, being a primary determinant of potential water velocities and stream power, which are in turn important controls on aquatic habitat and sediment transport within the reach. The slope of a stream reach is often strongly correlated with many biotic metrics and other PHab measures and is therefore very useful when interpreting biotic data.

Sinuosity, calculated as the ratio of the length of the flow path between the ends of the reach and the straight-line distance between the ends of the reach (Kaufmann et al. 1999), is measured at the same time as slope. These two measurements work best with two people: one taking the readings at the upstream transect ("backsighting") and the other holding a stadia rod at the downstream transect. Slope measurements can be measured from a point on the transect at water's edge, but sinuosity measurements should be taken from mid channel. If water depth or obstructions prevent this, attempt to estimate the correct bearing.

In small, highly sinuous, or densely vegetated streams, it may not be possible to obtain a clear line of sight from one transect to the next. If the midpoint of the next transect is not visible from the starting point, divide the inter-transect distance into sub-sections, using the "Supplemental Sections" (indicating the proportion of the total length represented by each section) on the field sheet. Otherwise, leave Supplemental Sections blank. Do not measure slopes across dry land/meanders in the stream. Although slope and sinuosity are measured independently, always record the two data points at each location.

An auto level should always be used for reaches with a slope of ≤ 1%. Either a clinometer or an auto level may be used for reaches with a slope of > 1%, and sometimes (e.g., in steep areas that are also heavily vegetated) a clinometer is preferable for logistical reasons. If a reach is visually estimated to be close to 1%, use the auto level. An auto level or hand level measures the elevation difference (rise) between transects; the distance between transects (run) is also required for a slope calculation. Conversely, if a clinometer is used, the percent slope is recorded directly.

Do not measure slope across dry land (e.g., across a meander bend).

Slope - auto level method

Step 1. Identify a good spot to set up the auto level (ideally near the middle of the reach, if there is good visibility from this location to both Transects A and K).

Step 2. Begin "shooting" the change in elevation of the water level of the stream from transect to transect. Try to start with one of the outer transects (like K). Have a crew member at Transect K hold the stadia rod at water's edge and perpendicular to the ground. Viewing through the auto level, look at the stadia rod and record the height. Record this information on the "Slope and Bearing Form" on the field sheet, and then have the stadia rod holder proceed to the next transect (e.g., Transect J), again holding the base of the stadia rod at water's edge.

Step 3. If there is a point along the reach at which there is no longer a clear line of sight from the auto level to the stadia rod positioned at the transect, at water's edge (or if the length of the stadia rod is exceeded in a steep reach, or if the auto level is bumped out of position before all the measurements are done), a new location must be set up for the auto level. To maintain a relationship with water heights of the various transects already measured, it will be necessary to "re-shoot" the height of the water at the last transect for which a valid measurement was attained. From there, assuming there is no more disturbance to the position of the auto level, the remaining transects can be sighted from the new position. On the Slope and Bearing Form corresponding to auto level use, indicate the transect at which the auto level's position has been changed (i.e., list the transect that was measured from the original and the new positions twice on the datasheet: once for the original position, and once for the new). Also indicate the segment lengths or distance between main transects (i.e., 15-m, 25-m or other). This data will later be used to determine the slopes between transects and for the reach as a whole.

Slope - clinometer method

Step 1. Stand erect next to the stadia rod (held perpendicularly to the ground) on level ground and a tie a highly visible piece of flagging around the rod at eye level. Then, beginning with the upper transect (Transect K), stand where the wetted margin intersects with the transect, and have a second person hold the flagged stadia rod perpendicularly to the ground at the wetted margin of the next downstream transect (Transect J).

Step 2. Use the clinometer to measure the percent slope of the water surface between the upstream transect and the downstream transect by sighting to the flagged position on the stadia rod and record the value in the "Slope and Bearing Form" section of the field sheets. The clinometer gives both percent slope and degree of the slope (the measurements differ by a factor of ~2.2), so be careful to read and record percent slope rather than degrees slope. Percent slope is read from the scale on the right-hand side when looking through most clinometers (but confirm this with the owner's manual for your own model).

Step 3. Continue measuring slope at each one of the transects. Note that when moving from transect to transect, the clinometer reader must stand exactly where the stadia rod had been placed during the previous reading.

Step 4. If the stream reach geometry makes it difficult to sight a line between transects, divide the distance into two or three sections and record the slope and the proportion of the total segment length between transects for each of these sections in the appropriate boxes on the slope form ("Supplemental Segment").

Sinuosity

Step 1. Take a compass reading from the center of each main transect to the center of the next main transect downstream and record this bearing to the nearest degree in the "Slope and Bearing Form" section of the field sheet. Bearing measurements should always be taken from the upstream to downstream transect.

Step 2. Proceed downstream to the next transect pair (I-J) and continue to record slope and bearing between each pair of transects until measurements have been recorded for all transects.

Photographs

Take a minimum of four photographs of the reach at the following locations: a) Transect A, facing upstream, b) Transect F, facing upstream, c) Transect F, facing downstream, and d) Transect K, facing downstream. It is also desirable, albeit optional, to take a photograph at Transect A, facing downstream and Transect K, facing upstream to document conditions immediately adjacent to the reach. Use digital photographs. Record the image numbers on the front page of the field form under "Photographs". An easy way to keep track of which site each series of photographs belongs to is to take a close-up of the front datasheet (containing legible station code and date) for that site prior to taking the series of photos.

Physical Habitat Inter-Transect-Based Measurements

Although most measures are taken near the main transects, a few measures are also recorded at the "inter-transects" located at the midpoint between main transects. These measures are: 1) Wetted Width, 2) Substrate Measurements ("Pebble Count")/Depth/CPOM/Cobble Embeddedness/Algal and Macrophyte Cover, and 3) Flow Habitats.

Inter-transect Wetted Width

Measure wetted width the same way it was measured for the main transects.

Substrate Measurements, Depth, CPOM, and Algal/Macrophyte Percent

Collect particle size measurements, water depth, CPOM, embeddedness and algal and macrophyte cover data the same way they were collected for the main transects.

Flow Habitats

Because many BMIs and algae prefer specific flow and substrate microhabitats, the proportional representation of these habitats in a reach is often of interest in bioassessments. Like the riparian and instream PHab measures, this procedure produces a semi-quantitative measure consisting of 10 transect-based visual estimates. These flow habitat types are products of geology, slope, and discharge, and one habitat type may change into another as water levels increase or decrease; therefore, the habitat types should be recorded at the time of sampling. On the inter-transect field sheet, record to the nearest 5% percentages of the various flow habitats present within the region between the upstream inter-transect and downstream inter-transect bracketing each main transect (the total percentage of flow habitats for each stream section must total 100%). Although these definitions differ from geomorphological definitions presented in other hydrologic references, they were developed to produce more easily standardized and objective categories that improve data comparability. Please adhere to the definitions used in this text when employing this SOP.

Discharge

Take a discharge measurement following the completion of all main transect and inter-transect sampling (see the *Discharge Measurement* section for details).

Stream Shading (Densiometer Readings)

Take a densiometer reading as close to directly over the DO logger as possible. See the *Stream Shading (Densiometer Readings)* section in the *Physical Habitat Transect-Based Measurements* module for details.

Data Quality and Management

Field data is entered from paper forms to a database entry shell. Once data is entered, another staff member should conduct a line-by-line review of the shell for data entry errors. See the *data processing protocol* for more details about data entry. Electronic data entry needs to be completed before BMI samples can be processed by staff at the ABL.

Once the field data is entered electronically, BMI samples will need to be delivered to the ABL, which is part of the Region 2 offices at the Nimbus Hatchery. Print and fill out a Chain of Custody (COC) form and ensure all the sample labels are filled out with labels both inside the jar and taped to the outside of the jar.

Once the ABL processes the BMI samples, they send the results directly to SWAMP. SWAMP will then upload the results to CEDEN, where they can be accessed.

Snorkel Surveys

Background

This monitoring protocol is an adaptation of the Salmonid Spatial Structure Monitoring Survey Protocol (Garwood and Ricker 2016) and the California Sea Grant Coastal Monitoring Snorkel Protocol (Sea Grant 2022), *but is under development and subject to change as we refine the.methods to meet our specific objectives.* Salmonids are used as a focal species for these efforts because they are good indicators of overall stream health (Moyle 2008), are a keystone species (Wilson 1995), are of recreational, tribal, and economic importance. Snorkel surveys are effective, cost efficient, and cause less impact on species of concern (Adams 2011).

This protocol is designed to collect the data needed to estimate the over-summer survival rate of juvenile Coho Salmon (*Oncorhynchus kisutch)* and steelhead trout (*Oncorhynchus mykiss)* through paired summer (May/June) and fall (August/September) snorkel dives. In streams where fish passage is limited, the early summer dives should take place just before stream disconnection to allow for analysis of over-summer survival. Snorkel data will be analyzed with habitat variables to assess relations between anthropogenic water use and over-summer salmonid survival. Collect habitat variables during the snorkel surveys at the pool unit scale and at the reach scale with continuous data loggers placed within the reach. Snorkel reaches are approximately 1-km in length and the data loggers are located approximately halfway through the reach.

By incorporating two surveys over the course of a season, this data can be used to assess over-summer "survival" (Woelfle-Erskine 2017) and to evaluate the probability of "extinction" (occupied patch becomes unoccupied) and "colonization" (unoccupied patch becomes occupied) in relation to habitat characteristics (Hines 2014).

Quality Assurance

Quality assurance measures for snorkel surveys include pre-survey snorkel training to review methods, fish identification, and snorkeling approaches, only diving when conditions allow and with proper equipment, and using calibration dives to assess observer bias. Quality assurance measures include:

- Conduct training in similar situations to what divers will encounter in the field, where snorkelers can observe focal species and cover all methods that will be implemented during the field season.
- Annual review of protocol.

- Review species identification and life history characteristics by working with experienced divers, viewing video from natural conditions, and comparing color images of species, especially those with juveniles that can be harder to speciate.
- Ensure underwater visibility is adequate and only snorkel with optimum light conditions; always use a dive light with adequate lumens (more is better).
- Use multiple divers/lanes in larger rivers to ensure complete visual coverage.
- Employ calibration dives to resample habitat units and assess observer bias, since underwater observations have imperfect detection.
- Take care to minimize the displacement of fish by avoiding disturbance to sampling units, diving in an upstream direction, and avoiding sudden movements.

Method Overview

Snorkel 1-km reaches centered on the most downstream site for each HUC 12 (Site 1). Surveyors must snorkel first and collect habitat data second, to minimize fish displacement. During the summer dive (day 1), establish pool units and collect data for every pool within the reach. During the summer calibration (day 2), every other pool unit should be snorkeled by a different snorkeler than the first day, to calibrate fish counts. During the fall dive, which is generally 6-8 weeks after the summer dives, (day 3), collect habitat data and snorkel every established pool unit. During the fall calibration dive (day 4), every other pool is snorkeled by a different snorkeler than day 3 to calibrate fish counts. A discharge measurement is collected during the same week as the dives. The calibration dives should be completed one day after the dive, to allow visibility and fish behavior to reset while also minimizing the time between dives.

It is important that field crews take the time to review access documents prior to the day of the survey to maximize efficiency while in the field. While the snorkeler is diving pools, the data recorder can enter data and measure habitat metrics <u>if it does not affect the snorkel effort (i.e. downstream of the snorkeler)</u>.

Snorkel surveys should be completed with a two or three-person crew: one data recorder and one or two divers. Most smaller streams will only require one diver, but larger streams might benefit from two divers. All crew members should be prepared to snorkel if needed. When possible, snorkelers should remain consistent for the entire reach.

Survey Priorities: People > Fish > Data

Staff safety is the highest priority when completing any surveys in the field. Do not snorkel a unit if you feel it is unsafe (e.g., harmful algal blooms, contaminants, sewage discharges, agricultural or industrial discharges, poor visibility, fast-moving water, stringers or other safety obstacles). The second priority is ensuring that the surveyor's actions are not threatening or endangering fish or wildlife. Lastly, data integrity is critical, and protocols should be closely followed to ensure quality data, but no actions should be carried out that might threaten the safety of the surveyors, fish, or wildlife. If you feel like any of these priorities are not being met, contact your supervisor.

Snorkel Survey Preparation

Prior to completing a snorkel survey, ensure equipment and surveyors are prepared for the survey. Before leaving the office, check the weather forecast. If heavy rains are expected, bring it to your supervisor's attention to discuss the likelihood of high flows creating unsafe conditions. If hot weather is forecasted, be sure to bring extra water or a water pump. Make sure to have the gear described in the Field Equipment List before leaving the office. It is important to ensure following:

- iPad is charged
- Flashlights and backup batteries are fully charged
- Backup tablet or phone in case of iPad failure
- Field gear has been decontaminated if previously used in a different watershed

Survey Approach

Use ESRI's Field Maps loaded with the snorkel reach start and end points to navigate to the site. When walking to the beginning of the snorkel reach, avoid walking through the reach to make sure you do not affect fish behavior or water clarity.

When approaching a habitat unit, visually determine if it meets the pool criteria (Figure 39). In general, identifying pools should be obvious for most habitat units. In the cases where it is less clear if it is a pool, discuss it with your field partner and use the minimum pool metrics below. When a pool is on the cusp of qualifying, snorkel the pool and take more accurate minimum pool metric measurements afterwards, rather than risk disturbing the fish. You can always exclude a pool after snorkeling if the minimum size thresholds are not met. <u>Snorkelers should do everything possible to avoid influencing the pool and spooking fish</u>. If a pool does not meet the minimum size requirements, it does not receive a pool number and surveyors should <u>not</u> retain the data. The most important thing is to remain consistent when defining pools within a reach. The minimum pool metrics below are general guidelines, and surveyors should use their best judgement to determine if the unit functions as a pool given the stream size.

Minimum pool metrics:

- o Depth: > 1-ft. (in an area at least as long as the max wetted width)
- o Surface Area: > 30-ft^2.

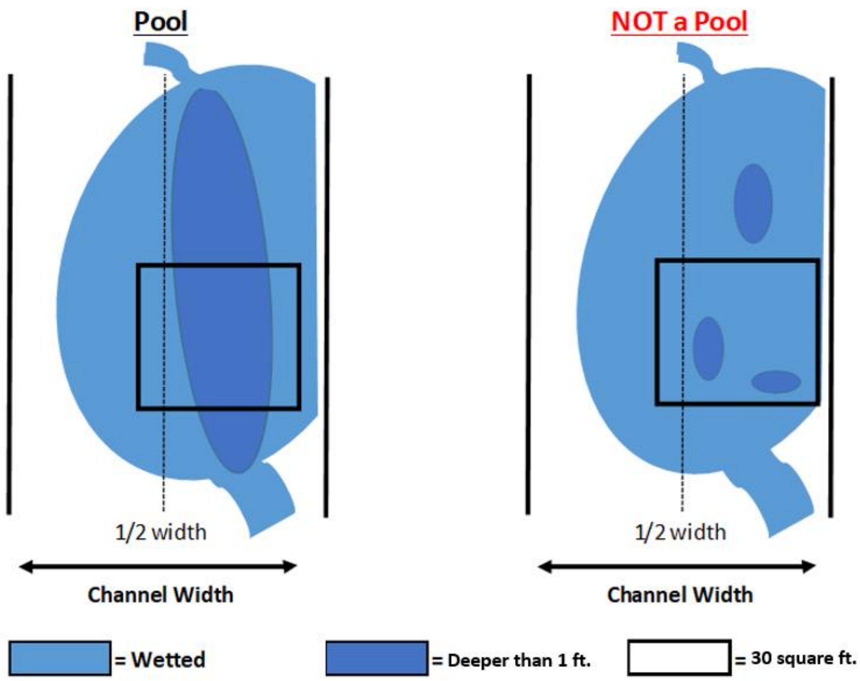


Figure 39. Top view of two habitat units, where the one on the left is a pool because it is greater than 1-ft. in depth for at least as long as the wetted width. The habitat unit on the right does not meet the minimum pool metrics because it only has a few isolated spots where the depth is greater than 1-ft. (source: Sea Grant 2022).

A ***side channel pool*** must meet the same requirements. For consistency, snorkel the main channel with more flow first, then snorkel side channel pools second (Figure 40).

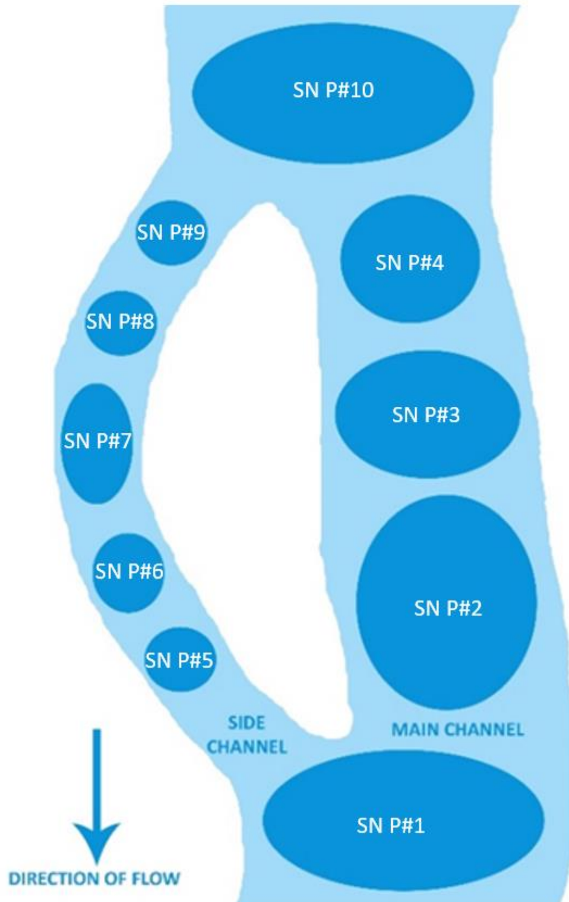


Figure 40. Aerial diagram of a main channel and a side channel with the snorkeled pools (SN P) labeled in the order.

All the pools within a reach will be identified and flagged during the first pass of the season. During subsequent passes, if a pool no longer meets the pool criteria (e.g., too shallow), surveyors should still do their best to snorkel the habitat unit. If it is no longer a pool, add a note in the comments but still collect the data.

Pool Boundaries

Assess the pool layout and identify the pool-unit boundaries. Pool boundaries are based on hydrologic and geomorphic breaks, or obstructions that would otherwise impede (juvenile) fish from passing from one unit to the next between dive passes. Unit breaks are typically composed of riffle crests occurring between deeper habitats and/or channel obstructions (e.g., wood, beaver dams, or boulders). However, distinct breaks will not always be present and breaking the unit may become subjective. When defining sample units, it is critical to avoid situations when you cannot ensure fish are retained in the sample unit (e.g., movement between adjacent pools). This is important to maintain independence at the sample-unit, in this case, the pool. During these surveys, error on the side of lumping debatable units together rather than splitting them. If there is a riffle between two pool units, split into two pools, but if there is just a shallow section in the pool that fish could very easily move upstream and downstream, call it one pool.

Establish a Plan

From the downstream pool tail or riffle crest, establish a plan prior to snorkeling the pool-unit. Consider lines of sight, depth restrictions, complex habitat features and any other factors that may influence your ability to identify and keep track of fish in the pool. You do not need to be able to see every fish at once, but rather keep track of all the fish in front of you. Your mental plan should focus on corralling the fish as you move forward and counting them as they swim past. For example, if there is refugia that would be difficult for you to assess fish within (e.g., deep undercut banks), your approach should herd them away from that protection, or ensure they have swum past you before reaching that refugia. When possible, try to get fish to swim past you on one side or the other, as this will make it much easier to count fish as they swim by.

Navigating the Pool

Snorkel upstream starting from the lower pool-unit boundary (e.g., pool tail/riffle crest) to the upstream end, covering as much of the unit as water depth allows. Often, the tail of the pool is too shallow to get the snorkelers face in the water to observe fish. If this is the case, snorkelers can shuffle their feet to try to spook fish upstream into the pool unit. Once snorkelers get into the pool, they should try to avoid sudden movements to reduce spooking fish and causing a sediment disturbance. Snorkelers will only count fish once the fish are downstream of them to reduce potential for double counting.

Single Dive or Lane Dive

Pool-units with complex habitat features and exceeding 15-ft in average width should be surveyed by two divers using lanes (double dive). If using lanes, divers will sum their counts upon completing the pool-unit. When diving in lanes, divers should split the creek into two lanes and attempt to split the fish into those lanes. Snorkelers should establish how fish that swim between them will be counted before diving each pool. Generally, one of the snorkelers will be responsible for all fish from the bank closest to them to the boundary of the other diver, while the other diver will only count fish between them and the bank closest to them. Snorkelers should communicate before, during, and after the dive to improve accuracy. If you complete a double dive, be sure to write it on the flagging so the snorkelers on the following day will know to complete a double dive as well.

Skipping Pools

If possible, skipping pools should be avoided, but in rare circumstances, surveyors may skip a pool for safety reasons or due to poor surveying conditions (wildlife carcass in pool, poor visibility, etc.). If a pool is skipped during the first pass, surveyors should still hang a flag stating that it was skipped and provide the purpose (e.g., "Skipped. Boar carcass in habitat unit"). When skipping a pool during the first dive, do not give it a pool number. When skipping a pool during later dives that were previously surveyed, survey crews should still record the habitat data they would normally collect, and they should use the comment field to explain why the pool was not snorkeled.

Counting

Salmonids will be counted and grouped by age classes based on size (≥100-mm = parr age1+, ≤100-mm = YOY age0) and species (Coho Salmon, steelhead trout). Any suspected resident steelhead will be included in the steelhead parr counts, but resident status can be noted in the comments section (example comments: "1 Res"). Adult (>500 mm) steelhead and Coho Salmon are reserved for suspected ocean-run individuals, are very rare to see while doing summer snorkel surveys and should be counted in Non-target Species Salmonids section of the survey form. All aquatic, non-salmonid fishes, amphibians, and crustaceans, will be identified to the lowest possible taxon and placed into binned counts (1-5, 6-25, 26-100, >100).

Managing counts while diving is one of the more challenging tasks, but there are different ways to approach it. When the diversity of species in the pool is low (<5 species-age categories), it can be easiest to keep track of them in your head. When species diversity and counts increase, it can become helpful to utilize strategies to keep the numbers straight. Surveyors can use dive slates or click-counters to help keep track of their counts, though they can be challenging to use while keeping an eye on the fish. If divers decided not to use a slate or click-counter, a helpful trick is to always keep your category/count in the same order in your head. In the survey forms, the order is Coho YOY, Coho parr, steelhead YOY, and steelhead parr. Some find it helpful to say the category/count repeatedly in their head as a mnemonic device, adding to them as you see more. For example:

> "…*coho YOY 0, coho parr 1, steelhead-YOY 3, steelhead parr 5…*
> "…*coho YOY 0, coho parr 1, steelhead-YOY 3, steelhead parr 5…*
> **** 3 more steelhead YOY swim past you****
> "…*coho YOY 0, coho parr 1, steelhead-YOY 6, steelhead parr 5…*

Another challenge to manage underwater is when schools of fish are large. Counting large numbers is a skill that is honed with experience, further refining your search image. Learning to recognize what amount of space a group of fish occupies will greatly increase your ability to accurately estimate large groups. For instance, if you can recognize the amount of space a group of 10 Coho YOY occupies, you can better estimate a group that looks roughly three times bigger to be about 30 Coho YOY. It is much easier to estimate in groups of 5 or 10 then hoping to individually count large schools of fish. When finished diving a pool-unit, record your counts as quickly as possible.

Dive lights are an important tool to consistently view and accurately count fish. Dive lights must always be used throughout the dive to aid in spotting and identifying fish, regardless of visibility. If you do not have a dive light, do not conduct the survey.

Data Recorder Communication

To avoid losing track of your fish counts, make sure to tell your data recorder your species-numbers **as soon as the dive is completed**. Try to tell them in the same order that they are listed in the form (coho Age0, coho Age1+, steelhead Age0, and steelhead Age1+). After the salmonids are recorded, record the binned counts for all other species.

Flagging The Pool

Hang flagging to provide important information for future dives. On the summer dive, hang a flag just downstream of the pool tail crest and at the upstream end of the pool. Do not remove the flagging until the last fall calibration dive. Flagging will also be used to mark and measure the average wetted width transect.

For marking the boundaries of a pool, include the following on the flagging: agency, pool number, if it was a double dive (circled "d"), and date to remove.

Downstream flag information example:

CDFW – [Pool Number] – Remove Fall 2024

Upstream flag information example:

CDFW - End of Pool [Pool Number] – Remove Fall 2024

For marking the average wetted width transect, include the following on the flagging: agency and pool number.

Average Wetted Width Transect example:

CDFW - [Pool Number]

Encountering Dry Habitats

If the reach is dry during the first survey of the year, fill out the Reach Level Data on Survey123 form and indicate in the notes that the stream is dry. Relocate and complete a snorkel survey at the next upstream field site (Site 2, then Site 3 if Site 2 is also dry). Be sure that there is at least 1-km of stream access at the upstream sites.

If the reach is dry during later surveys, complete the survey as usual. Using flagging and ESRI Field Maps to locate pool units and document relevant data. Surveyors will walk the entire reach and will still enter data for every pool unit. Enter a "0" in quantitative habitat metric fields (e.g., depths, widths) when the unit is dry.

Data Collection

During the first dive, collect both **habitat** and **snorkel data** for **all pools**. On the calibration dives (next day), **record salmonid and all other species** count data for **every other pool** and collect a **flow measurement** for the reach. The following sections match the Survey123 forms designed for this protocol. Please reach out to headquarters CEMAF staff if you have any questions or need clarification on the data collection protocol.

Reach Information

The Reach Information page is filled out at the start of the survey and includes data that is relevant to the whole survey.

- **Date, State Time:** Automatically filled, check for accuracy.
- **Tributary:** Select from the drop-down menu.
- **Site:** These should all be Site 1.
- **Surveyors Initials:** Two letter initials separated by a single space (e.g., EP KS).
- **Pass:** Enter the pass number. '1' for first dive or '2' for calibration dive.
- **Discharge:** Record the HACH discharge measurement (CFS) on the second pass. Enter –9999 during the first passes. Discharge should be measured in proximity, or directly at the PT logger flow site.
- **Visibility:** Determine visibility by moving a stadia rod away from snorkeler until ft. numbers are no longer distinguishable. Record distance between the snorkeler and the stadia rod in tenths of ft. Do this in a pool unit that is not included in the estimate so that you minimize disturbance. If you

encounter a noticeable visibility change in a unit, measure visibility again and record the new distance in the comment field for that unit. **If the visibility is less than 4-ft. for a reach, the survey should be rescheduled.** If the visibility is less than 4-ft. for an isolated pool, surveyors may choose to dive or skip the pool if they feel it is unsafe. Be sure to take detailed notes when visibility is poor.

- **Comments:** Enter any miscellaneous reach comments such as lack of ability to snorkel specific pools, lack of salmonid habitat, etc.
- **End Time:** At the end of the survey, come back to this page and enter the time you finished the last pool.

After the Reach Level Data page is populated, advance to the Unit Level Data page by clicking the arrow (>) on the bottom right corner of the page. Generate and populate "Pool Units" sub-pages for every snorkeled pool. Use the "+" button on the bottom corner of the Unit Level Data page to create subsequent pool units.

Pool Information (Every Pass)

- **Time:** Automatically filled, check for accuracy.
- **Unit Number**: This is the number of the pool unit you are on. When you start your reach, the first pool you see is pool number 1, the next pool is pool 2, etc. If you lose count of your pools at any time, either look back at the previous page or take a moment to hike back to the previous pool to check the flagging. Unit numbering errors can cause major problems with the data, so please double-check to make sure you are numbering your pools correctly. This takes a few seconds per pool and can save hours of work fixing data errors. If you find you've made a mistake, send your supervisor a detailed email ASAP with the error. <u>Pool numbers in the data must match up with the flags.</u>
    - Side Channel Numbering: When you encounter a side channel, choose which is the side channel and which is the main channel based on the amount of flow (main channel = more flow). Continue your pool numbering in the <u>main channel first</u>, then return to the side channel where you left off and continue numbering.
- **Surveyors Initials:** Two letter initials for the diver(s). If two divers, separate by a single space (e.g., EP KS).
- **GPS Waypoint:** Collect waypoints for surveyed pools for all passes at the downstream RCT. If the GPS function fails, use a handheld GPS, and manually enter the latitude and longitude of the sampled pool-unit into the comment field.

- **Pool Type:** Indicate whether the pool is a main channel or a side channel pool.
- **Photo:** For every pool unit, capture a photo (in landscape orientation) looking upstream, that includes the downstream RCT location and the pool. If the pool is dry, take a photo that would include the RCT and pool if it were wetted.

Habitat Data (First Passes Only)

- **RCT Depth:** Record RCT depth at the downstream end of the pool in tenths of ft. This will be used to assess the likelihood of juvenile fish passage. The RCT is the deepest point along the shallowest transect that separates the downstream end of the pool and the upstream end of the riffle. Imagine you were trying to cross the stream at the intersection of the pool and the riffle, and you were trying to stay as shallow as possible. The deepest part of that path would be the RCT.
- **Air Temp:** Record the air temperature (in the shade) for the first pool, PT pool, and last pool of the snorkel reach. Record the air temperature before water temperature.
- **Water Temp:** Record the water temperature (in the shade) for the first pool, PT pool, and last pool of the snorkel reach. Record the water temperature after air temperature.
- **Dominate Streambed Composition:** Indicate what the substrate is primarily composed of: clay, bedrock, or alluvium (cobbles, sands).
- **LWD Count:** Record the number of large woody debris (LWD) greater than 1-ft. in diameter and greater than 6-ft. in length that touches the water surface. Multi-stemmed logs are counted as one LWD (Figure 41).

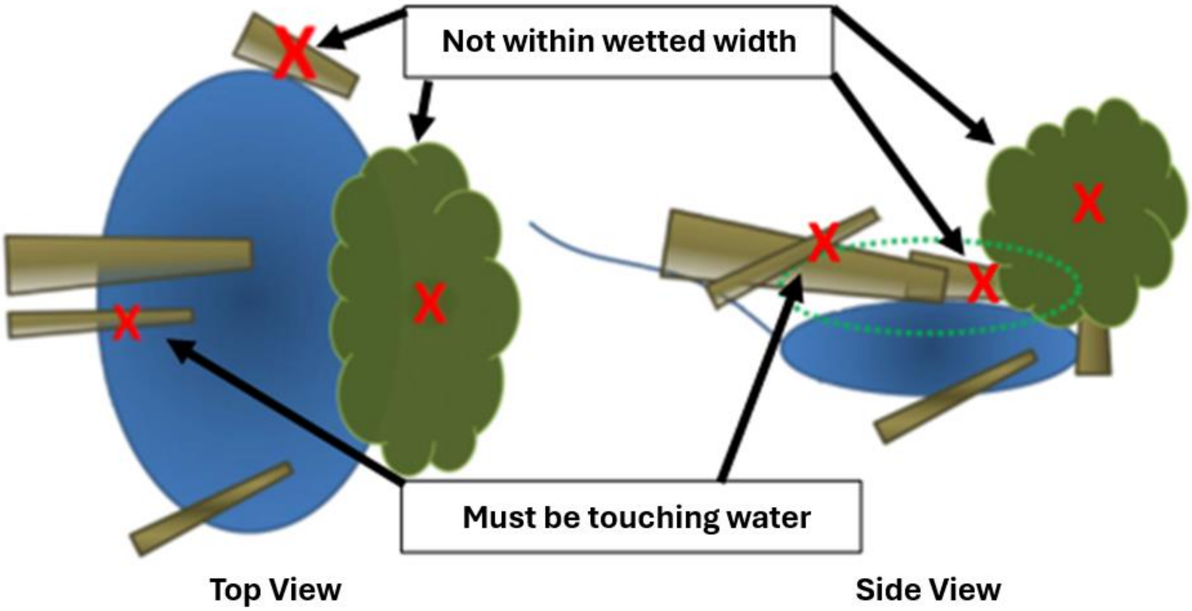


Figure 41. Top and side view of a habitat unit with a depiction of what should be considered LWD.

- **Average Pool Width:** Record the pool wetted width to the nearest 0.1-ft. that best represents the average width. During the first dive of the season, mark both banks with flagging where the width was measured. Write a "RR" or "RL" (river-right or river-left looking upstream) and the pool number on the flagging. Future widths should be measured at the transect established on the first survey. The average pool width location should only move if the initial transect is no longer wetted, and this should be notated in the comments.
- **Average Pool Depth:** Lay the measuring tape or stadia rod across the "average pool width" and average the depths at 25%, 50%, and 75% across the stream and record the average pool depth to the nearest 0.1-ft. For example, a transect with a width of 10 ft, would average the depths at 2.5-ft, 5.0-ft, and 7.5-ft.
- **Max Pool Depth:** Record the maximum depth of the survey area to the nearest 0.1-ft. The snorkeler should have a good idea of where the max pool depth is located.
- **Cover Rating:** Record the overall rating of the pools available fish cover (1-5). This rating is a visual three-dimensional score of all cover available to salmonids in relation to the total pool volume at the time of survey. Fish

cover includes LWD, SWD, boulders, root masses, undercut bank, submerged vegetation, overhanging vegetation, or a bubble curtain.

[1] No cover: Unit is void of fish cover.

[2] Poor: Lacking significant fish cover and complexity. Contains at least one form of cover but has limited availability.

[3] Average: Unit generally has fish cover but lacks complexity and contains at least two forms of cover.

[4] Good: Unit provides extensive quality fish cover for up to 50% of the area from at least three forms of cover.

[5] Excellent: Unit provides excellent quality fish cover and covers more than 50% of the area with at least four forms of cover.

- **Pool Obstruction:** Record the total percentage of the pool that the snorkeler was not able to directly view due to obstructions in the pool.
- **Pool Length:** Record the maximum pool length (downstream to upstream) along the thalweg to the nearest 0.1-ft.
- **Comments:** Record any notes about the pool habitat or snorkel data. Document any point of interest that might affect salmonid survival or habitat conditions within the unit that is not already captured by the data fields (spring or tributary input, land use impacts, etc.).

Target Species Snorkel Data (Every dive)

- **Coho Salmon YOY:** Record the number of individuals observed.
- **Coho Salmon Parr:** Record the number of individuals observed.
- **Steelhead YOY:** Record the number of individuals observed.
- **Steelhead Parr:** Record the number of individuals observed.
- **Salmonid Species YOY:** Record the number of individuals observed.
- **Salmonid Species Parr:** Record the number of individuals observed.

Non-target Species Data (Every dive)

- **Species:** Enter the binned counts for non-salmonid species. Select between 1-5, 6-25, 26-100, or >100. If you do not see the species as part of the list included in the spreadsheet, select add a comment and binned count to the 'Comments' (Non-target Species). If you frequently observe a species that you think should be added to the list, contact your supervisor or snorkel lead so it can be added. If you are unsure about the species, review the species identification guides. If you cannot find the species you are looking for in the guide, take a photograph and research it when you return to the office.

Note: Each region should have its own list of species that are found within the tributaries.

Data Quality, Processing and Management

Follow the same general quality control and upload procedures outlined in the installation section.

Open the Excel QC spreadsheet located on the CDFW Microsoft Cloud (i.e., Teams, SharePoint), here:

> *(Microsoft Teams) California Department of Fish and Wildlife\Wildlife Cannabis Monitoring Program - Documents\Data and Analysis\Snorkel\Survey123\QC Forms\YYYY_CEMAF Seasonal Monitoring Form**
>
> ** YYYY = year*

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State of California – Natural Resources Agency GAVIN NEWSOM, Governor
DEPARTMENT OF FISH AND WILDLIFE CHARLTON H. BONHAM, Director
California Environmental Assessment and Monitoring Program
Attn: Fisheries Branch
P.O. Box 944209
Sacramento, CA 94244

Appendix A: Changes to Protocols

Date	Section	Change

State of California – Natural Resources Agency
GAVIN NEWSOM, Governor
DEPARTMENT OF FISH AND WILDLIFE *CHARLTON H. BONHAM, Director*
California Environmental Assessment and Monitoring Program
Attn: Fisheries Branch
P.O. Box 944209
Sacramento, CA 94244

Appendix B: Office of the General Counsel-approved Temporary Access Permit

The Temporary Access Permit (TEP) and letter outline the monitoring activities to landowners and provide conditions for what they can expect. When mailing the TEP packet, include a duplicate TEP; one for the landowner's records and one to mail back in a postage-paid envelope (provided).

State of California – Natural Resources Agency **GAVIN NEWSOM, Governor**
DEPARTMENT OF FISH AND WILDLIFE ***CHARLTON H. BONHAM, Director***
California Environmental Assessment and Monitoring Program
Attn: Fisheries Branch
P.O. Box 944209
Sacramento, CA 94244

Date
Landowner Name
1234 Street Name
City, CA ZIP

Dear Landowner Name,

The monitoring team implementing the California Environmental Monitoring and Assessment Framework has been accessing your parcel since 2021 and hopes you will help us to protect California's remarkable diversity of plants and animals by continuing to grant us access. Without your support, we would not be able to meet the challenge of understanding how changes in land use and other ecological drivers, may impact fish and wildlife and the habitats upon which they depend.

Please complete and sign the enclosed Temporary Right of Entry Agreement for environmental monitoring and return it in the business reply envelope provided, or via email to kelly.souza@wildlife.ca.gov. Surveys will be conducted according to the conditions in the Agreement and can be cancelled by you at any time. We hope to begin our seasonal monitoring on April 9, 2024.

We are grateful for the cooperation and generosity of partners like you, without whom we would not be able to carry out this important work. If you have any questions or would like to discuss the Agreement, please contact me by phone at (916) 531-3195 or by email at kelly.souza@wildlife.ca.gov. Thank you for your support!

Sincerely,

Kelly Souza

Kelly Souza
Senior Environmental Scientist, Supervisor
Cannabis and Instream Flow Unit

TEMPORARY RIGHT OF ENTRY AGREEMENT FOR ENVIRONMENTAL MONITORING

A. PROPERTY/PARCEL INFORMATION

Assessor's Parcel Number (APN)	County	Location

B. PROPERTY OWNER INFORMATION ((*Please complete*)

Name	
Primary Phone	
Email Address	

If the Property Owner would like the Department of Fish and Wildlife (Department) to work directly with another person to enter the Property in accordance with this right of entry agreement (Agreement) (e.g., a caretaker), please complete Box C.

C. PROPERTY OWNER'S DESIGNATED CONTACT PERSON FOR PROPERTY ACCESS (*Complete only if the contact will not be the Property Owner.*)

Name	
Mailing Address	
Primary Phone	
Email Address	

If the Department does not need your permission as the Property Owner to enter the Property, but instead another person's (e.g., a tenant), please complete Box D and return the Agreement *unsigned* by you. If the Department needs both your permission as the Property Owner and another person's, please return the Agreement *signed* by you. The Department will request permission from the other person and the Agreement will not be valid unless the person identified below also signs it.

D. SEPARATE OR ADDITIONAL GRANTOR (*Complete only if the Department needs permission from a person other than or in addition to the Property Owner to enter the Property*.)

Name	
Mailing Address	
Primary Phone	
Email Address	

E. SEPARATE OR ADDITIONAL GRANTOR'S DESIGNATED CONTACT PERSON FOR PROPERTY ACCESS (*Complete only if the contact will not be the Separate or Additional Grantor or the person identified in Box C.*)

Name	
Mailing Address	
Primary Phone	
Email Address	

F. GATE INFORMATION (Confidential - For Department Use Only)

Gate Code (if applicable)	
Keyed (if property gated and key needed to open gate, please identify person who will open gate)	[ ] Property Owner [ ] Designated Contact for Property Owner [ ] Separate or Additional Grantor [ ] Designated Separate or Additional Grantor [ ] Other Name: Primary Phone: Email Address:

G. CONDITIONS

The undersigned hereby authorizes Department employees and volunteers, if any, to enter the Property identified above in accordance with the conditions listed below.

1. The Department may enter the Property on weekdays to access terrestrial riparian, and aquatic habitat on or adjacent to the Property to survey aquatic habitat fishes, aquatic insects, and vegetation by some or all the methods listed below. If the Department determines that a method not listed below is better suited to achieve the same objective, the Department shall consult with the undersigned before implementing the alternative method.

    - Water level/barometric loggers
    - Snorkel and macroinvertebrate surveys
    - Camera traps
    - Dissolved oxygen meters
    - Physical habitat surveys
    - Acoustic recorders

2. Surveys may be performed by two to three Department staff, walking, wading, or snorkeling up to seven times per year, usually for less than 2 hours.

3. The Department will notify the person who will be providing access to the Property at least 72 hours prior to each visit. If the Property is gated and a key is needed to access the Property, the Department will make the necessary arrangements with the person identified in Box E above to open the gate.

4. Department employees will drive and park their vehicles on and along existing roadways. If a vehicle needs to be driven or parked outside an existing roadway, the Department shall obtain permission from the person who will be providing access to the Property before doing so.

5. The Department shall be liable for any injury on the Property to the extent provided by the California Tort Claims Act (Gov. Code, § 810 *et seq*.).

6. The Department shall indemnify and hold harmless the Property Owner and/or Separate or Additional Grantor and agrees to repair or pay for any damage to the Property proximately caused by reason of the uses authorized by this Agreement to the extent provided by Government Code section 14662.5.

7. Other conditions may be added to this Agreement by consent between the Department and the Property Owner and/or Separate or Additional Grantor by addendum to this Agreement, which shall be made part of the Agreement.

8. The Department or undersigned may cancel this Agreement prior to its expiration upon written notice to the other party or parties, in which case the Agreement shall terminate 14 days from the date of the notice.

9. The term of this Agreement shall begin on the date of the Department's signature, which shall be the last signature, and shall expire on December 31, 2027, unless the Department and the undersigned have agreed to a different expiration date (paragraph 7), or the Agreement is canceled prior to its expiration (paragraph 8).

10. **SPECIAL CONDITIONS** (Note any season access restrictions, communication requests, etc.):____

I, the undersigned, hereby give my permission to the Department to enter the Property in accordance with this Agreement.

ACCEPTED this _______day of _________________________, 202_.

By: ____________________________________
Property Owner
«Current_Owner»

By: ____________________________________
Separate or Additional Grantor

By: ____________________________________
California Department of Fish and Wildlife

* * * * *

Please email the signed Agreement to the Department or send a scanned copy or photo via email to Kelly Souza at [kelly.souza @wildlife.ca.gov](mailto:kelly.souza@wildlife.ca.gov), unless other return arrangements are made. Thank you!

TEMPORARY RIGHT OF ENTRY AGREEMENT FOR ENVIRONMENTAL MONITORING

A. PROPERTY/PARCEL INFORMATION

Assessor's Parcel Number (APN)	County	Location

B. PROPERTY OWNER INFORMATION *(Please complete)*

Name	
Primary Phone	
Email Address	

If the Property Owner would like the Department of Fish and Wildlife (Department) to work directly with another person to enter the Property in accordance with this right of entry agreement (Agreement) (e.g., a caretaker), please complete Box C.

C. PROPERTY OWNER'S DESIGNATED CONTACT PERSON FOR PROPERTY ACCESS (*Complete only if the contact will not be the Property Owner.*)

Name	
Mailing Address	
Primary Phone	
Email Address	

If the Department does not need your permission as the Property Owner to enter the Property, but instead another person's (e.g., a tenant), please complete Box D and return the Agreement *unsigned* by you. If the Department needs both your permission as the Property Owner and another person's, please return the

Agreement *signed* by you. The Department will request permission from the other person and the Agreement will not be valid unless the person identified below also signs it.

D. SEPARATE OR ADDITIONAL GRANTOR (*Complete only if the Department needs permission from a person other than or in addition to the Property Owner to enter the Property.*)

Name	
Mailing Address	
Primary Phone	
Email Address	

E. SEPARATE OR ADDITIONAL GRANTOR'S DESIGNATED CONTACT PERSON FOR PROPERTY ACCESS (*Complete only if the contact will not be the Separate or Additional Grantor or the person identified in Box C.*)

Name	
Mailing Address	
Primary Phone	
Email Address	

F. GATE INFORMATION (Confidential - For Department Use Only)

Gate Code (if applicable)	
Keyed (if property gated and key needed to open gate, please identify person who will open gate)	**[ ] Property Owner** **[ ] Designated Contact for Property Owner** **[ ] Separate or Additional Grantor** **[ ] Designated Separate or Additional Grantor** **[ ] Other** **Name:** **Primary Phone:** **Email Address:**

G. CONDITIONS

The undersigned hereby authorizes Department employees and volunteers, if any, to enter the Property identified above in accordance with the conditions listed below.

11. The Department may enter the Property on weekdays to access terrestrial riparian, and aquatic habitat on or adjacent to the Property to survey aquatic habitat fishes, aquatic insects, and vegetation by some or all the methods listed below. If the Department determines that a method not listed below is better suited to achieve the same objective, the Department shall consult with the undersigned before implementing the alternative method.

    - Water level/barometric loggers
    - Snorkel and macroinvertebrate surveys
    - Camera traps
    - Dissolved oxygen meters
    - Physical habitat surveys
    - Acoustic recorders

12. Surveys may be performed by two to three Department staff walking, wading, or snorkeling up to seven times per year, usually for less than two hours.

13. The Department will notify the person who will be providing access to the Property at least 72 hours prior to each visit. If the Property is gated and a key is needed to access the Property, the Department will make the necessary arrangements with the person identified in Box E above to open the gate.

14. Department employees will drive and park their vehicles on and along existing roadways. If a vehicle needs to be driven or parked outside an existing roadway, the Department shall obtain permission from the person who will be providing access to the Property before doing so.

15. The Department shall be liable for any injury on the Property to the extent provided by the California Tort Claims Act (Gov. Code, § 810 *et seq*.).

16. The Department shall indemnify and hold harmless the Property Owner and/or Separate or Additional Grantor and agrees to repair or pay for any damage to the Property proximately caused by reason of the uses authorized by this Agreement to the extent provided by Government Code section 14662.5.

17. Other conditions may be added to this Agreement by consent between the Department and the Property Owner and/or Separate or Additional Grantor

by addendum to this Agreement, which shall be made part of the Agreement.

18. The Department or undersigned may cancel this Agreement prior to its expiration upon written notice to the other party or parties, in which case the Agreement shall terminate 14 days from the date of the notice.

19. The term of this Agreement shall begin on the date of the Department's signature, which shall be the last signature, and shall expire on December 31, 2027, unless the Department and the undersigned have agreed to a different expiration date (paragraph 7), or the Agreement is canceled prior to its expiration (paragraph 8).

20. **SPECIAL CONDITIONS** (Note any season access restrictions, communication requests, etc.):____

____

____

____

____

____

____

I, the undersigned, hereby give my permission to the Department to enter the Property in accordance with this Agreement.

ACCEPTED this _______day of __________________________, 202__.

By: ______________________________________

Property Owner «Current_Owner»

By: ______________________________________

Separate or Additional Grantor

By: ______________________________________

California Department of Fish and Wildlife

*** * * * ***

Please email the signed Agreement to the Department or send a scanned copy or photo via email to Kelly Souza at kelly.souza@wildlife.ca.gov, unless other return arrangements are made. Thank you!

Appendix C: Field Survey Equipment List

Equipment	Site Recon	Installation	Site Visit	Bioassessment	Snorkel	Removal
Hobo Water Level Loggers (U20L-01)		5	-	-	-	-
PT Housings (6-ft long, 1.5-in diameter, 3/8-in braided steel) and keyed padlock		4	-	-	-	-
Barologger Housing (16-in long, 1.5-in diameter)		1	-	-	-	-
Calibrated and Launched Hobo DO loggers (U-26-001)		4	1	1	1	-
DO Logger Housing (3-ft long, 2-in diameter PVC with cable and keyed padlock)		3	-	-	-	-
T-posts (10-ft, 2 per PT plus 2 back-up)		10	2	-	-	
Lag Bolt (for vertical benchmark)		3	-	-	-	-
Adjustable Hose Clamps (2-4-in clamping diameter)		20+	20+	-	-	-
Zip Ties (8-in and 11-in)		20+	20+	-	-	-
Staff Plates, Graduated to 1/100-ft		3	-	-	-	-
Stadia Rod (25-ft, Engineering, graduated to 1/10-ft and 1/100-ft)		1	1	1	1	1
Hollow Nut Driver (5/16-in and 7/16-in)		2	2	2	2	2
Post Pounder		1	1	-	-	-
Scissors, Knife or Multi-tool, Mallet		1	1	1	1	1
GPS, First Aid Kit, Vehicle Safety Kit	1	1	1	1	1	1
Flagging Rolls		1+	1+	1+	1+	1+
Sharpie Markers and Pencils	1	4	4	4	4	4
Auto Level and Tripod		1	1	1	1	1
iPad Tablet and Laptop	1	1	1	1	1	1
Densiometer (convex spherical)		1+	1+	1	-	1+
YSI Pro2030 DO/Conductivity meter (or similar)		1+	1+	1+	1+	1+
Clipboard, Paper Datasheets, Calculator (backup)		1	1	1	1	1
Padlock Keys (DO and PT housing keys)		1	1	1	1	1
Flow Meter (HACH FH950 or similar) with charger and extra thumb screws		1+	1+	1+	1+	1+
Bucket (3 gallon)		1	1	1	1	1
300-ft Measuring Tape (1/10-ft)		1+	1+	1+	1+	1+
Rebar (2 for discharge transect and 1 with 1/10-ft measuring tape affixed for stage gage)		3	3	3	3	3
HOBO Waterproof Shuttle, Coupler and Shuttle Cable		-	1	1	1	1
DO Logger Cleaning Kit		-	1	1	1	-
Work Gloves and T-post Remover		1	-	-	-	1
Temporary Entry Agreements and Ziplock bags	1	1				

Appendix D: Bioassessment Equipment List

- D-frame Kick Net
- Measuring Stick (yard)
- 7.5-m Stadia Rod (metric)
- Densiometer (convex spherical)
- pH Pen
- Alkalinity Testing Kit
- Flagging
- Sharpies
- Clipboard + SOP
- Datasheets
- Pencils
- GPS
- Clinometer (with compass)
- Wide-mouth Plastic Sample Jars (500-ml, ~3 per site, 1/2 filled with 95% alcohol)
- Waterproof Labels and Clear Tape
- Fine-point Tweezers
- Tray (to empty net into jar over the tray)
- YSI Pro2030 DO/Conductivity meter (or similar)
- 100-m Tape Measure (metric)
- iPad Tablet

Appendix E: Chain of Custody Form

State of California - Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE

GAVEN NEWSOM, Governor
CHARLTON H. BONHAM, Director

CHAIN OF COUSTODY

Original Collector:
Project Name:
CDFW Program: ______

Collector Name(s): ______________________________
Address: ______________________________
City/State/Zip: ______________________________
Phone No.: ______________________________
e-mail: ______________________________

Receiving Laboratory:
Name: Aquatic Bioassessment Laboratory
Address: 2005 Nimbus Road
City/State/Zip: Gold River, Ca. 95670

Billing Information: _____

*BMI sample information as entered into the SWAMP database

Sample Date	Stream Name	Site Code	Site Name/Description	GPS location of A Transect	Sample ID	# Jars

Relinquished by Original Collector (Signature)	Print Name	Affiliation	Date
Received by (Signature)	Print Name	Affiliation	Date
Disposition of Samples: Samples stored in 95% ETOH			

Appendix F: Snorkel Survey Equipment List

Personal Gear

- Backpack (1 per crew)
- Wetsuit or Drysuit
- Snorkel and Mask
- Hood
- Gloves
- Gravel guards
- Neoprene booties
- Boots

Survey Gear

- iPad Tablet with Survey123 Data Forms
- Clipboard and Datasheets (in case tablet fails)
- Printed Protocol
- Rite-in-the-Rain Notebook
- Dive Light (and fully charged batteries, 2 sets per surveyor)
- Thermometer
- Waterproof Camera
- Sharpies and Pencils (3 per clipboard or backpack)
- Fish/Amphibian Identification Guides
- 25-ft Stadia Rod (Engineering, graduated to 1/10-ft and 1/100-ft)
- Flagging
- 200-300-ft Tape Measure (1/10-ft)
- Dive Slate or Click Counters (if using)
- YSI Pro2030 DO/Conductivity meter (or similar)