Standard Operating Procedure for Streambed and Water Surface Elevation Data Collection in California

CDFW-IFP-003

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California Department of Fish and Wildlife
Instream Flow Program
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Water Surface Elevation Data Collection in California
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Acknowledgements

This standard operating procedure (SOP) represents the protocols for auto level usage of the California Department of Fish and Wildlife (CDFW) Water Branch Instream Flow Program (IFP). The processes in this SOP draw from current methods used by the IFP. Methods in this SOP are consistent with surveying standards as presented in Kavanaugh and Bird (1996), data collection procedures for physical habitat simulation model development (Bovee, 1997), and field protocols of the United States Fish and Wildlife Service (USFWS; USFWS 2009). Technical review of this document was provided by the staff at IFP.

Suggested Citation

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Available at: http://www.dfg.ca.gov/water/instream_flow.html.

Abbreviations and Acronyms

BM Elev	Benchmark Elevation
BS	Backsight
CDFW	California Department of Fish and Wildlife
FS	Foresight
HP	Headpin
IFP	Instream Flow Program
IH	Instrument Height
Instrument	Auto Level and Tripod
LBWE	Left Bank Wetted Edge
LOS	Line of Sight
RBWE	Right Bank Wetted Edge
SOP	Standard Operating Procedure
Stadia Rod	Graduated Measuring Rod
SZF	Stage of Zero Flow
TP	Tailpin
TuP	Turning Point
VBM	Vertical Benchmark
WSEL	Water Surface Elevation

Introduction

This document serves as the SOP for collecting streambed and water surface elevation data using an auto level by the CDFW IFP. It is intended for use with other CDFW IFP SOPs, as relevant. Instructions are provided for auto level and tripod set up, use of graduated measuring rod (stadia rod), establishing a vertical benchmark (VBM), closing the level loop, tying VBMs together, collecting water surface elevations (WSELs), collecting wetted bed profile and dry bed elevations, and measuring stage of zero flow (SZF). These procedures are components of a habitat-based hydraulic model used to develop flow vs. habitat relationships as part of an instream flow study for fish and wildlife resources.

The CDFW Instream Flow Program encourages staff and contractors to contact us with any questions or for assistance with project planning. For more information, contact Diane Haas of the CDFW IFP at: Diane.Haas@Wildlife.ca.gov or (916) 445-8575.

Scope of Application

This SOP provides procedural reference for CDFW staff collecting streambed and water surface elevation data in wadeable streams when site conditions and research objectives indicate it is an appropriate methodology and approach. It is also intended as an informational resource for staff from other state and federal agencies, nongovernmental organizations, private contractors, and other organizations throughout California.

Document overview

In this document, the following procedures for elevation collections are discussed:

- Considerations for Site Selection
- Establishing the Vertical Benchmark
- Auto Level and Tripod Setup
- Site Setup
- Differential Leveling Procedure for Establishing Backsight and Foresight Elevations and Instrument Height
- Collecting Water Surface Elevations
- Collecting Dry Bed Elevations and Wetted Bed Profiles

- Stage of Zero Flow
- Turning Points/Closing the Level Loop

Section 1: Preparing for Field Work: Site Selection

Before collecting elevation data, it is important to select transect locations that support the project objectives for modeling the area of interest. The location of the elevation transects may be targeted or randomly selected, as determined by the project manager to best suit the project's needs for data representativeness of the river's habitats. Crew members should ensure that they know where transects will be established before going into the field. If the crew is sampling an established site, they should have the location information for the vertical bench marks, elevation transects, and lengths for the elevation transects before going into the field. Crews should ensure that established site locations and lengths are replicated during each field visit. Crews should consider bringing photos and drawings of site conditions from previous visits into the field with them to assist in consistency.

Crew safety is of paramount importance; ensure that the river can be safely sampled by crews. Contact the CDFW Instream Flow Program for project planning assistance, as needed.

Establishing the Vertical Benchmark (VBM)

If the elevation transects are being established during the field work, the crew should establish one vertical benchmark (VBM) for each transect. If site conditions allow, multiple transects can share the same VBM, as long as each transect has a VBM to reference. The VBMs are labeled sequentially, with VBM1 on the most downstream transect of the site. VBMs must be established on permanent, unmovable points, such as a tree root or very large boulder. The preferred method of setting up a VBM is to hammer a lag bolt into a tree branch or root, leaving the bolt head and about 0.25" of the bolt exposed. Ensure that the stadia rod can be placed on the VBM without physical obstruction, and that the VBM can be seen easily from the river. Once established the VBM should be labeled with site name and VBM number.

Figure 1. Example of establishing a VBM: a reference elevation for surveying using a lag bolt into a tree root.

Section 2: Preparing for Field Work: Preparation and Use of Field Equipment

This section describes the equipment list, and how to prepare and use the auto level and tripod in the field. The procedures for inspection and set-up should be followed before continuing on to data collection in Section 3.

2.1 Equipment List

Before beginning field work, crews should pack the following equipment and ensure that it is all in working order:

- Rebar (2 per transect)
- Survey measuring tape
- Auto level
- Tripod

- Stadia rod
- Staff gauge
- Field data sheets (available online at: http://www.dfg.ca.gov/water/instream_flow.html)
- Pencils
- Previous site photos or drawings documenting previous site conditions
- Lagbolts for establishing vertical benchmarks
- Hammer
- Flagging
- Sharpie pen
- Clipboard
- Camera
- Global Positioning System (GPS)

2.2 Auto Level and Tripod Setup

An auto level and tripod (instrument) are used to record WSELs and dry stream bed elevations for IFP studies. Use care when setting up the instrument, as auto levels are fragile and expensive to repair or replace. The instrument must be set up to maintain a consistent level during the survey, and should be set up where it would not interfere with any flow measurement values being collected by other staff.

Collecting data using surveying equipment requires a team of two staff members; the staff recorder sets up and operates the auto level, while the evaluator holds the stadia rod. The staff recorder should have training in basic surveying and differential leveling. The staff recorder begins the set up procedure outlined in Section 2.2, while the staff evaluator begins the additional site setup as outlined in Section 2.3.

The staff recorder performs the initial set up of the tripod and auto level as follows:

Step 1: Visually locate the vertical benchmark (VBM), headpins (HP), and tailpins (TP) for all transects at the site.

Step 2: Position the tripod at a location with clear line of sight (LOS) to the VBM and as many of the headpins and tailpins as possible. Vegetation may have to be moved or removed as necessary to provide LOS to the auto level.

Step 3: Set up the tripod with legs spread at least three feet apart for maximum stability (Fig 2). Release the sliding mechanisms on the tripod legs and raise the tripod base to a height that will allow the user to see through the eye piece in a comfortable position where the user is not likely to bump or disturb the level, affecting its alignment. Lock or tighten the legs in place using the pegs on the bottom of each leg. Press the pointed tripod leg tips into the stream bed to stabilize the tripod and to reduce the risk of the equipment losing level (vertical control). If the river bed material is too large to allow a firm hold, stack cobbles around the legs to stabilize the tripod.

Note: Exercise caution when setting the tripod in swift moving water. Not only is it a safety hazard, but the water action can wear away the bed from beneath the tripod legs, compromising the level and/or height setting of the instrument and causing a loss of vertical control.

Figure 2. Example of tripod setup.

Step 4: Adjust the height of each leg until the surface of the tripod appears level.

Step 5: Wipe the top surface of the tripod free of any water or debris. Place the auto level on top of the tripod and thread the hanging tripod bolt into the auto level (do not over tighten). To level the instrument, adjust the appropriate tripod leg heights until the leveling bubble on the auto level base begins to move. Since the fine adjustment dial range is limited, the instrument must be leveled as much as possible using the coarse leg adjustments first.

Note: At this point it is a good idea to point the auto level toward the VBM and make sure the LOS is above the VBM. A backsight cannot be established at the VBM without a stadia rod reading.

Step 6: Turn the fine adjustment dials on the auto level until the bubble is centered inside the circle (Fig 3). To do this, turn the two fine adjustment dials at the rear of the instrument toward each other (turn the left dial counter clockwise, and the right dial clockwise) until the bubble is at the bottom of the target. Then adjust the third dial to move the bubble into the center of the target. Rotate the auto level 360^{o} and adjust the dials as needed to keep the bubble in the center of the target.

Figure 3. Example of fine adjustment dials and centered bubble on the auto level.

Step 7: Check again that the VBM and at least one pair of transect headpins and tailpins are visible from the auto level. If the VBM is not visible from the auto level, select a new location for the instrument. Repeat the process from Step 1 until the auto level is situated within sight of the VBM.

Note: Not all locations where elevation measurements are required may be visible from the first instrument setup location. However, the instrument can be moved to one or more new locations to gather remaining elevation data. See Section 3 for the procedure to maintain vertical control while changing the instrument location.

2.3 Additional Site Setup

Collecting elevation data using the differential leveling method requires a two person survey team, comprised of a staff recorder who operates the instrument and a staff evaluator who holds the stadia rod. Some time is required to set up the tripod, level the instrument, and check the LOS. While the staff recorder is setting up the instrument, the staff evaluator should be setting up the staff gauge, stringing the survey measuring tapes across each transect, and preparing the field data sheets.

Step 1: While the staff recorder sets up the instrument as in Section 2.2, the staff evaluator fills out the field sheet including date, time, site number, reach name, mesohabitat type, staff names, gauge start, unit length, and start time.

Step 2: Insert the staff gauge into the substrate near the stream's edge (Fig 4). The gauge should be located between the transects at the study site, but out of the path of foot traffic as to not disturb data collection. The gauge height is recorded at the beginning and the end of data collection, and accounts for any changes in water surface height that may occur during data collection.

Figure 4. Example of staff gauge used to account for water surface height changes during data collection.

Step 3: Record the water depth at the gauge in the "Gauge Start" field to the nearest 1/100th of a foot.

Step 4: Install survey tape measures from the HP to the TP at each transect. Record the transect lengths on the field sheet in the field marked "HP to TP". This data should be recorded in a centralized location database to ensure the distance from the HP to the TP remains consistent between field visits.

Step 5: Take photographs of the entire site, facing upstream, and note this on the field sheet. Take photographs at each transect, including a photo of the label tape above the headpin that indicates site number and transect number, and a photo of the transect from HP to TP.

Note: Transects are numbered from downstream to upstream (e.g. the transect furthest downstream is transect 1).

2.4 Establishing a Vertical Benchmark, Backsight and Foresight Elevations, and Instrument Height

Before elevation data may be collected, it is important to establish the reference elevations that are used for differential leveling. Differential leveling uses the concept of backsights (BS) and foresights (FS) to compute the relative difference in elevation between points. The initial reference elevations are marked on the field sheet before collecting elevations:

- Vertical benchmarks (VBM). These are typically used to establish a known reference elevation, which is assumed to be 100 feet. The height of the VBM is referred to as "BM ELEV" (Benchmark Elevation) on the field sheets.
- Backsight (BS). The vertical distance between the VBM and the instrument represents the BS and is indicated on the field sheets as "BS to BM".
- Instrument height (IH). The elevation of the VBM plus the BS is defined as the IH.

Once the BS elevation is established at the VBM, the instrument is used to collect FS elevations at desired points (e.g. WSELs and dry bed elevations). The numerical value or difference between the BS and FS represents the relative elevation of the desired point in relation to the VBM.

Note: Most of the auto levels used by CDFW have three horizontal cross hairs visible through the eyepiece. When using these instruments, the middle line should be read as level.

The following steps provide the procedure to collect elevation data using a tripod, auto level, and stadia rod. The staff evaluator maneuvers around the site placing the stadia rod at predetermined locations where elevation data need to be collected. The staff recorder looks through the auto level, and reads and records the height of the stadia rod.

To establish backsight and foresight elevations, and instrument height values:

Step 1: Record the BM Elev on the data sheet. This elevation is commonly assumed to be an elevation of 100 feet, unless the project manager has specified otherwise.

Step 2: Measure the BS by placing the stadia rod on the VBM; the stadia rod should be level. If necessary, the staff evaluator can slowly wave the stadia rod parallel to the LOS to establish level. The lowest numerical value read through the auto level eye piece represents level on the stadia rod. A bubble level may be attached to the stadia rod to ensure vertical accuracy.

Step 3: Shoot (Fig 5) and record the “BS to BM” elevation on the data sheet. Add the “BM ELEV” to the “BS to BM” and record this value as the “IH” on the data sheet. For example, if the VBM elevation is 100, and the “BS to BM” is 3.69, the IH would be 103.69.

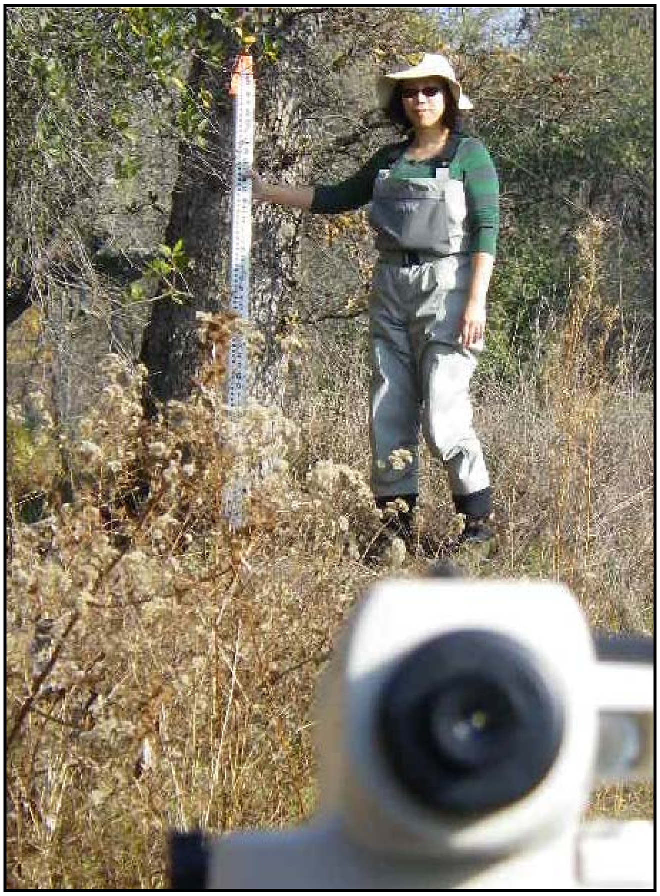


Figure 5. Example of recording a shot using the auto level with the stadia rod positioned on the VBM to establish instrument height before beginning the survey.

Section 3: Data collection

After completing site and instrument set up as in Sections 1 and 2, elevation data may be collected. This section covers collecting water surface elevations (WSEL), dry bed and wetted bed profiles, and stage of zero flow (SZF) elevations. These data are used to populate physical habitat models.

3.1 Collecting Water Surface Elevations

Before collecting WSEL data, record the total length (to the nearest 0.1 foot) of the survey measuring tape along the transect from the HP to the TP, and the location on the tape of the wetted edge of the left bank and the right bank. WSELs are measured near the left bank, middle of the channel, and the near right bank, assuming that the water surface appears level. If there are detectable changes in the height of the surface across the transect, more than three measurements may be necessary to fully capture water surface elevation. Field staff must make note of the changes in the height of the water surface and the relative widths with respect to the total wetted width. These notes and estimates of the higher and lower proportions will be crucial if the data are used in predictive models of river stage and discharge.

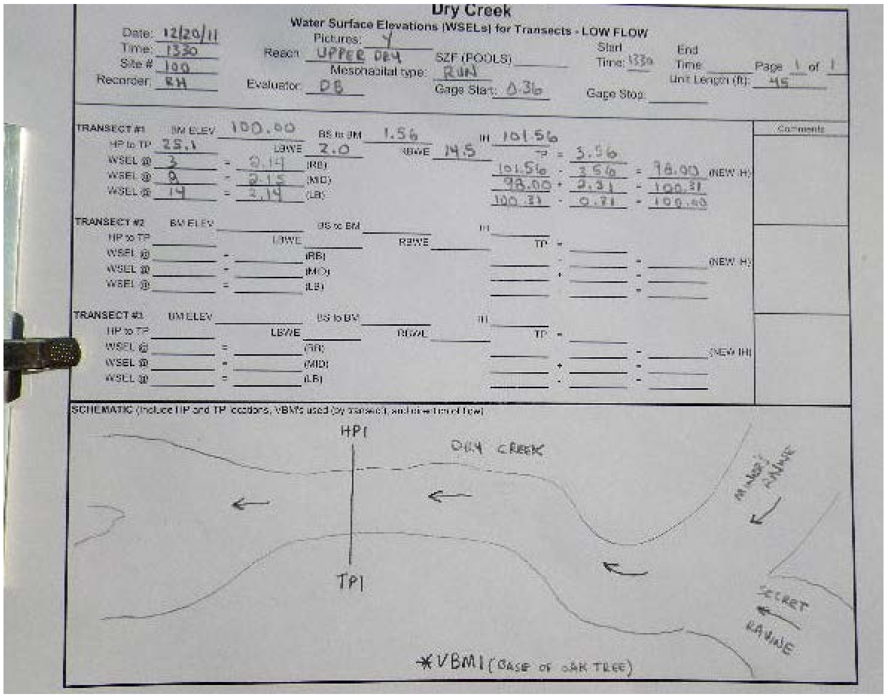
Note: The IFP measures units in tenths of feet. Some survey tapes used by the IFP read tenths on one side (yellow) and inches on the other (white). Always record the tenths reading on the yellow side of the tape when using this equipment.

Step 1: Record the length of the transect from HP to TP to the nearest 0.1 foot

Step 2: Record the left bank wetted edge (LBWE) and right bank wetted edge (RBWE) of the transect by placing the base of the stadia rod at the water's edge of each bank. Record the measurements on the field data sheet (see Figure 6 for an example).

Step 3: On the data sheet, draw a map of the unit site, indicating the following features (Fig 6):

- Shape of river
- Direction of flow
- Location of HP, TP, and transect
- Location and description of VBM


Dry Creek
Water Surface Elevations (WSELs) for Transects - LOW FLOW
Date: 12/20/11 Pictures: Y
Time: 1330 Reach: UPPER DRY SZF (POOLS) ____ Start Time: 1330 End Time: ____ Page 1 of 1
Site #: 100 Mesohabitat type: RUN Unit Length (ft): 45
Recorder: RH Evaluator: DB Gage Start: 0.36 Gage Stop: ____

TRANSECT #1 BM ELEV 100.00 BS to BM 1.56 HI 101.56 Comments
HP to TP 25.1 LBWE 2.0 RBWE 14.5 TP = 3.56
WSEL @ 3 = 2.14 (RB) 101.56 - 3.56 = 98.00 (NEW HI)
WSEL @ 9 = 2.15 (MID) 98.00 + 2.31 = 100.31
WSEL @ 14 = 2.14 (LB) 100.31 - 0.71 = 100.40

TRANSECT #2 BM ELEV ____ BS to BM ____ HI ____
HP to TP ____ LBWE ____ RBWE ____ TP = ____
WSEL @ ____ = ____ (RB) ____ - ____ = ____ (NEW HI)
WSEL @ ____ = ____ (MID) ____ + ____ = ____
WSEL @ ____ = ____ (LB) ____ - ____ = ____

TRANSECT #3 BM ELEV ____ BS to BM ____ HI ____
HP to TP ____ LBWE ____ RBWE ____ TP = ____
WSEL @ ____ = ____ (RB) ____ - ____ = ____ (NEW HI)
WSEL @ ____ = ____ (MID) ____ + ____ = ____
WSEL @ ____ = ____ (LB) ____ - ____ = ____

SCHEMATIC

Figure 6. Example field data sheet for collecting WSELs. This particular data sheet also includes map of site with location of transect, headpin, tailpin, vertical bench mark, and direction of flow.

Step 4: Select a location from each section of the transect (left, middle, right) to record a WSEL and report the distance on the tape to the staff recorder Standing downstream of the transect survey tape measure, hold the stadia rod level and slowly touch the bottom of the stadia rod to the surface of the water, forming a meniscus (Figs 7 and 8). It may be helpful to say “touch” to alert the auto level operator to the exact time the base of the stadia rod forms a meniscus.

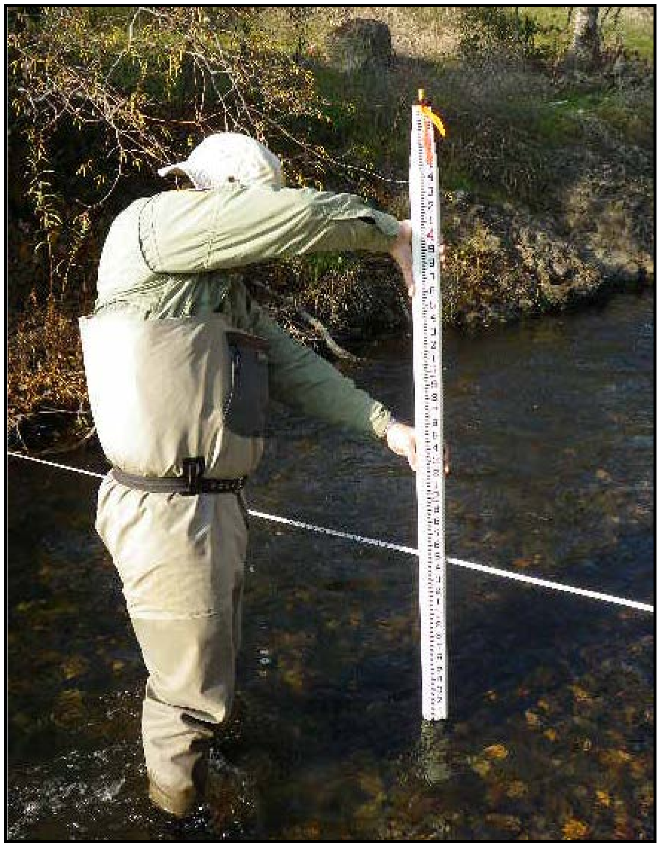


Figure 7. Example of plumb stadia rod while measuring WSEL.

Figure 8. Example of stadia rod forming meniscus.

Note: It is essential for the staff evaluator holding the stadia rod to orient themselves in a way as not to affect the elevation of the water surface while measuring the WSEL. It is good practice to hold the rod out from your body as far as possible while keeping the rod plumb.

Step 5: To record the WSEL, the staff recorder reads the scale on the stadia rod where it intersects with the middle auto level cross hair. Record the elevation most consistently read through the eye piece of the auto level. In rough or undulating water, additional readings may be necessary. Record the reading on the field data sheet.

Note: It may be difficult or impossible to make an accurate reading of the WSEL in an undulating current. Field staff must note when WSEL FS were taken where the water surface was not smooth, flat, and laminar. If the water surface is not smooth, collect an additional measurement where the water surface meets the river bank, and note actions taken on the field data sheet.

Step 6: Repeat this process at each location until all WSELs at the transect have been collected.

Step 7: When all readings have been measured for a transect, check the readings for variance. Ideally, readings across a transect should vary by less than a tenth of a foot. If there is a difference of a tenth of a foot or more between WSELs from the left bank to the right bank, observe the conditions across the transect and note which side of the river is most representative on the field sheet.

Step 8: Repeat Steps 1 through 6 for each elevation transect at the site.

3.2 Collecting Dry Bed Elevations and Wetted Bed Profiles

Dry bed elevations are collected at points along the transect (including the base of the HP and TP) between the ends of the tape and where the highest water elevation is observed and recorded (Fig 9). Dry bed elevation points may also need to be collected on exposed rocks inside the water's edge or on dry islands along the transect line. Dry bed elevations are typically recorded during low flow events, when more of the dry channel is exposed, and are used to complete the transect streambed profile. Collection locations may be determined by using the results of previous flow discharge depth measurements recorded at higher flow regimes on the transects. Field crews should enter the field with the list of locations to record dry bed elevations for each transect.

Step 1: Check that all dry bed elevations are visible from the current auto level location. Record elevations of points that are visible at the current location. Indicate on the field sheet the IH of the dry bed elevations recorded at the current instrument location.

Note: If all dry bed elevations are not visible from the current auto level location, the instrument can be relocated to a new position. The procedure for maintaining vertical control while establishing a new BS is given in Section 4. Set up the tripod and auto level and calculate the IH before proceeding with data collection (Section 2.4). Record the new IH on the field data sheet and clearly identify which dry bed elevations are recorded using the new IH.

Step 2: Record dry bed locations and elevations at visible locations on the data sheets. Take care to place the base of the stadia rod at locations along the tape (i.e. do not let the base of the rod deviate from the line of the tape).

Note: If the bank full height is located above the location of the head pin, start collecting the dry bed elevations at that point. Note the deviation in protocol on the field data sheet.

Step 3: Repeat step 2 as necessary until all visible dry bed elevation locations have been collected at each transect at the site.

Figure 9. Example of dry bed elevation collection.

3.3 Stage of Zero Flow

By definition, the Stage of Zero Flow (SZF) is the ground elevation where water would stop flowing at a particular cross section. The SZF is influenced by downstream hydraulic controls (any feature that holds back water and influences upstream WSELs). SZF data are generally collected for pools by identifying the highest low point of the streambed at the downstream hydraulic control for the pool, such as the pool tail crest (the distinct break or crest in streambed elevation located downstream from the pool). These SZF data are used to calibrate physical habitat simulation models. Because hydraulic controls can "migrate" with variation in stream discharge, measurement of SZF can be difficult and should be done when the flow is extremely low and the water is not turbid. SZF measurements are taken while the staff is in the field collecting other data from elevation transects.

To collect SZF measurements:

Step 1: To identify the location of the SZF, look for the change of gradient from pool to riffle.

Step 2: The staff evaluator moves to the area of gradient change, then works down the thalweg measuring water depth by placing the stadia rod on the streambed.

Step 3: The staff member with the stadia rod moves from side to side and upstream to downstream to find the highest low point of the streambed; that is, the highest point that is surrounded by lower points (read by the stadia rod as deeper water depths).

Note: Do not move downstream into the adjacent riffle, or upstream into the deeper sections of the pool.

Step 4: After the location of the SZF has been narrowed down, the staff recorder can measure the bed elevation of the point with the auto level to confirm that it is the highest low point.

Step 5: The staff recorder records the bed elevation value of the SZF on the field data sheet, and indicates its location on the field sheet map.

Section 4: Turning Points and Closing the Level Loop

At sites where all of the FS elevations are not visible from a single instrument location, the auto level and tripod can be moved to another location (or locations) to visually access the remaining points. Vertical survey control must be maintained at the new survey location by establishing a new IH. The IFP uses the turning point technique to maintain vertical control and ensure survey accuracy by triangulating around the VBM, commonly referred to as "closing the level loop." The IFP data sheets for elevation data collection are set up to accommodate up to three instrument set up locations using different IHs at each.

Step 1: With the auto level and tripod at the first location (IH(1)), look for a suitable turning point. A turning point is a point on the ground where the stadia rod can be placed to make a repeatable measure of elevation. The turning point is used to temporarily relate the elevation of the instrument between set up locations, for example IH(1) to IH(2). Select a point where the base of the stadia rod can be rested easily, with little chance of it moving off the point. The turning point should be an easily identifiable fixed point, such as a pointed rock or top of a transect marker pin, so if the rod does slip off the point, the evaluator can easily and with confidence replace the rod at the exact spot. Number turning points on the field sheet sequentially as needed (e.g., turning point 1 is TuP1).

Step 2: Place the stadia rod firmly on the turning point, checking that the rod is vertical.

Step 3: Read the FS elevation at the turning point and record it on the field sheet. Reenter the turning point elevation on the line below and subtract it from the original IH.

Step 4: The evaluator should remain on the turning point while the recorder moves the instrument.

Step 5: Move the auto level and tripod to a new location, IH(2). Set up the auto level consistent with Section 1.1. Confirm the BS can be read from the new location and the LOS of the instrument is higher than the VBM.

Step 6: Record the new BS elevation at the turning point. Record the elevation in the line below the original turning point elevation and add it to the sum from the previous line. This is the new IH, IH(2).

Step 7: If necessary, shoot remaining FS and BS elevations that were not visible at IH(1) and note the IH used for the dry bed elevations and WSELs.

Step 8: Return the stadia rod to the VBM and record the new FS on the last line below the new turning point elevation and subtract it from IH(2). The answer should be the “BM ELEV” of 100. This routine is considered “closing the level loop.” The allowable error of closure is +/- 0.02 ft. If the closure error exceeds this limit, the survey must be redone.

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