Quality Assurance Project Plan

Comparison of Stream Temperature Monitoring Protocols used by the Environmental Monitoring and Trends Section

by
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December 2005

Approvals

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Table of Contents

Abstract

The Washington State Department of Ecology (Ecology) Stream Hydrology Unit (SHU) operates a streamflow gaging program to obtain information for water resource management needs. Ecology also collects continuous stream temperature data at most of these monitoring stations. These temperature data may be useful for trend analyses, Total Maximum Daily Load (TMDL) studies, and determining compliance with water quality standards.

In addition, Ecology's Freshwater Monitoring Unit (FMU) measures continuous stream temperature at other locations using a different protocol. The FMU-collected data have been found to have acceptable data quality for the purposes listed above.

The goals of this project are to (1) assess the quality of the SHU-collected continuous temperature data in comparison to the FMU-collected data, and (2) assess the quality of the SHU-collected data to meet the purposes of trend detection, TMDL studies, and standards compliance.

Background

The Stream Hydrology Unit (SHU) is part of the Environmental Monitoring and Trends Section (EMTS) of the Washington State Department of Ecology (Ecology).

The purpose of this Quality Assurance Project Plan is to describe a study assessing the quality of the SHU-collected continuous temperature data to meet the purposes of trend detection, Total Maximum Daily Load (TMDL) studies, and standards compliance. This document presents detailed information on each of the 14 elements required of a QA Project Plan (Lombard and Kirchmer, 2004).

Management of surface water in Washington State requires a streamflow-measurement network capable of monitoring in all areas of the state. SHU operates a streamflow gaging network to provide basic data to address water resource management needs (Butkus, 2005a). SHU provides streamflow information in support of various statewide instream and out-of-stream planning and management efforts such as watershed planning, water resources management, flood plain management, TMDL evaluations, and other freshwater monitoring studies.

During water year 2005, SHU monitored continuous stream temperature at 128 stations in conjunction with streamflow monitoring. Of these, SHU operates 93 stations with telemetry. A telemetry station logs temperature and stage every 15 minutes and transmits these data to the Ecology Headquarters in Olympia, Washington via a Geostationary Operational Environmental Satellite (GOES) transmitter or a standard dial-up modem. These data are automatically imported into the streamflow database and published to Ecology's web site. The remaining 35 continuous temperature monitoring stations are stand-alone gages. A stand-alone gaging station logs data every 15 minutes and is downloaded periodically during station visits (typically once a month). Temperature and stage data are imported into the streamflow database manually and automatically published to the Ecology web site.

The main purpose of continuous stream temperature monitoring is to collect data that may be useful in interpreting the stage measurements. For example, stream temperature data can be used to identify periods when ice conditions are affecting the stage-discharge relationship. However, these stream temperature data may also be useful for other purposes including trend analyses, TMDL studies, and determining compliance with water quality standards. For example, the recently adopted water quality temperature standard requires stream temperature to be measured on consecutive days in order to apply the criterion. The continuous temperature results could be useful in assessing standards compliance under Ecology's policy for Section 303(d) of the federal Clean Water Act.

Project Description

Goals

1. Assess the quality of the SHU-collected continuous temperature data in comparison to data collected by the Freshwater Management Unit (FMU) protocols.

2. Assess the quality of the SHU continuous temperature data to meet the purposes of trend analyses, TMDL studies, and determining compliance with water quality standards under Section 303(d) of the federal Clean Water Act.

Objectives

1. Assess the variability of stream temperature data collected by the two protocols (SHU and FMU) used by Ecology's Environmental Monitoring and Trend Section (EMTS).

2. Assess the variability of stream temperature data collected by the two instruments used in EMTS.

3. Evaluate the observed stream temperature variability with the data quality requirements of other programs including water quality standards compliance, TMDLs, and trend analysis.

4. Evaluate the need for calibration checks or other quality control procedures in collecting stream temperature data with the SHU protocols and instrumentation.

Organization and Schedule

Organization

Ecology's Environmental Monitoring and Trends Section is organized into units where staff focus on specific functions, including monitoring of streamflow. The Stream Hydrology Unit (SHU) has 14 hydrologists and environmental specialists who provide streamflow information in support of various statewide instream and out-of-stream planning and management efforts. These staff are responsible for maintenance of specific stations and data functions that collect, store, and publish the continuous stream temperature data. In addition, staff from Ecology's Freshwater Monitoring Unit (FMU) will concurrently deploy temperature monitoring instruments according to their protocols. Project staff are shown in Table 1.

Table 1. Project Staff

SHU Personnel	Phone	General Duties
Jim Shedd	360-407-7025	Principle investigator
Howard Christensen	360-407-6479	Maintain flow stations
Casey Clishe	360-407-6691	Maintain flow stations
Kelsey Collins	509-575-2825	Maintain flow stations
Chris Evans	360-407-6052	Maintain flow stations and real-time data acquisition
Brad Hopkins	360-407-6686	SHU supervisor
Jim Shedd	360-407-7025	Senior review and quality assurance
Chuck Springer	360-407-6997	Maintain flow stations and Hydron Database administrator
John Summers	360-407-6022	Maintain flow stations
FMU Personnel	Phone	General Duties
Bill Ward	360-407-6621	FMU field methods and equipment procurement.

Schedule

Concurrent monitoring using the two protocols can be started at any time of the year. However, the exact time a particular station can be established is based on logistics. For example, in order to anchor the stream temperature loggers at a depth that may remain submerged throughout the dry season, instruments may need to be deployed as early as February (before the spring runoff). It is desirable to collect data for this evaluation over the widest range of temperature to detect possible temperature-dependant systematic errors.

There are a number of tasks to prepare for and complete the monitoring program. The tasks span the year and are noted in Table 2.

Table 2. Task Schedule.

Date	Task
December 2005	Assess equipment needs and submit purchase orders for replacement/ additional parts.
January 2006	Conduct pre-deployment temperature logger calibration checks, re-test loggers that fail to meet the accuracy criteria, and reject loggers that fail both tests.
February – July 2006	Pre-program temperature and deploy temperature loggers.
September – October 2006	Retrieve temperature loggers.
November 2006	Download data from temperature loggers, review data, delete identified anomalies, and begin to load finalized data into the database.
December 2006	Conduct post-deployment temperature logger calibration checks.
January 2007	Re-test loggers that fail the calibration check accuracy criteria, and adjust/reject results from the loggers that fail the re-test.
June 2007	Complete final report evaluating the difference between the two protocols.

Quality Objectives

There are two types of quality objectives that need to be identified: Measurement Quality Objectives (MQOs) and Data Quality Objectives (DQOs).

Measurement Quality Objectives

MQOs are "*acceptance criteria* for the quality attributes measured by project data quality indicators. [They are] quantitative measures of performance…" (USEPA, 2002). MQOs are the targets for precision, bias, and sensitivity against which laboratory quality control results are compared. Precision is assessed from the results of replicate analyses of samples and standards. Bias is commonly evaluated by comparing the results from method blanks, check standards, and matrix spikes to their expected values. Sensitivity is related to the detection and reporting limits for the measurement method used.

Data Quality Objectives

DQOs are needed in projects where the results are compared to a standard or used to select between two alternative conditions. SHU's continuous temperature data may be used for the following purposes:

1. Determining compliance with water quality standards under Section 303(d) of the federal Clean Water Act.
2. Water quality modeling needed to establish Total Maximum Daily Loads (TMDLs).
3. Evaluating trends in stream temperature.

DQOs have not been specified by the clients for the first two purposes. However, we assume that meeting the DQO for the third purpose (i.e., trend detection) will also enable the data to be used for these other purposes.

DQOs can be established to address statistical requirements for trend analysis. Linear trend analysis is a form of hypothesis testing of the model (Lettenmaier, 1977):

$$Y_t = \mu + \Delta\mu * t/t_l + \varepsilon_t$$

where,

y_t = the value of the monitored water quality variable at time, t
μ = the mean at the beginning of the time period
$\Delta\mu$ = the change in the mean over the time period
t_l = the length of the time period
t = the time elapsed since the beginning of the time period
ε_t = a stochastic error term

The hypothesis to be tested is:

H_0 (null hypothesis): $\Delta\mu = 0$ (no change in the mean value), and
H_a (alternate hypothesis): $\Delta\mu \neq 0$ (a change has occurred).

The size of trend ($\Delta\mu$) that can be detected depends on the degree of confidence one desires in the conclusion, the number of independent samples collected, and the variability in the data. Power, confidence level, and sample size are related so that both α (the probability of detecting a change when one has not occurred, *i.e.*, falsely rejecting the null hypothesis – type I error) and β (the probability of not detecting a change when one has occurred, *i.e.*, falsely failing to reject the null hypothesis – type II error) decrease with increasing sample size. Also, when one chooses a smaller α (i.e., assuming a stricter criterion before rejecting H_0), β increases (assuming sample size stays the same). Given values for α, β, and sample size (n), one can calculate the magnitude of the trend that can be detected relative to the standard deviation of the data.

The DQO is the specified magnitude of the trend that we wish to detect. Washington's Water Quality Standards (Chapter 173-201A-200(b)(i) WAC) define the level of acceptable measurable change as 0.3ºC. However, because the ability to detect trends is related to the variance of the data, separate DQOs for trend detection may need to be determined for different streamflow gaging stations. Depending on the variance measured at a particular station, DQOs may also need to be specified for different measures of stream temperature. For example, different DQOs may be needed for trends in maximum daily temperature vs. the 7-day average of the daily maximum temperature. This project will collect quality control data to evaluate the actual error attained as compared to the DQO set for trend analysis.

Measurement Quality Objectives for the Two Protocols

Stream Hydrology Unit (SHU) Protocol

Continuous temperature data collected by SHU is measured using two types of probes. Both thermistor probe types are deployed within a 2" galvanized slant pipe that extends from the gage house into the stream channel. The first is an internal thermistor within the submersible SDI-12 pressure transducer. The SDI-12 probe uses water temperature to correct for the change in pressure response due to temperature and adjusts the final pressure accordingly. Stations where a self-contained bubbler is used to measure stage height have a separate thermistor probe for measuring water temperature. The nominal accuracy of these thermistor probes as defined by the manufacturers is $\pm$ 0.2ºC.

Freshwater Monitoring Unit (FMU) Protocol

The accuracy and instrument bias of each FMU temperature logger is verified through both pre- and post-deployment calibration checks following the procedures described in the *Continuous Temperature Sampling Protocols for the Environmental Monitoring and Trends Section* (Ward, 2003) and in the TFW Stream Temperature Survey Manual (Schuett-Hames et al, 1999). The procedures require the temperature loggers be tested in controlled water temperature baths that bracket the expected monitoring range (near 0ºC and near 20ºC). The results are then compared to those obtained with a certified reference thermometer.

All temperature loggers that fail to meet their accuracy criteria (Table 3) will be checked a second time. Temperature loggers that fail a second pre-deployment check will not be deployed.

Data from temperature loggers that fail second post-deployment checks will be adjusted or rejected based on the following:

- If the difference between the pre- and post-calibration check results for a temperature logger is within the instrument accuracy criteria, then the raw data will be adjusted by the difference between the mean of the pre- and post-calibration check results, and the certified reference thermometer to correct for instrument bias, or
- If the mean difference between the pre- and post-calibration check results is greater than the instrument accuracy criteria, then the raw data results should be rejected.

Sampling bias will be minimized by following the deployment procedures described in the *Continuous Temperature Sampling Protocols for the Environmental Monitoring and Trends Section* (Ward, 2003). These procedures specify site selection and deployment methods designed to ensure that the temperature logger results are representative of the stream throughout the entire deployment period and not biased by solar radiation or low streamflow conditions.

Table 3. Summary of equipment, accuracy, and reporting limits.

Equipment	Accuracy	Reporting Limit
Certified Reference Thermometer/ # 61099-035, HB Instrument Co.	± 0.1 °C	0.1 °C
Field Thermometer/ # 1546RL, Brooklyn Thermometer Co.	± 0.2 °C	0.1 °C
Thermistor Thermometer/ #U-08402 Thermistor & #U-93823 Probe, Cole Parmer Co.	± 0.3 °C	0.1 °C
Temperature Logger/ #TBI 32-05+37 StowAway TidbiT, Onset Computer Corp.	± 0.2 °C	0.1 °C

Sampling Design

Representativeness

Due to limited resources, it is not possible to monitor the difference in stream temperature protocols and instrumentation for all of SHU's monitoring stations. A "sample survey" approach is often used where a complete "census" (e.g., monitoring every station) is not possible. A sample survey approach allows for the estimation of the difference in protocols by making inferences from a defined set of monitoring locations. The level of certainty for these estimates can be described.

Sample surveys rely on the selection of monitoring sites that are representative of the resource. USEPA (1997) describes two sample survey designs: probability-based and judgmental. Both designs use a stratified sampling method so that inferences can be made about other waters that the samples represent, with a known level of certainty. These two types of monitoring designs are described below.

The probability-based design uses monitoring stations that are selected in a statistically random method. Randomization in the site-selection process is the way to assure that sites are selected without bias. The random selection of stations provides that:

- Every possible station (population) has a known probability of being selected for monitoring (sample).
- The set of stations monitored (sample) is drawn by some method of random selection, or a systematic selection with a random start.
- Estimates are made about the population from the sample.

Judgmental design is the other sample survey approach recommended by USEPA (1997). Selection of monitoring locations is based on the best professional judgment that the sites are representative of the target resource (i.e., a subpopulation of surface waters). The method assumes that the stations selected represent all waters in a particular subpopulation. Monitoring station locations from an existing sampling network are periodically reviewed individually to determine the reasons the location was selected. However, there are some deficiencies in the judgmental design:

- The design assumes that stations selected by judgment represent all waters in the watershed.
- Estimates may still be biased due to factors unknown when selecting sites using best professional judgment.
- Complications may arise from unknown geographic features (i.e., surface-to-groundwater interactions) that provide for non-homogenous stream reach temperatures.

Based on an assessment of the advantages and deficiencies of each design, this project will use a judgmental sample survey design for selecting stations for this evaluation. The selection of which streamflow monitoring stations will be evaluated for this project will be based on two criteria:

1. There are acceptable reach characteristics for deploying instruments with the FMU protocols. The water temperature logger deployment location must be safe for staff to work in the stream. Also, the temperature probe must be placed deep enough for stream temperature data to be obtained during lower flows. It is important that the temperature probe is deployed such that it remains submerged during the period of data collection and can be relocated for retrieval.

2. For most of the SHU stations, the slant pipe containing the thermistor probe are deployed into a pool. However, some of the SHU stations may have the slant pipe installed close to the well-mixed channel. Stations with slant pipes installed near the channel will not be selected for this project since there is not expected to be a difference from the deployment site selected using the FMU protocol. Selecting stations where the slant pipe is installed in a pool will allow detection of the greatest possible difference in temperature within a reach when compared to measurements collected in the stream channel by the FMU protocols. Stream temperatures are likely to show the greatest difference between a pool and the stream channel.

The number of stations where temperature protocols is compared will be determined based on available funding, but is expected to be at least 10% of the total number of SHU stations with continuous temperature monitoring. The specific stations that are selected according to the criteria above will be determined when a decision about the available budget has been made by Ecology management.

Comparability

Another objective of this project is to assess the variability of stream temperature data collected by the two instruments used in EMTS. The variability from the comparative difference between the SHU temperature thermistor and the FMU temperature logger (i.e. StowAway TidbiT) will be evaluated. This comparison will be determined by deploying a FMU temperature logger to the end of the slant pipe housing the SHU temperature thermistor. The number of stations where instrumentation is compared will be determined based on available funding, but is expected to be at least 10% of the total number of SHU stations with continuous temperature monitoring.

In addition to the direct testing of the protocols at selected stations, comparable data will be mined from two other programs that use the same protocols (i.e., Schuett-Hames et al., 1999). Research funded by the Salmon Recovery Funding Board conducts continuous temperature monitoring in several intensively monitored watersheds (IMWs) to better understand how salmon and trout respond to current approaches to restore habitat. This project has 13 locations where both temperature monitoring protocols are used in the same reach. Ecology also conducts technical studies across a broad spectrum of temperature-related issues in rivers and streams. Many of these studies monitor temperature at sites selected to support water quality modeling in establishing TMDLs. Currently, these TMDL projects have 51 locations where both temperature monitoring protocols are used in the same reach.

Comparisons will be made of the temperature data collected from both the instruments and the different deployment locations in the reach. The daily maximum temperature recorded will be the metric compared in the analysis.

Precision and bias are the most relevant performance standards for stream temperature measured by different protocols. Precision and bias of different protocols are most often evaluated with side-by-side monitoring to characterize the measurement variability.

Bias will be inferred by the precision statistics of median scaled residual (MSR). This statistic provides a relative estimate of whether a protocol produces values consistently higher or lower than a different protocol.

$$MSR = 100*(P_i - O_i)/(\text{mean } O)$$, where P_i = predictions and O_i = observations

The data quality objective for this statistic will be the same as the acceptable level of measurable change of 0.3ºC as defined by Washington's Water Quality Standards (Chapter 173-201A-200(b)(i) WAC).

Precision among staff will be expressed in two statistics: (1) the relative error, and (2) median absolute deviation (Reckhow et al. 1986).

The relative error (% Error) presents an estimation of variation as a percentage of the measurement mean.

$$\% \text{ Error} = s/(X_\mu * n^{1/2})$$

where,

s = sample standard deviation
X_μ = sample mean of measurements
n = number of measurements

The data quality objective for this statistic will be the same as defined in the SHU Quality Assurance Monitoring Plan at 10% (Butkus, 2005b).

The median absolute deviation (MAD) describes the dispersion of results:

$$MAD = \text{Median of } \{|X_i - X_M|\}$$

where,

X_i = each measurement
X_M = median of all measurements

The data quality objective for this statistic will be the same as the acceptable level of measurable change of 0.3ºC as defined by Washington's Water Quality Standards (Chapter 173-201A-200(b)(i) WAC).

Completeness

Completeness is a measure of the amount of valid data needed to meet the goals defined for the uses of the data. The data collected for this project will be used to (1) assess the quality of the SHU continuous temperature data to meet the purposes of TMDL studies, (2) determine compliance with water quality standards, and (3) conduct trend analyses.

The use of continuous stream temperature data for TMDLs and water quality standards compliance is based on the ability to evaluate the temperature criteria defined by Washington's Water Quality Standards (Chapter 173-201A-200(1)(c) WAC). The temperature criteria established for protection of aquatic life is measured by the 7-day average of the daily maximum temperatures (7-DADMax). Assessing compliance with this standard may require that the 7-DADMax be calculated using the 7-day period that contains the maximum annual stream temperature.

The stream water temperature data collected may have periods of time with data gaps caused by instrument malfunction or from the probe being exposed to air from flows levels dropping below the deployment location. If these data gaps exist, information on air temperature will be obtained from the nearest weather station. If the data gap occurs during the same period as the hottest day of the year, the entire stream temperature data set may not be used for assessing standards compliance. The assumption is that the highest annual stream temperature will coincide with the highest air temperature. This situation may also preclude use of the data set for determining that standards were met. However, if there are other periods of the year that also exceed the 7-DADMax, then the data set may be used for compliance assessment.

Trend analysis is the other purpose being assessed for using the SHU continuous stream temperature data. The Seasonal Kendall's Tau test is the statistical method most often used for evaluating trends when water quality varies by season (Gilbert, 1987). The validity of the test does not depend on the assumption that data observations are normally distributed. Since the test is distribution free, it can be used even if there are missing values. Therefore, any periods with data gaps will not affect the ability to detect trend in stream temperature.

Sampling Procedures

FMU Temperature Instrument Placement

The FMU protocols will follow the procedures described in Ward (2003) and in the TFW Stream Temperature Survey Manual (Schuett-Hames et al, 1999).

Stream temperature monitoring stations must meet the following criteria:

- Be sited in a well mixed location, as close to the thalweg as possible, where temperatures representative of the entire stream may be obtained;
- Be unaffected by groundwater or tributary sources and about 6 inches off the stream bed;
- Be where representative stream temperature data may also be obtained during late summer low flows;
- Be well hidden to prevent loss to vandalism; and
- Be safe to access.

Water and air temperature loggers will be deployed in locations where representative temperature data may be obtained throughout the entire deployment period. All loggers will be deployed inside a 2-2½ piece of 1½ inch, camouflage-painted PVC pipe to shade them from sunlight and to prevent them from being found and vandalized. In addition, each water temperature logger deployment location will be photographed, and site-specific survey information will be documented on a standardized form.

Further, mid-deployment checks of the water temperature logger locations will rely heavily on the temperature and stream height results obtained by staff during ambient monitoring runs. Based on these results, the water temperature loggers may be re-located to a deeper location.

SHU Temperature Instrument Placement

The SHU instrumentation is installed with the flow monitoring equipment when the station is established. Temperature is initially set using the Thermistor Thermometer (i.e., Cole Parmer Co.) as the reference. The stream temperature is also measured using the Thermistor Thermometer during each site visit. These instantaneous temperature readings are recorded in Hydron, but are not used to recalibrate the continuous temperature instrumentation. One of the objectives of this project is to evaluate the need for calibration checks or other quality control procedures in measuring stream temperature with the current SHU protocols and instrumentation.

Site selection is, in most cases, the most important factor in developing accurate flow information. The SHU continuous temperature probes are deployed at the same location as the streamflow instrumentation.

The following characteristics are used to site the location of the SHU streamflow monitoring stations:

1. The stream course should be relatively straight and free flowing for 200-300 feet both upstream and downstream of the measurement site. The sites should be free of excessive turbulence.
2. The stream channel should be free of vegetative growth and be relatively stable (free of major seasonal scouring or deposition of bed material).
3. The steam bed should be relatively uniform with only minor irregularities (no large cobble or boulders).
4. During low-flow conditions (typically Aug-Oct), the stream channel should be confined to a single course.
5. The stream bank should be stable and able to contain the maximum measurable streamflow.

Quality Control Procedures

As noted earlier under the *Data Quality Objectives* section, the accuracy and instrument bias of each FMU temperature logger is verified through both pre- and post-deployment calibration checks following the procedures described in Ward (2003) and Schuett-Hames et al. (1999).

If a recently retrieved FMU temperature logger has a consistent bias of more than 0.2ºC, then the raw data may be adjusted or flagged with an appropriate data qualifier. If the pre- and post-deployment biases are not consistent, then the data may be adjusted or rejected. Finalized station data will be validated by deleting the pre-deployment, post-deployment, and anomalous data from the raw data set.

There are currently no quality control procedures for the continuous temperature data collected with the SHU instrumentation. Continuous temperature data collected by SHU is measured using two types of probes. These instruments are deployed when the stations are first established. The temperature is initially calibrated using a Thermistor Thermometer (i.e., Cole Parmer Co.) as the reference. The stream temperature is also measured using the Thermistor Thermometer during each site visit. These instantaneous temperature readings are record in Hydron, but are not used to recalibrate the continuous temperature instrumentation. One of the objectives of this project is to evaluate the need for calibration checks or other quality control procedures in measuring stream temperature with the current SHU protocols and instrumentation.

Data Management Procedures

The data collected by the SHU protocol are managed in Hydstra®, a commercial database utility designed specifically for the management and analysis of hydrologic data. Manual calibration readings, such as handheld thermistor readings, are entered into the database by the sampler.

Temperature data are collected and imported into the Hydstra® database in two ways. The first is by using GOES equipped stations or Data Collection Platforms (DCP). These stations log data every 15 minutes and then transmit these data via the GOES satellite system in three-hour blocks. These transmissions are received at Ecology Headquarters using an LRGS (Local Readout Ground Station) system. This receiver is located on the roof of the Ecology Headquarters building (Figure 1).

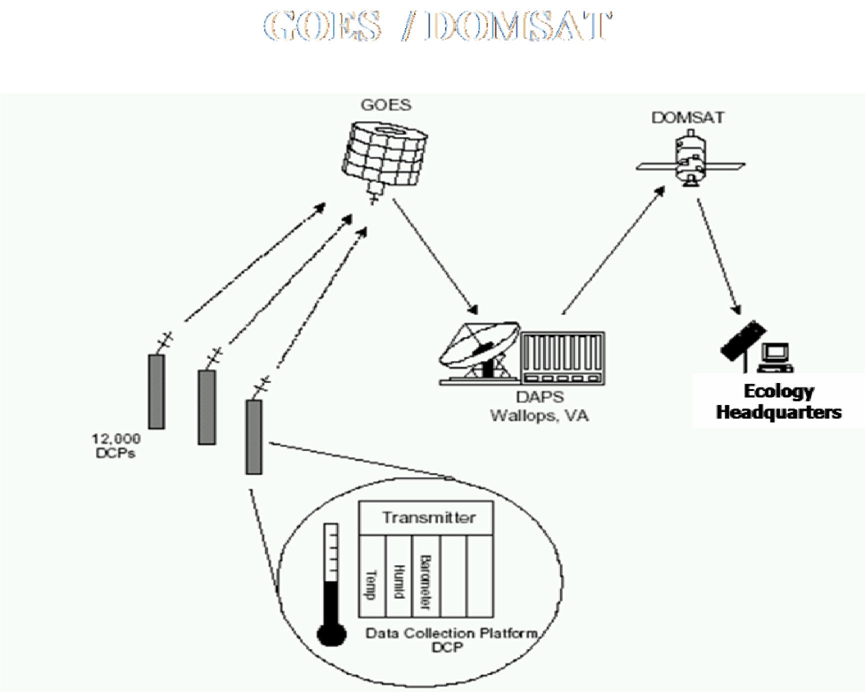

Figure 1. Telemetry Data Flow

At set intervals, the GOES transmissions are processed at Ecology using DECODES, a commercial software package designed by Ilex Engineering to filter and archive raw satellite transmission data. Decoded transmissions are then routed to a raw transmission file where the Hydstra® system processes the files every hour. The real-time web reports seen on the SHU web page are generated using these transmission files.

Data gaps are inherent to remote telemetry data collection. To fill these gaps, a second method of data collection is used. At a minimum of once every four to six weeks, each DCP is visited by staff to download the logger files. Both the GOES-equipped stations and the stand-alone stations are downloaded in this fashion. These logger files are then manually imported into the Hydstra® database, effectively backfilling any data gaps for the GOES-equipped stations and appending new data to the stand-alone station files.

The data collected by the FMU protocol will be reviewed and entered into Ecology's FMU Access® Data Logger Database where results may be exported in Excel® files, text (.txt) files, and plots. The database also enables the exportation of the annual station daily maximum, minimum, and mean data summaries into Ecology's Environmental Information Management (EIM) Database.

Reports

All of the continuous temperature data collected and mined for this project will be compiled. The daily maximum temperature recorded will be the metric compared in the analysis. A final report will be prepared that addresses each of the project objectives:

1. Assess the variability of stream temperature data collected by the two protocols (SHU and FMU) used in the Environmental Monitoring and Trends Section (EMTS).

2. Assess the variability of stream temperature data collected by the two instruments used in EMTS.

3. Evaluate the observed stream temperature variability with the data quality requirements of other programs including water quality standards compliance, TMDLs, and trend analysis.

4. Evaluate the need for calibration checks or other quality control procedures in measuring stream temperature with the SHU protocols and instrumentation.

For each of these objectives, the final report will evaluate both the precision and bias using the statistical data quality objectives defined above.

Data Verification and Validation

The data will be verified and validated by the following procedures:

- Standardized protocols for calibration checks and field procedures will be documented.
- Data will be checked for entry errors and completeness.
- Pre- and post-calibration check results and field measurements will be reviewed to ensure the data quality objectives were met.
- Results will be checked for reasonableness using data plots, field measurements, and stream height/flow information (if available).
- Detected data errors will be corrected, flagged with data qualifiers, or deleted.

Data Quality (Usability) Assessment

The data quality assessment process determines whether monitoring questions can be answered and the necessary decisions made with the desired confidence. The data quality assessment evaluates the usability of the data and describes the graphical and statistical tools that are used to determine if the monitoring objectives have been met. Stream temperature measurements that have met specified measurement quality objectives and passed data validation will be used in the final project report.

The results presented in the report will be useful for several purposes. In particular, the SHU continuous temperature data may be useful for trend analyses, Total Maximum Daily Load (TMDL) studies, and determining compliance with water quality standards. Each of these purposes will serve different clients who will need to assess if the report results serve their particular objectives. Each client will need to determine which conclusions can be drawn from the reported results.

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