Protocol for Placement and Retrieval of Temperature Data Loggers in Idaho Streams

Water Quality Monitoring Protocols—Report No. 10

Version 2

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Acknowledgements

This document is an updated version of DEQ's *Protocol for Placement and Retrieval of Temperature Data Loggers in Idaho Streams*. This version retains much of the language used in the original protocol and draws heavily on previous work done by Idaho Department of Environmental Quality (DEQ) staff and other local, state, and federal agencies engaged in temperature monitoring activities.

Thanks to Don Zaroban, DEQ Technical Services Division; Hawk Stone, DEQ Boise Regional Office; and Don Essig, DEQ State Office Surface Water Division, for peer reviewing this revised protocol. Special thanks to Mark Shumar, DEQ Technical Services Division, for assistance in authoring portions of the *Data Handling* section of this document, and for peer reviewing this revised protocol.

Disclaimer

The purpose of this document is to describe guidelines for the placement, retrieval, and documentation of various types of temperature data loggers at individual stream sites and subsequent temperature data handling. This guidance protocol consists of recommended procedures and does not have the force and effect of law or rule; rather, this protocol is designed to serve as primary reference tool to assist in the collection of surface water temperature data. This protocol describes several methods based on specific types of loggers and the scenarios for which they were developed and function best. Trade names are referred to or mentioned in this document solely to identify materials or instruments that have been successfully used to collect and store temperature data. Mention of specific manufacturers or trade names does not imply endorsement by the Idaho Department of Environmental Quality and should in no way be taken to suggest superiority over comparable products.

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1 Introduction

This protocol describes guidelines for the placement, retrieval, and documentation of temperature data loggers at individual stream sites and subsequent temperature data handling. This protocol consists of recommended procedures and does not have the force and effect of law or rule. This protocol supplements the Idaho Department of Environmental Quality (DEQ) technical procedures manual (Ralston and Browne 1976) in light of recent advances in temperature monitoring technology. It is intended to reduce the variability of temperature data due to sampling techniques and contribute to a standardized process for collecting temperature data using data loggers. Even though monitoring requiring multiple data loggers is not specifically covered, this protocol may be applied to each logger used in such circumstances. This protocol provides background information, methods, forms, and suggested equipment lists. It does not cover lakes, reservoirs, and large (nonwadeable) rivers.

1.1 Background

Much research has demonstrated that water temperature has direct and profound effects on organisms that live or reproduce in the water. Hynes (1972) described effects of water temperature on primary production, algae, higher plants, invertebrates, and fish in running waters. Due to the foundational role that water temperature plays in aquatic ecosystem functioning and because many human activities impact temperature, water temperature criteria have been developed and adopted into Idaho's water quality standards (IDAPA 58.01.02). Numeric water temperature criteria in the standards protect the following aquatic life:

Cold water biota (250.02.b)
Salmonid spawning (250.02.f.ii)
Bull trout (250.02.g)
Kootenai River white sturgeon (250.02.h)
Seasonal cold water biota (250.03.b)
Warm water biota (250.04.b)

Heat often has a synergistic effect with other stressors on aquatic organisms (Bell 1973) and is also used, in combination with pH, to define numeric criteria for un-ionized ammonia in the water quality standards (IDAPA 58.01.02.250.02.d and 250.04.d, respectively).

The numeric temperature criteria set forth in Idaho's water quality standards take the form of four reduced metrics:

Maximum temperature (max)—the highest temperature in the quality assurance (QA)/ quality control (QC) validated data set.
Maximum daily average temperature (MDAT)—the mean temperature calculated over a period of 1 day.
Maximum weekly maximum temperature (MWMT)—the highest weekly maximum temperature in the QA/QC validated data set. The weekly maximum temperature is the mean of daily maximum temperatures measured over a consecutive 7-day period ending on the day of calculation.
Maximum weekly average temperature (MWAT)—the highest weekly average temperature in the QA/QC validated data set. The weekly average temperature is the mean temperature calculated over a 1-week period.

In addition to anthropogenic heat sources such as point-source discharges, stream water temperatures are influenced by water source, ground water, precipitation runoff, solar radiation (including shading), air temperature, climate, and geologic setting (Stevens et al. 1975); thus, these factors should be considered when designing any water temperature study, placing temperature sensing devices, and interpreting temperature data.

2 Methods

Numerous sources have recommended methods to help standardize surface water temperature monitoring and reduce sampling variability (Stevens et al. 1975; Ralston and Browne 1976; Clesceri et al. 1998; Essig 1998; Oregon Plan for Salmon and Watersheds 1999). The following sections describe methods for working with data loggers before, during, and after placement and how to process the resulting data.

2.1 Pre-Placement Procedures

Gathering useful, accurate, and defensible data starts with proper procedures before any temperature data loggers are deployed.

2.1.1 Identify Data Collection Objectives

The foremost step in developing methods for instream water temperature data collection is identifying the objectives of the study. For what purposes are the data needed, and who will use these data? Common water temperature monitoring objectives for the State of Idaho include: baseline monitoring to determine spatial and temporal temperature patterns, assessment monitoring to evaluate aquatic life beneficial use support status of a water body, and compliance monitoring to measure the influence of point source discharges to a water body.

With recent advances in technology, and widespread availability (and affordability) of temperature data loggers, comes a wealth of instream data collected by various federal, state, and local government agencies and other entities. In identifying a need for temperature data, DEQ recommends that some effort be made to obtain temperature data where it may already exist. This could be as simple as contacting other agencies in the area to inquire about data sharing possibilities or accessing publicly available databases such as the following:

NorWeST (*http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html*)
Water Quality Portal (*http://www.waterqualitydata.us*)
StreamNet (*http://www.streamnet.org)*
Columbia River Data Access in Real Time (DART)
(*http://www.cbr.washington.edu/dart/query/wqm_graph*)
US Geological Survey National Water Information System (NWIS)
(*http://waterdata.usgs.gov/id/nwis/qw)*

By collaborating with other agencies, DEQ may be able to reduce resources and costs associated with temperature monitoring.

2.1.2 Develop a Quality Assurance Project Plan and a Field Sampling Plan

A quality assurance project plan (QAPP) is the overarching document that guides development of a specific project and defines the quality assurance (QA) objectives and criteria for a project.

The QAPP is designed to comply with DEQ's *Quality Management Plan* (DEQ 2012) and defines data quality objectives, including data precision, accuracy, and measurement range and data representativeness, comparability, and completeness. As a rule of thumb, a minimum of 10% of the sites should be replicated for QA purposes; however, the QAPP or field sampling plan (FSP) may specify a different percentage if necessary. Project personnel should include the "acceptable" loss rate of the data, and perhaps even the data loggers themselves. The QAPP also contains information related to special training or certification of project personnel, documentation and records handling, sampling process design and methods, sample handling and custody, analytical methods, quality control (duplicates and blanks), instrument/equipment calibration and maintenance, and data acquisition and management (including verification and validation). The study timeline, milestones, products, and perhaps the budget are also documented. The QAPP must be reviewed and approved by the QA officer, and in some cases the QA director, prior to collecting data. DEQ is in the process of developing a statewide generic QAPP for instream temperature monitoring that will be available for use in the near future. For more information on DEQ's Quality Management System—including guidance and templates for QAPPs and FSPs—DEQ staff are directed to see the QA intranet page.

If a generic QAPP is used, an FSP must also be developed and approved prior to collecting data in the field. FSPs may not be necessary in cases where individual, project-specific QAPPs have been developed. FSPs typically serve to supplement generic QAPPs and include project-specific information tailored to the applicable monitoring event(s). FSPs should be developed using the appropriate FSP template, available in TRIM. At a minimum, the FSP should include the following:

1. Rationale for the proposed data collection
2. Type of data to be collected
3. Methods to be used in collecting data including the location(s), frequency, and duration of data collection
4. Equipment needed for the data collection activity
5. Site-specific considerations, especially the basis for site selection

Monitoring objectives, such as assessing compliance and beneficial use status, must be clearly identified and documented, and the project tailored accordingly. For example, if the monitoring is being conducted to assess fish-related beneficial uses, project personnel must also document the species of interest, the most sensitive life stages, and any critical time period(s) related to the life cycle.

Depending on the purposes of the monitoring activity, additional measurements or observations may be useful in interpreting the temperature data. Factors that can influence temperature measurements include, but are not limited to, water depth, water velocity, stream discharge, ground water inflow, habitat type, channel width, solar input, overhead cover, air temperature, and distance from the streambank. These parameters should be considered for measurement in each surface water temperature monitoring activity.

As flows diminish during summer months, it is common for data loggers to be exposed to atmospheric conditions. Collecting air temperature and water depth (or discharge) data concurrently may help identify whether data loggers became exposed to air temperatures. The data can then be validated to omit non-representative data from the final data set.

2.1.3 Select Data Loggers and Other Equipment

Once the project manager has identified the need for data collection and has decided which methods are necessary to meet the data collection objectives, a type of data logger must be selected. Countless data loggers are available on the market today, are easy to acquire and use, and are relatively inexpensive to purchase. Most data loggers fall into one of the following categories:

Mechanical—simple, standalone electronic devices that do not require a computer to operate
Electronic—programmable electronic devices that require a computer and special software
Wireless—wireless, programmable, electronic devices (some of which have remote control and real-time data capabilities allowing for data download from anywhere)

Research into the various capabilities (particularly measureable range and sensitivity) of the many products available is prudent to achieve the best possible outcome for any temperature data collection project. While wireless data loggers are currently more expensive than other models, they use cutting-edge technology, have a longer battery life, and should be considered for use in situations where a site is in a remote or difficult to access area, where it may not be possible to conduct periodic site visits to download data, or where real-time data are needed. A list of temperature data logger manufacturers commonly used in the Pacific Northwest is provided below (Table 1).

Table 1. Names, phone numbers, and websites of temperature data logger manufacturers commonly used in the Pacific Northwest.

Manufacturer Name	Phone Number	Website
Onset Computer Corporation	1 (800) LOGGERS (564-4377)	www.onsetcomp.com
SensiTech	1 (800) 843-8367	www.sensitech.com
Vemco Limited	1 (877) 626-4749	www.vemco.com

When selecting a data logger, consider the following:

1. Durability of the logger and the nature of the stream environment where the logger will be placed
2. Measurement range, accuracy, and resolution appropriate for the purposes of the study
3. Battery type and life
4. Memory capability of the instrument

The exact specifications needed for the temperature data logger must be specified in the QAPP.

Additional equipment is typically necessary to secure a logger in place. Most temperature data logger manufacturers sell protective cases to house the data logger. These cases may help prevent damage to instruments exposed to field conditions and address potential issues such as solar radiant heating of the logger and instream camouflaging. In some cases, additional housing may be necessary to meet project needs. Thus, the equipment needed to install the data logger can vary greatly depending on the type of logger, design of protective housing, physical characteristics of the stream, and method of submerging and attaching the logger instream. Supplemental logger housing devices are simple to make, are inexpensive, provide total shade for the logger, may protect the logger from moving debris, and can provide for secure attachment via a cable. It is recommended that field personnel allow the supplemental housing and attachment cable to rust to reduce the equipment's visibility and vulnerability to vandalism. A suggested field equipment list is included in Appendix A, but it should be tailored according to the project needs and deployment methods used.

DEQ recommends using submersible logger models for instream data collection. Non-submersible models require waterproof housing and additional equipment and have increased costs and maintenance requirements. If a non-submersible model is used, desiccant must be added to the waterproof housing to absorb any moisture that may seep in. Silicone should also be used to create a water-tight seal around any openings or O-rings. Because data loggers housed within waterproof cases are not in direct contact with the water and are actually recording air temperatures within the housing, there will be a short time lag (approximately 15 minutes) until the air inside the housing reaches the same temperature as the surrounding water (Dunham et al. 2005). Thus, this type of model is not necessarily appropriate for monitoring water temperatures within short time intervals; for instance, if the objective of the study is to record temperatures every 15 minutes or less for compliance purposes, the precision of those measurements will likely be inadequate. It is recommended that submersible data loggers be used in situations where water temperatures must be measured precisely and within a short time period (Dunham et al. 2005).

For loggers housed in a protective case, case transparency is an important factor. If not totally shaded, loggers placed in clear, translucent, or even black cases may act as heat collectors and record artificially high values due to solar radiation warming inside the case. Dunham et al. (2005) have demonstrated that the maximum temperatures measured by loggers housed in clear cases were up to 5°C warmer than temperatures measured by loggers in reflective cases. White, non-translucent cases are recommended to avoid solar radiant warming.

While frequently recommended in many protocols, building additional housing for water quality monitoring equipment has the common drawback of associated maintenance related to keeping the housing clear of sediment, aquatic plants, and other materials that may enter the stream and potentially interfere with measurement accuracy. Project personnel should plan their monitoring activity carefully, giving extra consideration to whether additional housing is value-added.

DEQ recommends the use of property tags to identify legal ownership of deployed data loggers (see section 2.2.2 for further details).

2.1.4 Perform Data Logger Accuracy Checks and Calibration

It is necessary to verify that temperature data loggers are working properly (in accordance with the manufacturer's specifications) by performing simple accuracy checks prior to deployment in the field, and after retrieval from the field. Accuracy checks must be conducted using a National Institute of Science and Technology (NIST)-traceable temperature measurement device (e.g. thermometer, logger) under laboratory conditions. *Accuracy* is a measure of the agreement between a "true" (reference) value and a measured value. For the purpose of performing accuracy checks, the reference value is taken to be that which is given by the NIST-traceable device, which is used to verify that the data loggers are within the acceptable accuracy range (tolerance level) specified by the manufacturer.

The tolerance level of temperature monitoring devices (e.g. thermometers, thermocouples) are set by the manufacturers such that they will pass a 4:1 accuracy ratio when calibrated for NIST traceability. For example, if a thermometer has an accuracy level of ±0.5°C it must pass calibration with an accuracy of ¼ of its tolerance or ±0.125°C (0.5/4) when calibrated to a NIST-traceable device. Although the thermometer would appear to be more accurate (to levels at or below ±0.125°C), it is only guaranteed to represent real world temperatures at the ±0.5°C level of accuracy.

Many spirit-filled thermometers have tolerance values between ±0.5 and ±1.0°C; mercury filled thermometers can be more accurate with tolerances near ±0.1 or ±0.2°C; thermocouples can be manufactured with tolerances across this range, with some inexpensive models at a ±0.5°C tolerance and other more expensive devices in the ±0.1 – 0.2°C range. The use of a NIST thermometer is no longer necessary in that NIST certificates can be obtained for a nominal fee and will provide the accuracy of a specific unit, which can then be used for accuracy checks in place of an actual thermometer. The option of obtaining a NIST certificate, for a NIST-traceable unit, may be more desirable as NIST liquid-filled glass thermometers are costly and can pose a hazard to the user.

Because there are a variety of temperature monitoring devices available today (and used at DEQ), levels of acceptable accuracy must be identified in individual QAPPs as appropriate for the specific data loggers chosen for a specific project.

Precision is another important objective in any water quality monitoring plan and is defined as the amount of agreement among repeated measurements of the same parameter. Precision should be assessed by taking repeated measurements, thus a minimum of 10 data points is recommended here.

For accuracy check purposes, DEQ provides the following guidelines:

- Launch the loggers according to the manufacturer's instructions.
- Confirm that the clocks in the computer and loggers, and the clock (timepiece) used for the instantaneous measurements in the field, are consistent.
- For efficiency, check multiple loggers for accuracy at the same time.

To perform accuracy checks, the following two-point test method is recommended in order to test the loggers for accuracy across the range of temperatures likely to be encountered in the field:

<u>Room Temperature Bath</u>

1. Prepare a room temperature bath (~ 20°C) in a large container and verify a uniform temperature (mixing may be required) using a handheld thermometer (this should be the same thermometer to be used in the field during field audits).

2. Program the loggers to collect temperature measurements once every minute for 10 minutes, yielding 10 temperature measurements.

3. Place the launched loggers in the room temperature bath for a period that is sufficient enough to equilibrate the loggers to the temperature of the bath. Generally speaking, if the loggers have been stored at room temperature, this equilibration period should be relatively quick (approximately 5 minutes).

4. Use a NIST-traceable device to take temperature measurements and record the date and time of each QA measurement. If the NIST-traceable device is a temperature data logger with a NIST certification, you will program it and launch it synchronously with the other loggers.

5. Calibrate your field thermometer (according to the manufacturer's instructions) concurrently to ensure consistency in the QA measurements.

6. Compare the logger data to the NIST-traceable device data. Be sure to document each pair of readings and the magnitude of any discrepancy; if desired, the data can be viewed graphically (Figure 1).

If it appears that any of the loggers are recording temperatures at levels substantially different than the NIST-traceable device, consider that it should not be used in the field; any device that records temperature differences outside of the tolerance level specified by the manufacturer (e.g. 0.2°C, 0.5°C) is suspect and must not be used in the field.

<u>Ice Water Bath</u>

1. Prepare an ice water bath (~ 0°C) in a large insulated container and verify a uniform temperature (mixing may be required) using a handheld thermometer.

2. Place the launched loggers in the ice water bath for a period that is sufficient enough to equilibrate the loggers to the temperature of the bath (15 minutes is generally recommended) and repeat steps 4-6 above.

Post-retrieval device checks must also be conducted using the same procedures discussed above. See section 2.3 for more information. An example temperature data logger accuracy check and calibration form is available to DEQ staff (Appendix B or TRIM record #2013AJZ2).

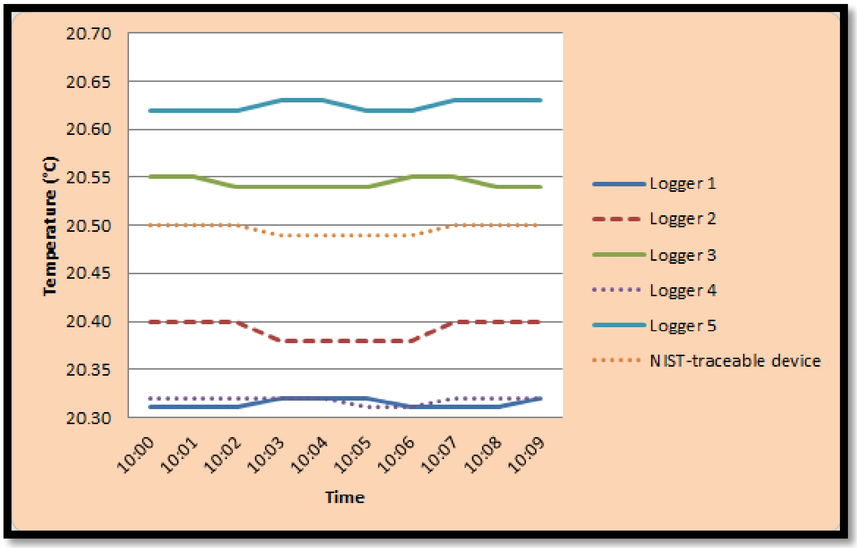

Figure 1. Accuracy Check of Loggers 1-5 against a NIST-traceable device.

2.2 Field Placement Procedures

After following all pre-placement procedures, the loggers are ready for placement in the field.

2.2.1 Launching the Logger

Launch the logger according to the manufacturer's recommendations. Program the logger to meet the specific objectives of the study as identified in the QAPP. Data loggers should be programed to record temperature measurements in degrees Celsius (°C) using a date format of mm/dd/yyyy and a time format of hh/mm/ss. Record the logger serial number, data collection interval, site description, and whether "triggered" or "delayed" start was used. Project personnel must document whether the logger was programmed to record multiple or single measurements and whether the reported value is an instantaneous or averaged measurement. *While many loggers can be programmed to take several measurements within a given time frame and then record an average of those values, DEQ recommends that single (instantaneous) measurement values are recorded for comparisons to Idaho water quality standards temperature criteria.* Other temperature statistics, such as daily or weekly averages and maximums, can be easily determined from these data after the raw data has been downloaded, eliminating the need to program the logger to compute these statistics itself. Furthermore, programming the logger to record instantaneous measurements will prolong the battery life of the unit.

According to IDAPA 58.01.02.10.17, temperature measurement intervals should be short enough that the difference between consecutive measurements around the daily maximum or minimum is less than 0.5°C. Thus, temperature measurement intervals are recommended to be no greater than one hour apart for comparison to Idaho's temperature criteria; more frequent intervals are recommended during summer months, especially as flows diminish, temperatures increase, and thermal fluctuations become more frequent and more pronounced. If the objective of data collection is to measure maximum daily water temperatures, it may be advised that the loggers be programmed to collect data every 30 minutes through the period of concern. Data loggers can often be programmed to collect data more frequently between defined dates or even times of day. One option is to program the logger to take more measurements during the hottest part of the day and fewer measurements during nighttime hours, but the project manager should be aware that doing so may complicate data analysis and processing.

Continuous temperature monitoring may be necessary to establish wasteload allocations for point-source discharges or to comply with permit requirements established by EPA or DEQ. If this is the case, the data logger must be programmed consistent with the permit requirements.

2.2.2 Placing the Logger

The site selected for logger placement must be representative of the goals and objectives of the monitoring activity. The investigator should be aware of the spatial and temporal scale at which the data is anticipated to be analyzed and select sites accordingly. For example, the data may be used to assess attainment of temperature criteria at a particular site, stream reach, catchment, watershed, cataloging unit, or basin scale.

If the monitoring is being conducted to assess nonpoint source temperature impacts, the logger could be placed at the downstream end of the reach of interest with relatively uniform morphology, land use, and cover. Likewise, if the objective of the study is to assess beneficial use support status, instream temperature data loggers could be placed at the downstream boundary of the assessment unit where the water is adequately mixed and not influenced by localized warm or cool water sources such as ground water, point sources, or direct sunlight.

For point source temperature assessments, loggers should be placed just upstream of the discharge point (to establish background or ambient conditions) and at the downstream edge of any applicable mixing zone or within the effluent itself, depending on the type of assessment needed. If the goal is to establish a wasteload allocation for a point source discharger, then the temperature of the effluent is needed.

Loggers must not be placed too close to the streambed, where they can be buried in sediment or debris and influenced by ground water inflow. Verify that the site is well-mixed horizontally and vertically with instantaneous temperature measurements using a hand-held thermometer. In assessments of flowing waters, well-mixed waters normally occur in the center of the thalweg (Figure 2). The thalweg marks the natural direction (or profile) of a watercourse and is almost always the line of fastest flow in a stream system and deepest point in any given cross-section of the stream channel. Take caution that the site is not susceptible to excessive scour, which may displace the logger (Dunham and Vinyard 1998).

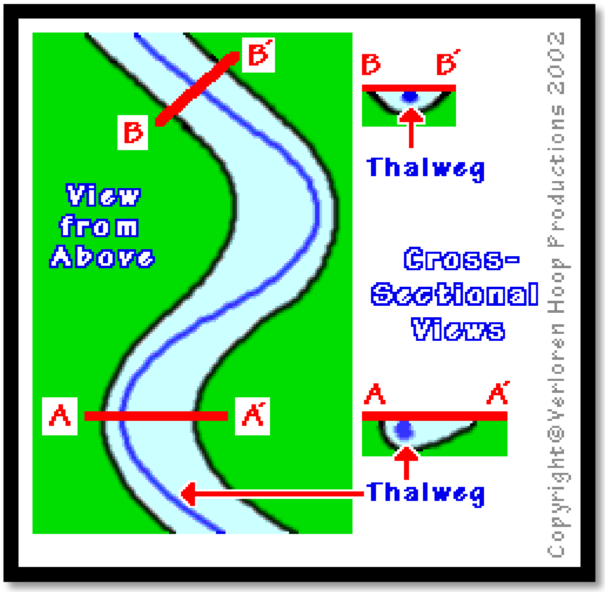

Figure 2. Stream channel sketch, showing the cross-sectional views of the thalweg.

TidbiT data loggers (Figure 3) are ideal for streams subject to low flow conditions (e.g., intermittent streams, urban streams) because they are small, discrete, and more likely to stay completely submerged during periods of low flow. They can also be used in high mountain streams that experience pronounced variations in water levels throughout the year and urban streams subject to human disturbances. Due to their small size, rigorous locality documentation is necessary to help relocate them during site visits. Survey tape, metal tags, or some other type of site marker can be placed strategically at the monitoring site to help locate the data logger during future visits. Locality documentation is discussed in greater detail in section 2.2.3.

Figure 3. TidbiT v2 water temperature data logger—UTBI-001.

The US Forest Service Rocky Mountain Research Station developed a method for securing TidbiTs to submerged boulders using an underwater-suitable epoxy. This method has been rigorously tested and has proved to be quite successful (Isaak and Horan 2011), thus gaining popularity in recent years. This method is especially useful for mountain streams that are difficult to access, experience high-stage flood events from snowmelt, and have boulders pervasive in the aquatic environment. This method should be considered for long-term or multiyear projects where it may be infeasible to deploy and retrieve monitoring equipment within the period of interest. This method also works well where culverts are available and the TidbiT can be epoxied to a submerged part of the structure.

Another popular method for attaching instream temperature data loggers is to connect them via cable to a tree (or other immobile object) in or near the stream. If this method is used, it is important to disguise the cable by burying it in the substrate to minimize the risk of disturbance or vandalism; further camouflaging may also be considered. Data loggers can also be deployed instream by driving a piece of rebar into the stream bed (in the thalweg) and attaching the data logger with zip ties or cabling (Figure 4).

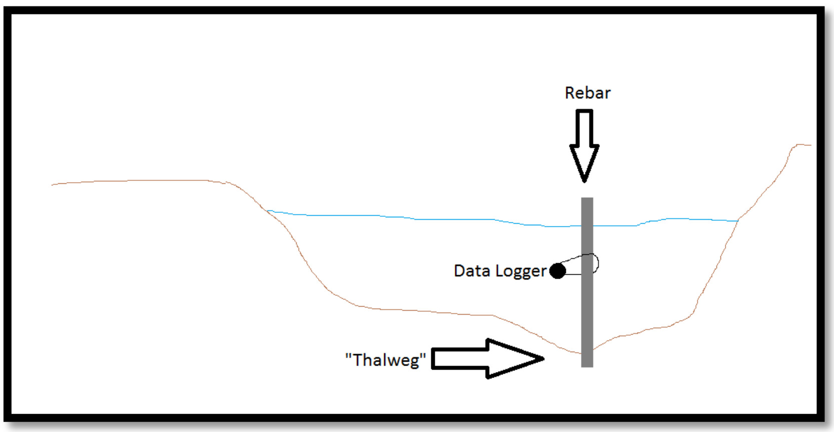

Figure 4. Sketch of a temperature data logger attached to rebar, which has been driven into the thalweg of the streambed.

Each data logger that is placed in the field should have a State of Idaho property tag affixed to it. It is recommended that a short message also be attached to the data logger which identifies it as a scientific measurement device which should not be disturbed; a phone number or address should also be included. In the event that a data logger is encountered in the field by a member of the public, this will increase the likelihood of them leaving it instream, or returning it to the appropriate person.

2.2.3 Documenting the Location

A thorough and complete description of each site location should be completed to ensure the logger can be relocated and to account for factors that influence surface water temperature. The locality description should be sufficiently detailed that a person unfamiliar with the project could locate the data logger; at minimum, it should include the following:

- Water body name
- Assessment unit
- Latitude and longitude, recorded with a GPS unit (identify datum used)
- Site sketch (plan-view)
- Site photographs
- Date and time of logger placement

- Detailed narrative description of the placement of the data logger and site marker

Locality information needed to assess aquatic life temperature criteria contained in the Idaho water quality standards is listed on the example locality documentation and logger information metadata sheet (Appendix C). Maps and directions used to locate the site should be used and kept as part of the study record.

When placing a logger, find a suitable location to attach a site marker to further assist in identifying the location. Once the site marker has been attached, stand with your back to the marker and use a compass to point straight to the location of your data logger. Record the compass reading on the locality documentation form.

2.3 Site Visits, Field Audits, and Data Retrieval

Whenever feasible, interim site visits are recommended to make any needed physical adjustments to the logger. Site visits are especially important for spring high-flow placements, because it is common for loggers to become exposed to air as water levels diminish over the summer months. Interim visits can also be used to perform field audits. Field audits can include taking instantaneous temperature measurements (using the same handheld field thermometer which was used and calibrated during the pre-deployment accuracy checks) for QA/QC purposes and/or to periodically download the data in the field to help ensure that the logger is performing properly and to lessen the likelihood of data being lost. When an interim site visit is made, project personnel must record the date, time, and any pertinent field conditions. If interim downloading is preferable, project personnel will need to relaunch the logger to begin a new collection interval.

When retrieving the logger, document the condition of both the site and the logger. At a minimum, note whether the logger is still submerged in the water or whether it has been buried by sediment. Record any signs of vandalism or disturbance, and note whether the integrity of the logger has been compromised. Follow the manufacturer's procedures for downloading data. An example field audit form is provided in Appendix D.

Upon project completion, all field equipment should be removed from the stream if possible. Post-retrieval accuracy checks must be performed using the same procedures described in section 2.1.4 to assess instrument drift or malfunction and to aid in data cleaning and analysis.

Many data loggers specify a drift rate of 0.1°C per year. The QAPP must establish an acceptable level of instrument drift; in general, drift must not exceed the manufacturer's specifications, unless otherwise specified in the QAPP. Any findings of instrument drift must be documented and discussed in detail for reporting purposes.

2.4 Data Handling

Once field data has been collected and retrieved from the field, the data must be offloaded from the logger(s) following the manufacturer's instructions, viewed graphically, QA/QC validated, and uploaded to DEQ's Idaho Assessment Database Supplementary Application (IDASA).

2.4.1 Data Validation

The first step in data validation is to omit the first and last days of the data set if the loggers were recording measurements prior to being placed in the stream. Incomplete data due to deployment and retrieval lag times must be removed from the data set. Next, the data should be viewed graphically and analyzed for anomalies, which may indicate that the logger was out of the water. Project personnel must be knowledgeable about effectively identifying such anomalies in a data set. The key to recognizing suspicious data lies in knowing how a logger behaves when recording air temperatures, as opposed to water temperatures. To help recognize the difference, additional information may need to be consulted, including comparison of data between loggers placed in other parts of the stream, air temperature data from a nearby weather station or air temperature logger, field audit notes, water level or discharge (flow) information, etc.

Data "cleaning" (trimming) steps have been identified to reconcile data files and provide for more accurate temperature data analysis (Sowder and Steel 2012); DEQ staff are encouraged to read the article for further details on data cleaning and validation. The data should be carefully scrutinized, validated and trimmed to remove spurious and unwanted records. IDASA allows for data validation after the raw data has been uploaded to the program, but project personnel may elect to validate and trim the data prior to uploading to IDASA *as long as they document the changes made to the data record in IDASA and keep the raw data files in TRIM (DEQ's document management system) as part of the project record*.

2.4.2 Uploading Data to the Database

After data have been downloaded according to the manufacturer's specifications, the temperature data must be uploaded into IDASA. To facilitate the upload, several steps must be taken to ensure compatibility with the database. *The following steps for data handling assume that the logger is a HOBOware product (manufactured by Onset) that will be downloaded with its associated software; if the logger is from a different manufacturer, its applicable download software must be used and some of the following instructions may not apply.*

Data must be exported from HOBOware to a file format suitable for entering into IDASA. IDASA accepts text files (.txt) with very specific date and temperature column formats. IDASA was originally built to handle text files created by Boxcar software. HOBOware no longer creates that specific format, so several steps need to be taken to get the proper text file format.

1. Export the data to an Excel .csv file by clicking on the toolbar icon in HOBOware to initiate the process.
2. Once the .csv file has been created, convert it to a .txt file using the converter program built specifically for this purpose by DEQ's Wei Zhang. Click the link below to download the converter program to your computer: *\\deq\dfs\Deploy\ClickOnce\temp_logger_data_convertor\publish.html.* If the link does not work, consult the DEQ Surface Water Program.
3. Follow the converter program's instructions to navigate to and process your .csv file. The converter program takes the.csv file that HOBOware created and converts it to a .txt file with the specific format needed for IDASA uploads.
4. Open the IDASA application on your computer (ensure that you are working with the correct version of IDASA) and then click on the **temperature logger** button that appears on the first screen.

5. When the Temperature Logger page opens, click on the first button called **Import Boxcar Text File** and enter your username and password (obtained from the DEQ Surface Water Program).
6. In the next window, click **Add File** (*do not attempt batch mode*).
7. Navigate to your newly created text file on your computer and click **Open**.
8. The program will ask you if the file contains a specific year of data as a way to ensure the correct file is being opened. Choose **yes** if the year is correct, otherwise you may need to check the name or format of your data file.
9. Fill in the New Site Information completely. Once complete, close the page; you will see the site information pages where you can add further information or add information for the particular data logger at another time.
10. The next screen will be the Data Modification/Clean-up Form. If you have not done so already, clean the data by removing the dates that contain erroneous or suspicious data that you do not wish to retain. Follow the instructions provided in IDASA to remove data points. *Staff must click on **Notes** and add information about any data that were removed or any other pertinent information about the logger and its data.*
11. You will next be directed to the calibration page, where you must add notes detailing any issues that occurred when calibrating the temperature loggers. DEQ staff should use the temperature data logger accuracy check and calibration form provided in Appendix B (or TRIM #2013AJZ2) to calculate the appropriate final calibration to be applied to the data set. The final calibration is the average difference between the values obtained in the pre-deployment and post-retrieval accuracy checks. *Changes to the data set must be documented—no exceptions!* After leaving these screens, data entry is complete.
12. The data chart will appear and you can print it, change metrics, or add notes.
13. After closing the data chart, the Criteria Evaluation Form appears next, where you can set the criteria and dates of evaluation for the various aquatic life uses, if desired. You can leave the dates as default settings or click on **Set Criteria** to change the dates specific to your circumstance.
14. Once dates are set, click on **Calculate Exceedances** and the table will be formatted with all the applicable criteria exceedances. This table and the associated criteria exceedance information can be printed as well.
15. Close the program; data entry to IDASA is complete. The program can be revisited at a later time for additional analysis.

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Appendix A. Suggested Field Equipment List

- [ ] Calibrated data loggers
- [ ] Backup data loggers
- [ ] Data logger cases (if using)
- [ ] Property tags for loggers
- [ ] Calibrated field thermometer
- [ ] GPS unit w/compass
- [ ] Laptop computer w/ interface cable (if launching loggers and/or offloading data in the field)
- [ ] Property tags
- [ ] Polarized sunglasses (helps to see submerged logger)
- [ ] Camera w/ extra batteries
- [ ] Timepiece
- [ ] Waders
- [ ] Field forms
- [ ] Metadata sheets
- [ ] Rite-in-the-Rain™ notebook
- [ ] Sharpies/pens/pencils
- [ ] Maps
- [ ] Cell or satellite phone
- [ ] First-aid kit
- [ ] Tools
- [ ] Pocket knife
- [ ] Tape measure
- [ ] Zip ties
- [ ] Bailing wire
- [ ] Epoxy
- [ ] Wire cutters
- [ ] Pliers
- [ ] Cable clamps
- [ ] Crimping tool
- [ ] Post driver
- [ ] Wrenches
- [ ] Steel cable
- [ ] Rebar
- [ ] Bricks w/ holes
- [ ] Sandbags
- [ ] Desiccant
- [ ] Silicone grease
- [ ] Locks

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Appendix B. Example Temperature Data Logger Accuracy Check and Calibration Form

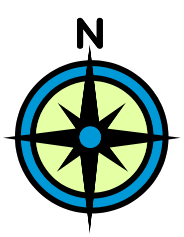
Temperature Data Logger Accuracy Check & Calibration Form				
Data Logger Serial Number (ID):				
Manufacturer Specifications[1] (°C):	Accuracy:		Drift:	
NIST Thermometer Serial Number (ID):				
PRE-DEPLOYMENT Accuracy Check Performed by:				
Accuracy Check Date (mm/dd/yy):				
Room Temperature Bath				
TIME (00:00)	NIST Temp (°C)	Logger Temp. (°C)	Difference	Pass/Fail
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
		Average Difference	***0.00***	
Ice Water Bath				
TIME (00:00)	NIST Temp (°C)	Logger Temp. (°C)	Difference	Pass/Fail
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
		Average Difference	***0.00***	

POST-RETRIEVAL Accuracy Check Performed by:				
Accuracy Check Date (mm/dd/yy):				
NIST Thermometer Serial Number (ID):				
Room Temperature Bath				
TIME (00:00)	NIST Temp (°C)	Logger Temp. (°C)	Difference	Pass/Fail
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
		Average Difference	***0.00***	
		Drift	***0.00***	Pass
Ice Water Bath				
TIME (00:00)	NIST Temp (°C)	Logger Temp. (°C)	Difference	Pass/Fail
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
			0.00	Pass
		Average Difference	***0.00***	
		Drift	***0.00***	Pass

Appendix C. Example Locality Documentation and Logger Information Metadata Sheet

Location Information

Water Body Name:	Site ID:
Assessment Unit:	Site Map Attached? Y / N (circle one)
Latitude/Longitude:	Datum:
Site Marker Location:	Compass Reading:
Photo Numbers or File Names	Photo Description/Comments
Upstream:	
Downstream:	
Right Bank:	
Left Bank:	
Logger Location:	
Misc 1:	
Misc 2:	
Site Sketch (including logger placement)	



Detailed narrative description of data logger and site marker location:

Logger Information

Manufacturer:	Model:
Serial Number:	
Pre-Deployment Accuracy Check Performed? Y / N (circle one)	Post-Retrieval Accuracy Check Performed? Y / N (circle one)
Raw Data File Name(s)	Raw Data File Location(s)
Start Type: ❑launched in field ❑triggered ❑delayed	
Collection Interval (minutes):	
Measurement Type: ❑single ❑multiple	
Value Type (required if multiple measurement type used): ❑ average ❑minimum ❑maximum	
Deployment Date (mm/dd/yy):	Deployment Time:
Field Audits Performed? Y / N (circle one)	Field Audit Forms Attached? Y / N (circle one)

Notes:

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Appendix D. Example Field Audit Form

Water Body Name:	Site ID:
Audit Date:	Audit Time:
Instantaneous Temperature (°C):	Air Temperature (°C):
Weather Conditions:	
Wetted Width (m):	Water Depth (m):
Logger Submerged? Y / N (circle one)	Data Downloaded? Y / N (circle one)
Condition of Logger:	
Photo Numbers or File Names	Photo Description or Comments
Notes:	