iUTAH GAMUT Monitoring Quality Assurance and Quality Control Plan

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1. Overview

iUTAH (innovative Urban Transitions and Aridregion Hydrosustainability) has established monitoring networks in three watersheds in northern Utah: the Logan River, the Provo River, and Red Butte Creek. These networks are intended to monitor Gradients Along Mountain to Urban Transitions (GAMUT) for water resources using a common suite of environmental sensors deployed at terrestrial/climate and aquatic sites. Protocols to ensure that the data are reliable and of high quality are integral to all environmental monitoring, but are particularly important given the geographic scope of the GAMUT network and the broad audience for which the data are intended.

The intent of this plan is to specify and document the practices implemented by iUTAH GAMUT technicians and the iUTAH Cyberinfrastructure (CI) Team and that should be followed to help ensure the data collected is of the highest quality. This plan describes the standardized framework under which GAMUT will operate its baseline collection efforts. Data will be associated with a version of this plan to document the protocol under which they were collected. Subsequent versions of this document will be developed as plans for quality assurance and quality control evolve. The Watershed Technicians are responsible for implementation of the plan, and will review and update the plan every three months in collaboration with the CI Team. The research leads of the GAMUT network should review and approve each major version of the document.

2. Quality Assurance and Quality Control

Campbell et. al (2013) differentiate between quality assurance and quality control of sensor data. *Quality assurance* (QA) refers to a “set of processes or steps taken to ensure that the sensor network and protocols are developed and adhered to in a way that minimizes inaccuracies in the data produced” whereas *quality control* (QC) “occurs after the data are generated and tests whether they meet the necessary requirements for quality outlined by the end users.” In short, quality assurance occurs prior to the collection of the data, and quality control occurs after the data are collected. They also point out that the implementation of QA/QC reduces the need for and expedites post processing.

3. Quality Assurance Plan

Several aspects in the GAMUT network design contribute to quality assurance of the data. These include standardizing the design, sensor selection, programming, and deployment of the monitoring sites to the highest degree possible. Additionally, data management and implementation of CI is standardized across the sites to promote consistent data curation. Other standard quality assurance practices addressed in this document include steps for cleaning, maintenance, and calibration of equipment and sensors.

3.1. Site Standardization

Standardization of monitoring sites helps facilitate comparison, interpretation, and utilization of data. The GAMUT was initially designed to maintain consistency in the type and placement of all sensors installed at a given type of monitoring site (climate or aquatic). Ideally, the location of each site would be such that measurements at the site are representative of a large area (valley scale). This enables more accurate interpolation between sites and minimizes any bias caused by small local climatic features. To this end, efforts were made to position climate stations in open areas and aquatic stations within the main channel flow. However, due to utilization of previously installed equipment, permit requirements, and/or budget constraints, there ended up being some deviations from these standards across sites (Appendix A). To the extent possible, all GAMUT installations include the instrumentation listed in Tables 1 and 2.

Reliable and standardized equipment for supplying power and providing communications also contribute to QA by ensuring that data are consistently collected and streaming to a centralized base station. The power and communications equipment at each site include a battery and power supply regulator, a radio or cell phone modem, a datalogger, a solar panel, and an antenna. The battery, radio or modem, and datalogger are housed in an enclosure that is attached to a mast along with the solar panel and antenna.

ACTIONS:

- When new GAMUT sites are deployed, the Watershed Technicians ensure that instrumentation is as consistent as possible with existing GAMUT sites, described here.
- When a new GAMUT sensor is deployed, technicians coordinate to make installations consistent across networks.

3.1.1. Description of Climate Site and Standard Suite of Sensors

Figure 1 shows a typical GAMUT climate station sensor configuration. Due to anticipated deep snowpacks at some stations and other site specific constraints, sensor heights are somewhat variable between sites. Table 1 shows the range of instrument heights across the all GAMUT climate sites.

Table 1. Standard GAMUT climate sensors

Manufacturer	**Instrument**	**Variables**	**Sensor Placement**
Campbell	HC2S3	Air Temperature/Relative Humidity	2 meters above ground
Apogee	ST110	Air Temperature	2 meters above ground
Campbell	CS106	Barometric Pressure	Inside enclosure
RM Young	5303	Wind Speed/Direction	5-7 meters above ground
Geonor	TB-200	Precipitation	~1 or 2.5 meters (2 pedastal options) above ground**
Judd Communications	Depth Sensor	Snow Depth	2 to 4 meters above ground**
Hukseflux	NR01	Incoming and Outgoing SW and LW	2 to 4 meters

		Radiation	above ground**
Apogee	SP-230	Incoming SW Radiation	2 to 4 meters above ground**
Apogee	SQ-110	Incoming and Outgoing PAR	2 to 4 meters above ground**
Apogee	SI-111	Surface Temperature	2 to 4 meters above ground**
Acclima	ACC-SEN-SDI	Soil Moisture, Temperature, Conductivity	5 cm, 10 cm, 20 cm, 50 cm, 100 cm* below ground
Campbell	CS210	Enclosure Humidity	Inside enclosure
Campbell	18166	Enclosure open door sensor	Inside enclosure

*Bedrock conditions at some sites preclude the installation of a sensor at 100 cm. At these sites, the "100 cm" sensor is installed as deep as possible.
**The height of installation is based on the anticipated depth of snow accumulation.

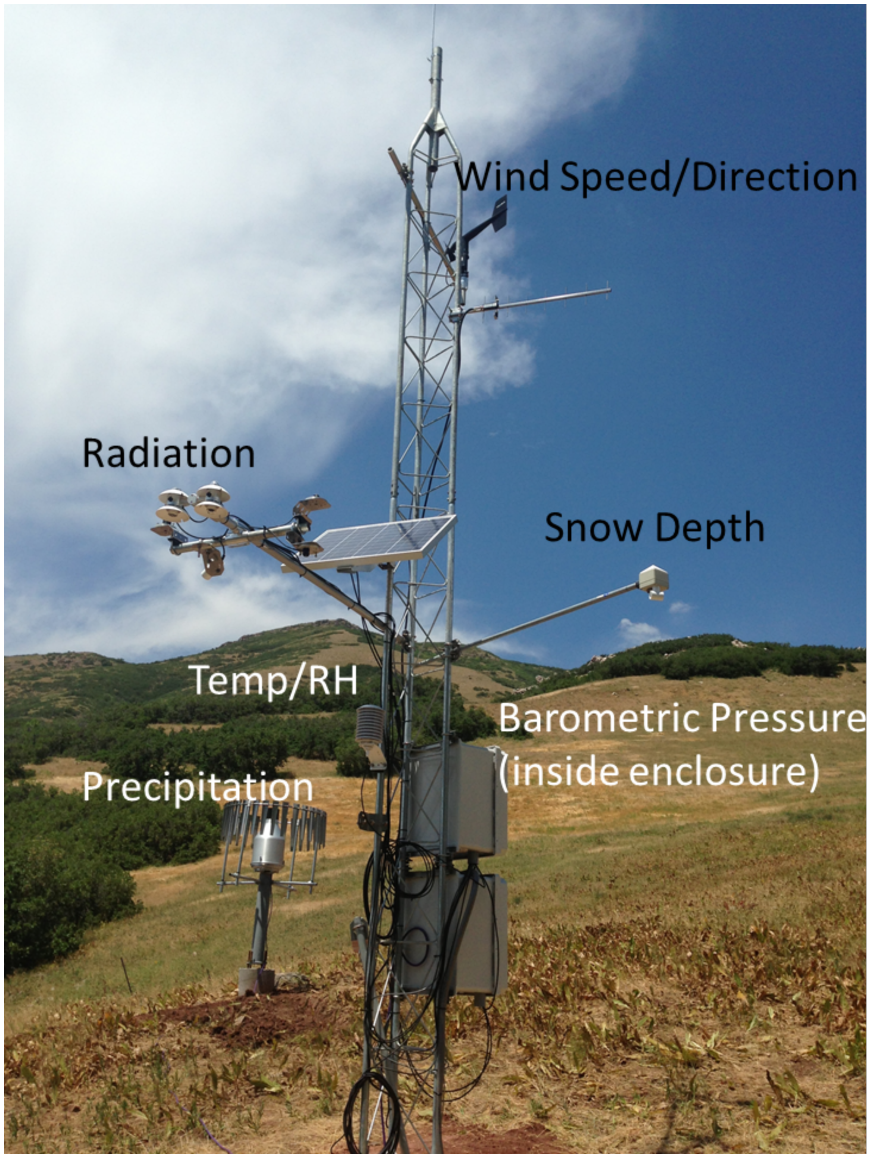

Figure 1. Photograph of typical GAMUT climate station.

3.1.2. Description of Aquatic Site and Standard Suite of Sensors

Due to highly variable site conditions across the three GAMUT watersheds, there is no “standard” sensor mounting configuration for aquatic sites. Efforts were made to ensure that sensors were deployed in the main channel of flow, in uniform flow without excessive turbulence, and where sensors would not go dry. There is however, a standard suite of sensors at all sites across the GAMUT network (Table 2). Deviations from this standardized set of sensors are detailed in Appendix A.

Figure 2 shows an example aquatic site from the Red Butte watershed. At all sites, sensors are housed in ABS pipes that extend into the river. The YSI EXO sonde housings terminate in pump screens or a 4” ABS pipe cap with holes drilled into the bottom. The turbidity sensor housings terminate in pump screens with the bottom removed. Pressure transducer housings terminate with bolts extending through the diameter of the pipe to stop the sensor. Some sites employ hose clamps to secure pressure transducers to the pipes. Most sites also have stage plates installed that are used to manually read and record the water level.

Table 2. Standard GAMUT aquatic sensors

Manufacturer	**Instrument**	**Variables**	**Site Type**
YSI	599100-01	Dissolved Oxygen	Basic/Advanced
YSI	599870-01	Specific Conductivity - Water Temp.	Basic/Advanced
YSI	599795-02	pH	Basic/Advanced
YSI	599101-01	Fluorescent Dissolved Organic Matter (fDOM)	Advanced
YSI	599102-01	Blue Green Algae - Chlorophyll *a*	Advanced
Campbell	CS451	Water Depth	Basic/Advanced
FTS	DTS-12	Turbidity	Basic/Advanced

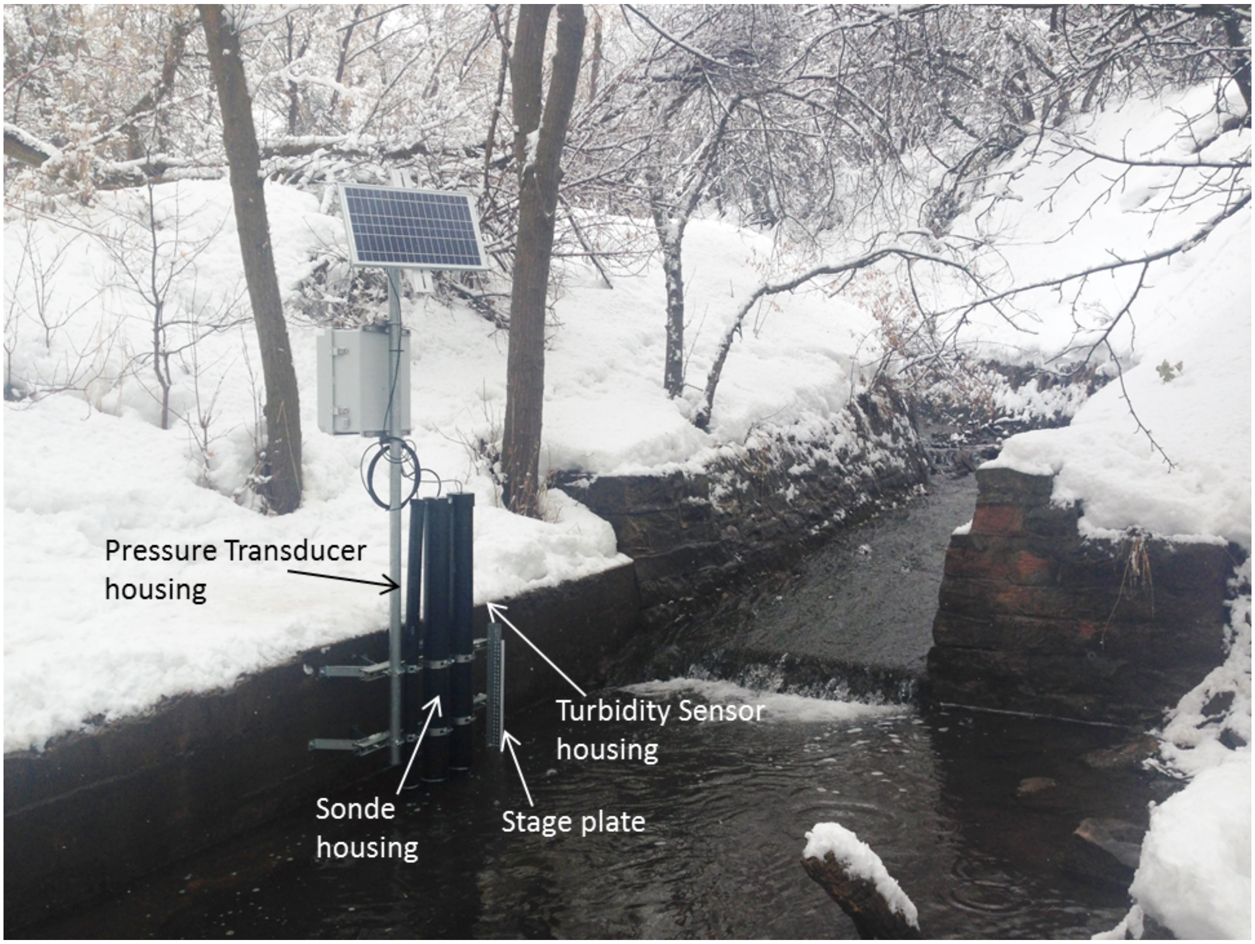

Figure 2. Example aquatic station configuration.

3.2. Data Curation: Datalogger Files/Programs

Datalogger programs have been standardized between sites and across the three GAMUT watersheds to the extent possible to ensure that the code and methods used to generate data are consistent. There are site specific components to each program (such as site identifiers and sensor calibration coefficients), but the baseline versions are the same between sites of the same type. Aspects of datalogger programs that facilitate data curation include: semantic consistency of variable names between sites, consistent averaging methods for the same variables, designation of constant variables/offsets in a constants table specific to each site, archival of datalogger programs with associated change logs housed on the iUTAH CloudShare, and archival of datalogger files with associated date ranges housed on the iUTAH CloudShare.

Raw data from each monitoring site are downloaded from remote sites on a regular schedule using Campbell Scientific's Loggernet Software and are stored in comma delimited files on the Loggernet Server using Loggernet's native data format. Loggernet appends new data to the end of each datalogger logger file each time a station is polled for new data. The Loggernet Server machine is backed up with an incremental daily backup and a full backup weekly to offsite storage. Datalogger files are backed up as part of this process. Additionally, datalogger files are archived each time a change to the datalogger table definitions is made (e.g., when a new datalogger program is sent to the datalogger) or at least annually (a new data file is created at the beginning of each year).

Protocols have been developed for uploading new datalogger programs to remote monitoring sites in efforts to minimize the loss of data and to ensure that old versions of datalogger files are archived and can be matched to the data collected using each program version (Appendix B). There are two types of changes to datalogger programs that could be executed:

1. In some cases, changes will be made to the programs for testing by the iUTAH Watershed Technicians. So long as these changes do not have a direct effect on the measurement sequences or output tables, the change can be implemented by the technician following the procedures put in place by the iUTAH MDF Data Manager.
2. When a broad change needs to be implemented, as agreed upon by a majority vote of the Watershed Technicians, a simultaneous upgrade to a new version of the program at all GAMUT sites will be performed in coordination with the iUTAH MDF Data Manager.

ACTIONS:

- The Watershed Technicians are responsible for maintaining and updating the datalogger programs and change logs on the iUTAH CloudShare whenever a new program is deployed to a site.
- The Data Manager is responsible for archiving datalogger files to iUTAH CloudShare whenever a new datalogger file is generated.
- The CI Team is responsible for the archival of datalogger files on the server.
- Updates to datalogger programs are initiated by Watershed Technicians when a change is required, and execution is coordinated between the Watershed Technician and the CI Team.

3.3. Data Curation: Data Processing by the Sensor or the Datalogger

All measured variables are considered continuous functions of time and each GAMUT site uses discrete samples in attempt to capture the behavior of the continuous variable. To do this accurately requires knowledge of how the instrumentation behaves in both static and dynamic conditions as well as signal processing theory (Brock et al. 2001, WMO 2010). A casual comparison between projects similar to the GAMUT network (Little Bear River Research Watershed, USU Climate Network) reveals that there is little standardization of sampling rate and averaging methods, which appear to be somewhat arbitrary and based on researcher experience and intuition. A comprehensive investigation of measurement methods has yet to be undertaken and the present measurement procedures currently employed by the GAMUT network are based on a mixture of WMO recommendations, manufacturer settings, power requirements, and researchers' intuition. Nonetheless, consistent measurement procedures are followed between sites. See Appendix C for the current measurement plan.

There are several sensors that include internal processing prior to the reporting of values. The FTS DTS-12 sensor makes 100 instantaneous readings over 5 seconds and reports a suite of output values (median, minimum, maximum, variance, etc. of the 100 values). The YSI EXO sonde also performs internal processing prior to reporting a value as follows: after the central wiper has wiped the sensors, multiple readings are made by each sensor and rolling averages are computed. When the data are considered stable, a value is reported. Because stabilization occurs differently for each sensor, the total internal processing time will vary. However, this process is usually completed within 14 seconds after the wiping occurs.

For other sensors, averaging has been incorporated in the datalogger programs for some variables to minimize spurious data points and capture conditions over the measurement recording interval. In general, data values are obtained by making measurements every 10 seconds and reporting the average every 15 minutes. For some sensors (pressure transducers, snow depth sensors, soil moisture sensors, precipitation gages), the persistence of anomalies necessitated the implementation of of burst-style sampling on the datalogger (Appendix C). Averaging periods and methods may be further adjusted, which will be documented in the datalogger change logs.

ACTIONS:

- When new GAMUT sites are deployed, the Watershed Technicians ensure that the measurement plan is consistent with other GAMUT sites.
- When a new GAMUT sensor is deployed, technicians coordinate to make the method of measurement consistent with other sensors and between sites.
- Measurement sequences at each site are only changed during program updates following the workflow documented in Section 3.3 (Data Curation).

3.4. Data Curation: Operational Databases

Cyberinfrastructure has been deployed to support the curation of streaming sensor data and to make it available on the Internet. The Observations Data Model (ODM), a community standard for hydrologic data storage and retrieval (Horsburgh et al., 2008), has been implemented for the GAMUT data. Data stored according to ODM are housed in relational databases at the single observation level with complete metadata. ODM databases promote semantic and syntactic consistency and facilitate cross-dimension retrieval and analysis. Data are imported into the ODM databases (one for each watershed) using the ODM Streaming Data Loader, a program that runs on the Loggernet server and is administered by the CI Team. The Streaming Data Loader is modified when changes are made to datalogger programs as specified by the workflow in Appendix B so as to maintain continuity in and availability of the data.

ODM databases house the raw data collected at GAMUT sites as well as higher level data products generated in post processing. Note that as data products are created, the raw data are always retained. The performance of any data edits results in a new versions of the data series. The database server on which the databases are hosted and the database files themselves are backed up regularly to offsite storage as part of the iUTAH server backups.

ACTIONS:

- The Data Manager will create the metadata for new sites and new sensors in the ODM databases.
- The Data Manager will map data files and ensure the proper scheduling and execution of the Streaming Data Loader.

3.5. Equipment Management Database and Website

To support quality assurance in the GAMUT network, the CI Team has developed and implemented a database and website to track equipment, deployments, and other events related to field equipment and site maintenance. The GAMUT technicians have access to the website (http://data.iutahepscor.org/gamutmanagment) to add and edit equipment, sites, site visits, field activities including deployments, calibrations, and cleaning. The interface can be used to address questions such as what sensors are deployed at a site, the deployment history or factory service history of a sensor, and the history of field activities performed at a site.

ACTIONS:
- The Watershed Technicians will record and input data related to equipment, site visits, deployments, calibrations, and other maintenance actions using this website on a regular basis. At minimum, site visits and field activities should be updated monthly.
- The CI Team will respond to issues with and provide support for the site.

3.6. Replicate Sensors

According to Campbell et al. (2013), the best practice for maintaining quality assurance is the deployment of replicate sensors. While this practice is cost prohibitive for most of the variables being monitored at GAMUT sites, there are replicate sensors deployed for air temperature, water temperature, and incoming shortwave radiation. Additional sensors are also necessary to perform checks on field sensors (Wagner et al., 2006) and for the replacement of sensors in the case of factory or lab maintenance. As of Version 1.0 of this document, there are limited spare sensors in the GAMUT network, so plans to need to be established to address these eventualities.

ACTIONS:
- The Watershed Technicians will determine options for acquiring spare sensors for performing field checks and in the case of sensor replacement.

3.7. Factory Maintenance Schedule

Several of the sensors in the GAMUT network recommend regular factory maintenance, as detailed in Table 3. Whether factory maintenance will be conducted with the recommended frequency is yet to be determined, and might vary for each sensor model. Budget constraints, the quality of the data without factory service, and the amount of lost data will need to be considered by the Watershed Technicians and the GAMUT research leads in making decisions about factory service frequency.

Table 3. Climate/Aquatic Station Sensor Recommended Factory Service

Sensor	**Variable**	**Recommended Factory Service**	**Notes**
FTS DTS-12 Turbitty	NTU	1 year $500/sensor	
YSI EXO pH Head	pH	1 Year $170/sensor	Replace when the sensor no longer gives reliable data.
SUNA Nitrate Sensor**	NO_3	1 Year $1270/sensor	
HC2-S3	Temp/RH	1 year $120/sensor	Expect 1% per year drift for RH. These sensors will drift more in high humidity areas than low humidity areas.
CS106	Pressure	1-2 years	CSI may start re-calibrating in-house soon. This would result in

		$220/sensor	cheaper price.
CS210	Enclosure Humidity	N/A	Replace every 3-5 years.
NR01	4 component radiation	2 years. $750/sensor	
5305	Wind	N/A	
SP-230	Incoming SW radiation	2 year $50/sensor	
SQ-110	PAR	2 year $50/sensor	
SI-111	Surface temperature	2 year $100/sensor	
Judd Depth Sensor	Snow Depth	N/A	
TB-200	Precip	When needed $250/sensor	
CR800/ CR1000	Datalogger	3 years $250/logger	Internal Li Ion battery good for ~10 years. Recalibration ~$40 cheaper if documentation is not required.
CR3000	Datalogger	3 years $305/logger	Internal Li Ion battery good for ~10 years. ~$40 cheaper if documentation is not required.
ACC-SEN-SDI	Soil Moisture	N/A	Replace when necessary.

*Recalibration prices current as of Febuary, 2014
**As of version 1.0 these sensors are not yet deployed.

When a sensor is retrieved and sent to the factory for maintenance, these steps will be followed in attempt to maintain the output of high quality data:

1. Retrieve a sensor for servicing
2. Deploy a back up sensor (when possible)
3. Take notes detailing the retrieval and deployment
4. Record the retrieval, deployment, and factory service details on the equipment management website

ACTIONS:

- Watershed Technicians will observe sensors and data to help determine whether factory maintenance should be performed according to the recommended schedule. Decisions will be made in consultation with the GAMUT research leads.

3.8. Field Maintenance Schedule and Procedures

3.8.1. Climate Sites

Climate sites are mostly autonomous and require relatively little regular maintenance, though regular visits will be made to ensure that sensors are undisturbed and collecting data. Table 4 outlines recommended routine maintenance for sensors deployed at climate sites.

Table 4. Climate Station Sensor Maintenance Recommendations

Sensor	Variable	Regular Maintenance
HC2-S3	Temp/RH	Replace corroded, discolored, or clogged filters when necessary.
CS106	Pressure	Clean external case with damp lint-free cloth if necessary.
CS210	Enclosure Humidity	
NR01	4 component radiation	Periodically clean dome with water/alcohol, inspect dome for condensation, perform instrument inversion test.
5305	Wind	Monthly visual/audio inspection. Check to ensure that propellor is spinning freely and no snow/ice buildup has occurred. Replace bearings in field about every 5-6 years if noisy or low wind speed threshold is unacceptable. Propellor $8.64 x 2. Vertical shaft 31.90 x 2.
SP-230	Incoming SW radiation	Periodically clean dust/organic deposits with water or alcohol.
SQ-110	PAR	Periodically clean dust/organic deposits with water or alcohol.
SI-111	Surface temperature	Apply spider repellent to entrance of sensor annually. Clean dust and dirt with cotton swab and alcohol when necessary.
Judd Depth Sensor	Snow Depth	Check desiccant pack inside sensor when sensor is opened. NOTE: manufacturer does not recommend opening sensor. Check for insects in solar radiation shield.
TB-200	Precip	Service whenever bucket needs to be emptied, or at least 2 times/year. See section 3.9.1.2 for more detail.
CR800/ CR1000	Datalogger	

CR3000	Datalogger	
ACC-SEN-SDI	Soil Moisture	Replace when necessary.

ACTIONS:

- At a minimum, all climate sites should be visited every two months for cleaning and maintenance. The field checklist in Appendix D will be followed for each visit.
- For all site visits, field notes should be completed and information about the visit then transferred to the Equipment Management website.
- Snow removal will be performed as-needed in the winter (Section 3.8.1.1).
- Maintenance will be performed on Geonor precipitation gages at least every six months (Section 3.8.1.2).

3.8.1.1. Snow Removal

During the winter, there will periodically be the need to clear the solar panels and radiometers of snow. This should be detectable by monitoring the weather, station power, and incoming shortwave radiation measurements and should be performed as soon as is practical following storm events. Detailed notes should be kept about timing of snow removal from radiometers and solar panels, as radiation data can be impacted by snow accumulation on the sensors. Experience and power budgeting indicates that stations should be fully functional for 7-10 days when solar panels are covered with snow.

3.8.1.2. Geonor Maintenance

Geonor precipitation gauges require routine maintenance that should be performed when buckets need to be emptied, or at least twice per year. See Appendix E for details.

3.8.1.3. Other maintenance tasks

- Periodically clean solar panels to remove dust buildup.
- Check level of radiation sensors and precipitation bucket. Adjust as necessary.
- Cut down vegetation under snow depth sensors prior to first snowfall.
- Change desiccant packs when enclosure relative humidity is >40%.
- Spray WD-40 in locks annually.
- Change signage when necessary.

3.8.2. Aquatic Sites

Aquatic stations require regular calibration and cleaning. This should be performed no less than monthly, and ideally at two week intervals based on the practices of similar monitoring networks and the necessary frequency for sonde calibration. More frequent site visits should be implemented if the monitoring of site data reveals issues that should be addressed (Wagner et al, 2006). Site visits include sensor cleaning and calibration and monitoring for ice buildup, debris buildup, and extreme low or high water levels. On a longer time scale, the station discharge rating curve will need to be monitored for stability.

Table 5. Routine Aquatic Sensor Maintenance Recommendations

Sensor	Variable	Regular Maintenance
FTS DTS-12 Turbidity	NTU	Inspect wiper blade and replace if necessary.
YSI EXO pH Head	pH	Replace when the sensor no longer gives reliable data.
SUNA Nitrate Sensor**	NO_3	

ACTIONS:

- Watershed Technicians will visit aquatic sites monthly, at a minimum.
- Regular cleaning and inspection will be performed for each site visit (Section 3.8.2.1).
- Deep cleaning will be performed as needed, at least every 6 months (Section 3.8.2.2).
- Stage will be recorded for each site visit (Section 3.8.2.3).
- The turbidity wiper blade and pressure transducer desiccant will be checked every visit and replaced as needed (Section 3.8.2.4 and 3.8.2.5).
- A baseflow discharge measurement will be established prior to 2014 spring runoff at each site (Section 3.8.2.7).
- For all site visits, field notes should be completed and information about the visit then transferred to the Equipment Management website. Details regarding what should be included in aquatic station field notes are included in Appendix D.

3.8.2.1. Regular Cleaning

Regular cleaning should be performed for every site visit. The EXO Sonde and turbidity sensor should be pulled and rinsed. A bucket of river water can be used to clean the sensors. Clean between the sensors on the sonde, but do not pull the individual sensors apart or force anything between them. The sensor housings should be checked for accumulation of leaves or debris. The pressure transducer should NOT be pulled for cleaning unless there is reason to suspect serious build-up of sediment of biological matter. If the pressure transducer must be pulled, the steps in Appendix G should be followed.

3.8.2.2. Deep Cleaning

Several times each year, the probe housings and pump screens will need to be scrubbed to remove sediment and biological growth. This is most effectively done by removing the entire probe housings from the mounting structure, and scrubbing with wire brushes. If the pressure transducer housing is removed, care should be taken to replace it in the same position so that the datum is unchanged. Notes should also be made that it was removed and may have shifted.

3.8.2.3. Stage Reading

At all sites with a stage plate, the stage should be read and recorded on the field sheet along with the date and time each time the site is visited. Stage should be recorded with a precision matching that of the stage plate markings.

3.8.2.4. Turbidity Wiper Blade

The turbidity sensor wiper and wiper blade should be checked every site visit. The blade needs replacement when the blade becomes cracked or damaged. Cracks can be observed in the blade itself and will also be evidenced by streaks across the sensor face. The wiper blade is changed by loosening the thumbscrew to remove the entire wiper arm, then removing and replacing the rubber blade. If serious damage or corrosion is evident on the wiper arm, it may need replacing also. Replacement of the wiper blade or wiper arm should be noted in the site visit notes on the field sheet.

3.8.2.5. Pressure Transducer Desiccant

The pressure transducer has a tube of desiccant beads attached to the end of the cable in the enclosure. The desiccant will turn from blue to pink/purple when exposed to moisture and should be changed periodically. To change out the desiccant, use a spare tube and fill it with loose desiccant and remove and replace the entire tube of desiccant. Alternatively, unscrew the top of the deployed tube and replace desiccant in the field. The expired beads inside of the tube can be discarded or re-generated. Replacement of the desiccant tube should be noted in site visit notes.

3.8.2.6. Other Maintenance Tasks (CHRIS)

- Clean solar panels
- Swap enclosure desiccant

3.8.2.7. Discharge Measurements

Establishing a robust relationship between stage and discharge at each GAMUT aquatic site will require the development of detailed plans for measurement, maintenance and evaluation of stage-discharge data. This will be accomplished in subsequent versions of this document. Initially, baseflow measurements should be conducted at all sites using standardized methods. Initially, water surface elevations and stage plate locations will be surveyed concurrently with discharge.

3.9. Field Calibration Schedule and Procedures

Several of the aquatic sensors are subject to drift that needs to be addressed by regular calibration. All of the calibration is performed on the YSI EXO sondes, and details can be found in the manual (Xylem, 2012). Steps are specified in Appendix E to provide complete documentation. Calibration is performed for DO, SC, pH, fluorescent dissolved organic matter (fDOM), blue-green algae and Chlorophyll (total algae). In general, these calibrations are performed on-site, in the field. Calibration criteria are adapted from Wagner et al. (2006). Note that calibrations as well as materials and standards used for calibration should be recorded on the field sheet and then entered into the Equipment Management website. Calibration will be conducted with at least monthly frequency under Version 1.0 of this document. The project will move to bi-weekly calibration as soon as is feasible.

ACTIONS:

- Watershed Technicians will perform calibration checks and calibrations if needed at aquatic sites monthly, at a minimum.
- Calibrations will be recorded in field notes and then transferred to the Equipment Management website.

3.10. Visual Data Monitoring

An important component of quality assurance for sensor data is actively monitoring the streams of data being collected. Incoming data from all sites will be visually checked every other day by the GAMUT technicians using ODM Tools (http://his.cuahsi.org/odmtools.html, https://github.com/UCHIC/ODMToolsPython) or a similar software application. The data will be assessed following the workflow below.

Workflow

1. Perform visual checks data every 2-3 days. When this cannot be achieved due to sickness, vacation, etc., a technician from another watershed may fill in as needed.
2. Identify problems and QA/QC issues and document in Monitoring Log.
3. Prioritize and track problems.
4. Address problems based on priority in relation to other GAMUT tasks.

Visual Monitoring Checklist

This table describes what to look for during visual checks. Initially this will require experience and could be somewhat subjective. In later versions of the QA/QC plan, there will be more rigorously defined pass/fail criteria.

Item	Description	Variables
Range	Physically believable values (based on experience)	All variables
Internal Consistency	Similar values for sensors measuring the same variable	Air temperature, water temperature, sensor body temperature, solar radiation
Spatial Consistency	Measurements are consistent between sites where applicable	Upstream vs downstream discharge, General weather patterns, Typical elevation differences
Persistence/Slope	Changes in values are typical (spikes vs flatline)	All variables
Physical Consistency	Values should be consistent with physical processes	Snow surface temperature (< 0), Soil temperature follow typical 1d heat transfer
Equipment Considerations	Monitor status of equipment	Minimum water depths, Geonor bucket capacity and antifreeze mixture

Monitoring Log

The monitoring log is not yet standardized, but whatever system is used should have the following characteristics (See example in Appendix F):

- QA/QC notes - Document any issues related to QA/QC. This could include increased drift or noise, changes in offsets, or unusual spikes. These notes will be used later for flagging or QC operations.
- Problems - Document and track the status of problems such as broken sensors or equipment in need of adjustment.

Prioritization

Problems will be addressed according to their priority level as determined by the Watershed Technician. The following framework will be used for determining priority:

Priority Level	**Description**	**Timeframe for addressing**	**Example**
Urgent	Problem immediately affects key data	Day	Loss of power
High	Problem has minor effects on data	Week	Calibrations
Medium	Problem will eventually affect data	Weeks	Cleaning
Low	Unlikely to have effect on data	Months	Desiccant change

ACTIONS:

- Watershed Technicians will review data and perform the above checks every 2-3 days.
- Watershed Technicians will maintain a “Monitoring Log” to document and prioritize observed issues at each monitoring site.

3.11. Data Checking: Automated Alerts

In order to identify potential issues in data streams occurring between regular visual checks of the data and to eventually reduce the required frequency of visual checks, the CI Team has deployed automated alerts. The alerts are implemented on the ODM databases in SQL Server and send email notifications to the appropriate Watershed Technician when data screening criteria are not met. Current data screening rules include:

- Check Battery: Battery voltage should be above 12 volts. This ensures that the site has adequate power and that the solar panel is functional.
- Check NANs: Reports if there are more than ten NAN/-INF values (i.e., no data values). This helps verify that sensors are collecting valid data.
- Check Repeats: Reports if there are more than fifteen consecutive unchanging values. This check also helps verify that sensors are collecting valid data as persistence can indicate a sensor malfunction.
- Check Latest: Data values should be reported within 24 hours. This checks that there is communication with a site and that all sensors are reporting values.

Additional rules will be implemented as technicians identify conditions for which they wish to be notified (e.g., range checks, rate of change checks, checks for internal and external consistency).

ACTIONS:

- The Data Manager will create automated alerts on the SQL Server and ensure that they are delivered to the Watershed Technicians on a daily basis.
- The Watershed Technicians will review the automated alerts daily to determine whether action needs to be taken or if records should be made in the “Monitoring Log”.
- The Watershed Technicians will determine the desired rules for additional alerts.

3.12. Recording Events: Equipment Management

In order to prepare for post-processing of raw sensor data, records of events that may impact data values are being tracked in the Equipment Management website and database. These events include site visits and calibrations, but significant events also include environmental phenomena such as weather events, very low or very high water levels, dam releases, canal openings/closures, etc. Any events that may affect data quality should be recorded in the field sheets for each site visit and transferred to the Equipment Management database for later comparison with the data streams. Campbell et al. (2006) point out that it is crucial to record events in order to assist in identifying (or potentially disproving) that data are inaccurate.

ACTIONS:

- Watershed Technicians will record significant events/issues to the Equipment Management website at least monthly.

4. Quality Control and Post Processing Plan

QC consists of procedures that are implemented to identify and/or correct inaccurate data. Automated QC procedures are under development by the CI Team, and will primarily consist of automated flagging of data for subsequent review by GAMUT technicians. They will be based on rules determined by the GAMUT technicians, and may reflect the criteria implemented for automated alerts.

After the implementation of QA and based on the results of QC, there may be data that need to be adjusted (e.g., in the case of drift corrections) or even removed from the quality controlled data record. This will be performed in post processing, as may be the derivation of new data products from the raw data. In general, the Watershed Technicians will perform the post processing steps using tools developed and supported by the CI Team. The iUTAH Data Policy specifies that post processing of data products to be published within the iUTAH MDF will be completed within six months of data collection. As the GAMUT network is still under development, the goal for completion of post processing of initial GAMUT data is July 1.

The variables for which data edits will be performed and for which additional data series will be derived are listed in Table xx. When known, the specific steps or algorithms are specified. In general, ODM Tools Python will be used to generate QC1 from QC0 data series.

Variable	Data Product
AirTemp_avg	QC1
RH	QC1
DewPt_avg	QC1
VaporPress_avg	QC1
BP_avg	QC1
WindSp_avg	QC1
WindDir_avg	QC1
WindDir_std	QC1
Precip_tot	QC1
JuddDepth	QC1
SWIn_NR01_avg	QC1
SWOut_NR01_avg	QC1
LWIn_Cor_NR01_avg	QC1
LWOut_Cor_NR01_avg	QC1
NetRad_NR01_avg	QC1
	Albedo using outgoing shortwave and incoming shortwave radiation
PARIn_avg	QC1
PAROut_avg	QC1
TargTemp_SI111_avg	QC1
VWC_5cm_avg	QC1
SoiTemp_5cm_avg	QC1
SoilCond_5cm_avg	QC1
Permittivity_5cm_avg	QC1
VWC_10cm_avg	QC1
SoiTemp_10cm_avg	QC1
SoilCond_10cm_avg	QC1
Permittivity_10cm_avg	QC1
VWC_20cm_avg	QC1
SoiTemp_20cm_avg	QC1
SoilCond_20cm_avg	QC1
Permittivity_20cm_avg	QC1
VWC_50cm_avg	QC1
SoiTemp_50cm_avg	QC1
SoilCond_50cm_avg	QC1
Permittivity_50cm_avg	QC1
VWC_100cm_avg	QC1
SoiTemp_100cm_avg	QC1
SoilCond_100cm_avg	QC1
Permittivity_100cm_avg	QC1
WaterTemp_EXO	QC1
SpCond	QC1
pH	QC1
ODO	QC1
ODO_Local	QC1
TurbMed	QC1
Stage	QC1
	Discharge using site specific stage-discharge relationships
BGA	QC1
Chlorophyll	QC1
fDOM	QC1

4.1. Flagging and Qualifiers

Flags, or data qualifiers, may be used to provide annotations or descriptions about each data point. For Version 1.0 of this document, there are no specific data flags implemented for the GAMUT data, but details will be included in subsequent versions. Also, as automated QC develops, qualifiers will be implemented to automatically identify suspect data. Other purposes of flags include indicating whether a data point was estimated or if it is uncertain due to some environmental condition, spatial inconsistency, or internal inconsistency. Flags may also be applied manually and retroactively as the technicians perform post processing of their data, and flags should be used to qualify data points been subject to processing steps requiring annotation (e.g., interpolation).

ACTIONS:

- The CI Team will work on the implementation of automated flagging.
- The Watershed Technicians will determine the rules to guide automated flagging.
- The Watershed Technicians will compile a list of qualifiers to be used for flagging data.

4.2. ODM Tools Python

ODM Tools Python (https://github.com/UCHIC/ODMToolsPython) is a software application currently under development by the CI Team. It allows data managers to query and export, visualize, and perform QC editing of data stored in an ODM database. The program features tools for tasks such as interpolating missing or erroneous data points, filling data gaps, performing linear drift corrections, and functions for deriving new data series from existing data series. User-defined functions can also be implemented. Important functionality includes the automated scripting of edits to ensure that editing steps are traceable and reproducible.

ODM Tools Python will be used by the Watershed Technicians to perform QC post processing edits on the sensor data streams. Note that the term 'editing' is used to refer to data corrections, but all edits will be performed on a copy of the raw data. The original, raw data will always be retained. The script generated by ODM Tools will serve as the record of all edits made to the raw data and can be executed at any time to regenerate the quality controlled dataset.

ACTIONS:

- The CI Team will provide training and support for the use of ODM Tools Python.
- The Watershed Technicians will implement post processing using ODM Tools Python at least every three months. Post Processing should be completed six months after the collection of the raw data. The steps described in this plan will be followed.

4.3. Quality Control Levels

In the ODM semantics, "data series" are assigned "quality control levels" by a technician or data manager. The raw data streaming from the sensors are quality control level 0 (QC0) data. For the variables of interest, data series that have been reviewed, have corrections applied, and are approved by the GAMUT technicians are designated as quality control level 1 (QC1). As the Watershed Technicians perform post processing, intermediate quality control levels may be used as steps to achieve QC1. Steps for data processing are described in Section 4.4. As the project evolves and the GAMUT data are more broadly used, additional quality control levels may be employed. Proposed quality control levels are:

- Quality control level 0: Raw and unprocessed data that have not undergone quality control.
    - QC 0.1: Automated checks and automated flagging applied.
    - QC 0.2: Obvious out of range values removed.
    - QC 0.3: Periods of erroneous data removed.
    - QC 0.4: Linear drift correction applied.
    - QC 0.5: Data gaps filled
    - Final step: Sanity and visual checks performed and additional annotations added (events, comments, etc.)
- Quality control level 1: Quality controlled data that have passed QA/QC procedures such as sensor calibration and visual inspection and removal of obvious errors. These data are approved

by Technicians as the best version of the data.

- Quality control level 2: Derived products that require scientific and technical interpretation and may include multiple-sensor data (e.g., discharge derived from stage, basin-average precipitation derived from multiple rain gages).
- Quality control level 3+: Higher level data products involving analysis and interpretation.

4.4. Data Processing

Wagner et al. (2006) specify that data corrections should not be made unless the source of error can be explained by the field notes or data from other stations or other variables. Note that complete and accurate field notes are essential to performing the quality control steps. It is also often helpful to check for internal consistency (related variables at the same site) and external consistency (same variable at different sites) when there are questions regarding phenomena in the data. More guidance for specific variables and sites will be developed in subsequent versions of this document. Because ODM Tools Python includes Python scripting of the steps to correct errors, all changes between QC0 to QC1 data will be recorded. Technicians should also record annotations in a document or as comments in the Python scripts to reflect why corrections were made.

The process of achieving QC1 from QC0 will depend on the variable, and will likely evolve in subsequent versions of this document. At the most basic, data series will be visually reviewed by technicians to ensure that the data reflects site conditions and is the best approximation of accurate data available. Steps that are more involved for achieving QC1 will require several iterations of data review, some of which are detailed below. Additional steps may be implemented in subsequent versions of this document as familiarity with the sensor data develops.

4.4.1. QC 0.1: Automated Checks and Flags

See Section 4.1. This functionality is still under development.

4.4.2. QC 0.2: Removal of Out-of-Range Data Values

Anomalies may consist of data values outside of the expected measurement bounds for an instrument at a site during a time period. Anomalous data values will be identified as Technicians make visual inspections of the data and by using the threshold filters in ODM Tools Python. Options for addressing anomalous values include:

- Linear interpolation for short periods of anomalous values. The Technicians and GAMUT leadership need to determine the maximum acceptable gap for linear interpolation. This may be variable-specific.
- Deletion if the period of anomalous values is greater than what is acceptable for linear interpolation.
- Another correction method determined for that particular time period and particular variable. These may include estimates based on historic data, relationships with other stations or model results (Campbell et al., 2006). At this point, it is not foreseen that the GAMUT Watershed Technicians will perform this step, but it may be important to other researchers trying to fill gaps for higher level data products.

4.4.3. QC 0.3: Removal of Periods of Erroneous Data

There may be periods during data collection when the data reported by sensors is erroneous or in question due to sensor malfunction or environmental conditions (e.g., DO sensor buried in sediment, soil moisture sensor affected by lightning). There may also be periods where values are at the maximum or minimum reporting level for a sensor, periods where values that do not change during a measurement period (flatline), or periods of values that change too greatly during a measurement period. These periods will be identified by Technicians' visual inspections, ODM Tools Python threshold filters, automated alerts, and by Technicians' recordings of field conditions. The options for addressing periods of erroneous data are the same as those for the removal of out-of-range values.

4.4.4. QC 0.4: Application of Drift Correction

Linear drift correction should be performed on those variables that are subject to instrument drift, fouling, and/or for which calibrations are performed (DO, SC, pH, fDOM, chlorophyll, blue green algae). Fouling, drift, and calibrations result in shifts for which retrospective correction is required. Note that many sensors will exhibit a shift after cleaning occurs even if there is no calibration performed, which should also be addressed through drift correction. The correction moves the points prior to calibration up or down to a specified value and regressively applies the correction to past values up to a specified point (the point in time of the previous cleaning or calibration). Linear drift correction may be performed via the ODM Tools Python interface. Wagner et al. (2006) provide additional guidance on drift correction, and there may be other types of drift correction implemented in subsequent versions of this document.

4.4.5. QC 0.5: Fill Data Gaps

Data gaps should be detected by either visual inspection or by using a data gap filter in ODM Tools Python. Minor data gaps will be filled by linear interpolation (the period that is acceptable for filing by linear interpolation should be determined by Technicians and GAMUT leadership). If the data gap is large, it should be left in the record. At a higher level of quality control or in a subsequent version of this document, more advanced algorithms for filling data gaps may be implemented.

4.4.6. Final Data Evaluation

A final data evaluation should be conducted to finalize the QC1 data series and review the corrections implemented. The following visual analyses may help in verifying that the QC1 data series make rational sense and represent the best estimate of actual conditions at the site:

1. Plot the QC0 and QC1 data series on the same plot and examine the differences.
2. Plot the QC1 data series with the same variable at other sites to verify that they make rational sense (e.g., discharge at a downstream site should exceed that of an upstream site where there are no diversions).
3. Plot the QC1 data series with any independent observations of the same variable at the same site (e.g., observations made using alternate sensors or field check instruments).

Additionally, any annotations regarding environmental events, instrumentation malfunctions, or other pertinent details may be added as flags or as comments in the Python code.

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Appendix A: Watershed and Site Specific Details

<u>Red Butte Creek</u>

Site Name: Foothill Drive Advanced Aquatic
Site Abbreviation: RB_FD_AA
Lat/Long: 40.757225°, -111.833722°
Deviations from Table 2 sensor list: None
General comments: This site is somewhat difficult to access due to a steep bank. The easiest access point is ~20 feet downstream of the sensors.

Photo:

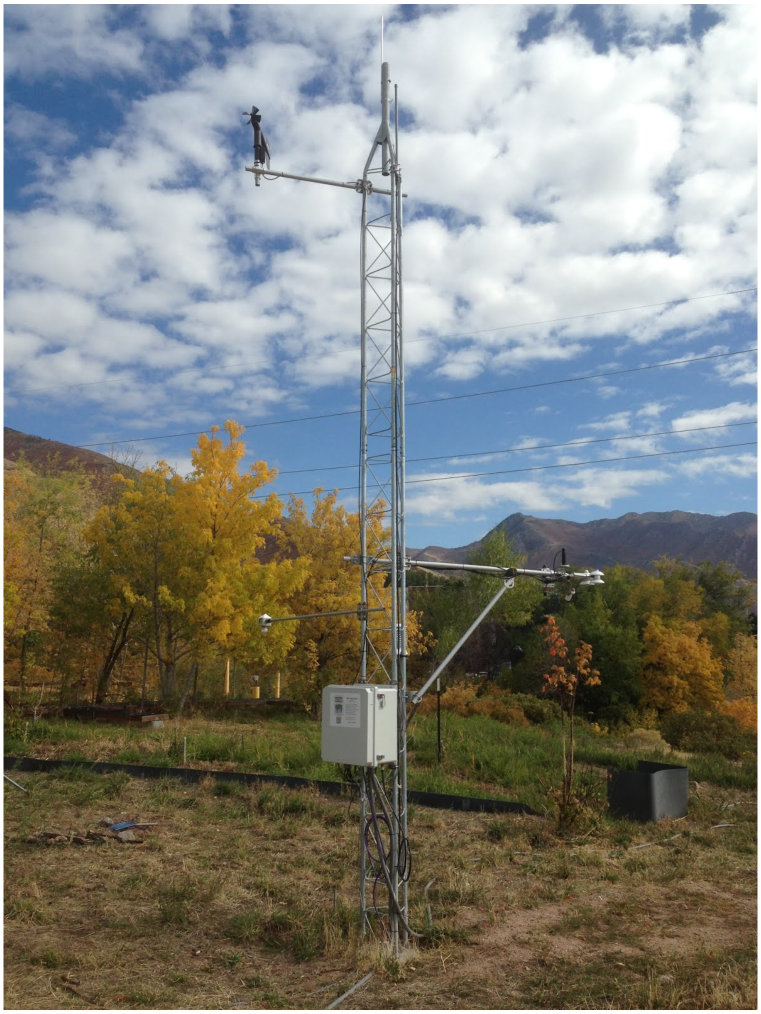
Site Name: Cottam's Grove Basic Aquatic
Site Abbreviation: RB_CG_BA
Lat/Long: 40.763958°, -111.828286°
Deviations from Table 2 sensor list: None
General comments:
Photo:

Site Name: Red Butte Gate Basic Aquatic
Site Abbreviation: RB_RBG_BA
Lat/Long: 40.774050°,-111.817798°
Deviations from Table 2 sensor list: None
General comments:
Photo:

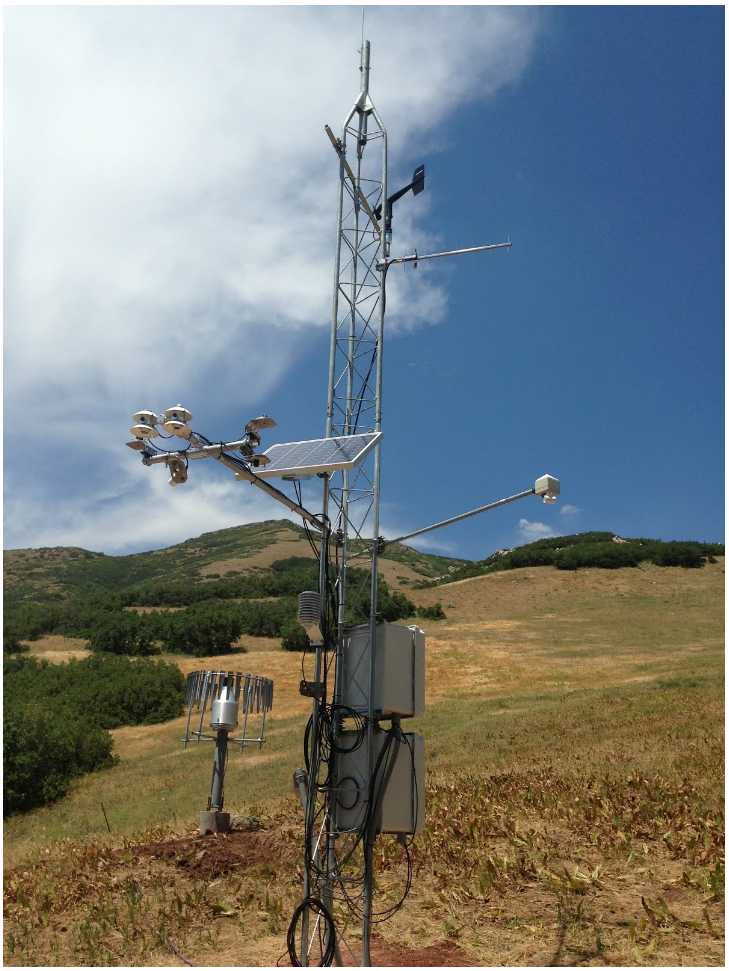
Site Name: Above Red Butte Reservoir Advanced Aquatic
Site Abbreviation: RB_ARBR_AA
Lat/Long: 40.779602°,-111.806669°
Deviations from Table 2 sensor list: No pressure transducer at this site because of close proximity of USGS stream gauge.
General comments:
Photo:

Site Name: Knowlton Fork Basic Aquatic
Site Abbreviation: RB_KF_BA
Lat/Long: 40.809522°,-111.765403°
Deviations from Table 2 sensor list: None
General comments:
Photo:

Site Name: Green Infrastructure Research Facility (GIRF) Climate
Site Abbreviation: RB_GIRF_C
Lat/Long: 40.760800°,-111.830474°
Deviations from Table 3 sensor list: None
General comments:
Photo:



Site Name: Above Red Butte Reservoir Climate
Site Abbreviation: RB_ARBR_C
Lat/Long: 40.780567°, -111.807222°
Deviations from Table 3 sensor list: None
General comments:
Photo:



Site Name: Todd's Meadow Climate
Site Abbreviation: RB_TM_C
Lat/Long: 40.789054°,-111.796416°
Deviations from Table 3 sensor list: This site includes an additional 9 soil moisture sensors and 9 soil oxygen sensors installed near the surface, just north of the climate tower. These were installed in October, 2013 to support research by Dr. Steven Hall.
General comments:
Photo:

Site Name: Knowlton Fork Climate
Site Abbreviation: RB_KF_C
Lat/Long: 40.810122°, -111.766950°
Deviations from Table 3 sensor list: None
General comments:
Photo:

<u>**Logan River**</u>
Site Name: TWDEF Climate
Site Abbreviation: L_TD_C
Lat/Long: 41.864805°, -111.507494°
Deviations from Table 3 sensor list: None

Site Name: Franklin Basin Climate
Site Abbreviation: L_FB_C
Lat/Long: 41.949815, -111.581352
Deviations from Table 3 sensor list: None

Site Name: Franklin Basin Aquatic
Site Abbreviation: L_FB_A
Lat/Long: 41.949815, -111.581352
Deviations from Table 3 sensor list: Not yet built.

Site Name: Tony Grove Climate
Site Abbreviation: L_TG_C
Lat/Long: 41.885493, -111.568767
Deviations from Table 3 sensor list: Precipitation not measured due to the availability of SNOTEL precipitation data at same location.

Site Name: Tony Grove Aquatic
Site Abbreviation: L_TG_A
Lat/Long: 41.876117, -111.564669
Deviations from Table 3 sensor list: Not yet built.

Site Name: Waterlab Advanced Aquatic
Site Abbreviation: L_USU_AA
Lat/Long: 41.739034, -111.795741
Deviations from Table 3 sensor list: None

Site Name: USU Campus Climate
Site Abbreviation: L_USU_C
Lat/Long: 41.742296, -111.811717
Deviations from Table 3 sensor list: A “co-op” station not operated or maintained by iUTAH. See weather.usu.edu.

Site Name: Main Street Bridge Aquatic
Site Abbreviation: L_MSB_A
Lat/Long: 41.721091, -111.835096
Deviations from Table 3 sensor list: None

Site Name: Golf Course Climate
Site Abbreviation: L_GC_C
Lat/Long: 41.721091, -111.835096
Deviations from Table 3 sensor list: None

Site Name: Mendon Road Advanced Aquatic
Site Abbreviation: L_MR_AA
Lat/Long: 41.720633, -111.886478
Deviations from Table 3 sensor list: None

Tony Grove	Climate			6324
Tony Grove	Sapflux	L_TG_S	Likely delayed until 2014	
Tony Grove	Aquatic	L_TG_A		6183
USU Water Lab	Aquatic	L_USU_A		4640
USU Campus	Climate	L_USU_C	41.742296, -111.811717	4787
Main Street Bridge	Aquatic	L_MSB_A	41.721091, -111.835096	4519
Golf Course	Climate	L_GC_C	41.721091, -111.835096	4478
Mendon Road	Aquatic	L_MR_A	41.720633, -111.886478	4434

Provo River (JOE)

Site Name: Provo River Below Jordanelle Reservoir Aquatic
Site Abbreviation: PR_BJ_AA
Lat/Long: 40.59507, -111.42864
Elevation: 1790 meters
Deviations from Table 2 sensor list: This Site does not include a CS451 (pressure transducer).
General comments: You need a key to access the USGS shed. Everytime the shed is open an alarm goes off. You need to send a text message to the Central Utah Water Conservancy District (CUWCD) at 801-376-0686 to let them know you are the one who set off the alarm. All flow data will be obtained from the CUWCD.

Site Name: Beaver Divide Climate Station
Site Abbreviation: PR_BD_C
Lat/Long: 40.612508, -111.098289
Elevation: 2508 meters
Deviations from Table 3 sensor list: This site does not have a Judd snow depth sensor, TB-200 (Geonor Precipitation gauge), CS106 (barometer), or NR01 (Hukseflux). This site does have a campbell scientific TE525-20 tipping bucket rain gauge.
General comments: This site is located near a SNOTEL site as well as a Forest Service RAWS station. All precipitation and barometric data will be used from their sensors.

Site Name: Trial Lake Climate Station
Site Abbreviation: PR_TL_C
Lat/Long: 40.678111, -110.9483
Elevation: 3040 meters
Deviations from Table 3. sensor list: This site does not have a Judd snow depth sensor or TB-200 (Geonor Precipitation gauge). The solar radiation and wind sensors are located higher than sensors at other sites due to extreme snow depths during the winter time. The wind sensor is 6.27 meters off of the ground.
General comments: This site is located near a SNOTEL site. All precipitation data will be used from their sensors.

Photo:

Appendix B: Protocols for Updating Datalogger Programs

Scenario 1: Update is planned out and is less time sensitive (e.g., addition/deletion of long term variable, additional tables being created because of adaptive sampling, etc.)
NOTE: Data for 1-2 time steps may be lost during this process.

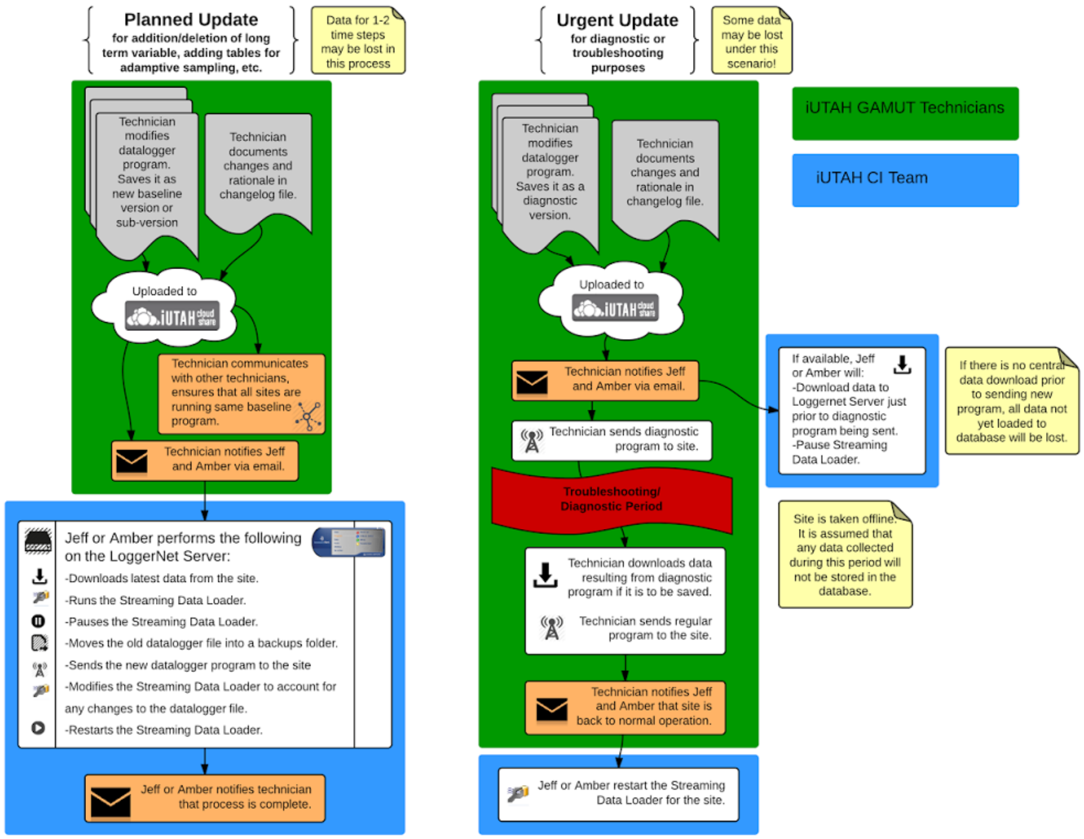
1. Technician modifies code in datalogger program and saves it as a new version. Changes that are specific to a site can be saved as sub-versions.
2. Technician documents all changes made to the program and rationale for the changes in a changelog file for each program in iUTAH CloudShare. Notes are made within a section for each new version of the file.
3. Technician communicates changes to other technicians and ensures that all sites are running the same baseline version of the program.
4. Technician uploads modified datalogger program to iUTAH CloudShare. NOTE: Baseline aquatic/terrestrial programs should be stored in the Templates folder. Site-specific programs should be stored in the associated folders.
5. Technician notifies CI Team via email.
6. Members of the CI Team connect to iUTAH LoggerNet server and perform the following:
    a. Downloads the latest data from the site
    b. Runs the Streaming Data Loader to make sure all data from the old program are loaded into the database
    c. Pauses the Streaming Data Loader
    d. Moves the old datalogger file into a backups folder
    e. Sends the new datalogger program to the site (this overwrites all data on the datalogger)
    f. Modifies the Streaming Data Loader configuration file to account for any changes to the datalogger file(s) imposed by the new program
    g. Restarts the Streaming Data Loader
7. The CI Team notifies the technician that the process has been completed
8. A record is logged in the equipment management database indicating that the program has changed

Scenario 2: Update is for troubleshooting/diagnostic purposes and is time sensitive
NOTE: Some data may be lost under this scenario.

1. Technician modifies code of datalogger program and saves it as a new version that is to be used for diagnostics or troubleshooting
2. Technician documents all changes made to the program and rationale for the changes in a changelog file for each program in iUTAH CloudShare. Notes are made within a section for each new version of the file.
3. Technician notifies the CI Team that troubleshooting/diagnostics will take place. If available, the CI Team will coordinate a data download from the central Loggernet Server just prior to the diagnostic program being sent and pause the Streaming Data Loader. ***NOTE: If there is no central data download prior to sending a new program to the site, any data on the logger that has not been retrieved by the central Loggernet instance will be lost.***
4. Technician connects to site of interest, and sends diagnostic program to the site. ***NOTE: This will destroy any data on the datalogger, and we are assuming this action effectively takes the site offline and any data collected during diagnostics/troubleshooting is not going to be loaded***

into the database.

5. Technician downloads any data resulting from the diagnostic program to his/her laptop at the end of troubleshooting activities if it needs to be saved.
6. When the troubleshooting/diagnostic program is terminated, the previous program (or a new program version) is loaded back onto the datalogger by the technician for normal operations.
7. Technician notifies the CI Team that the site has been placed back into normal operation.
8. The CI Team ensures that the Streaming Data Loader is started again for the site.


Planned Update
for addition/deletion of long term variable, adding tables for adamptive sampling, etc.
Data for 1-2 time steps may be lost in this process
Technician modifies datalogger program. Saves it as new baseline version or sub-version
Technician documents changes and rationale in changelog file.
Uploaded to
Technician communicates with other technicians, ensures that all sites are running same baseline program.
Technician notifies Jeff and Amber via email.
Jeff or Amber performs the following on the LoggerNet Server:
-Downloads latest data from the site.
-Runs the Streaming Data Loader.
-Pauses the Streaming Data Loader.
-Moves the old datalogger file into a backups folder.
-Sends the new datalogger program to the site
-Modifies the Streaming Data Loader to account for any changes to the datalogger file.
-Restarts the Streaming Data Loader.
Jeff or Amber notifies technician that process is complete.
Urgent Update
for diagnostic or troubleshooting purposes
Some data may be lost under this scenario!
Technician modifies datalogger program. Saves it as a diagnostic version.
Technician documents changes and rationale in changelog file.
Uploaded to
Technician notifies Jeff and Amber via email.
Technician sends diagnostic program to site.
Troubleshooting/ Diagnostic Period
Technician downloads data resulting from diagnostic program if it is to be saved.
Technician sends regular program to the site.
Technician notifies Jeff and Amber that site is back to normal operation.
Jeff or Amber restart the Streaming Data Loader for the site.
iUTAH GAMUT Technicians
iUTAH CI Team
If available, Jeff or Amber will:
-Download data to Loggernet Server just prior to diagnostic program being sent.
-Pause Streaming Data Loader.
If there is no central data download prior to sending new program, all data not yet loaded to database will be lost.
Site is taken offline. It is assumed that any data collected during this period will not be stored in the database.

Appendix C: Measurement Plans

Baseline Aquatic Site Measurement Plan:

Manufactuer	Instrument	Variable Name	Variable	Units	Scan Rate	Processing	Storage Interval
Campbell	CR800	RecNum	Record Number	N/A	15 min	Sample	15 min
Campbell	CR800	TimeStamp	Time Stamp	MST	15 min	Sample	15 min
Campbell	CR800	Site	Site Name	N/A	15 min	Sample	15 min
Campbell	CS210	RH enc	Enclosure humidity	%	10 sec	Sample	15 min
Campbell	CR800	BattVolt	Battery Voltage	V	15 min	Sample	15 min
Campbell	18166	Door Tot	Enclosure open door sensor	Binary	3min	Totalize	15 min
Xylem (YSI)	599870-01	WaterTemp EXO	Water Temp	c	15 min	Sample	15 min
Xylem (YSI)	599870-01	SpCond	Specific Conductivity	uS/cm	15 min	Sample	15 min
Xylem (YSI)		pH	pH	N/A	15 min	Sample	15 min
Xylem (YSI)	599100-01	ODO	Dissolved Oxygen	mg/L	15 min	Sample	15 min
Xylem (YSI)	599100-01	ODO Sat	Dissolved Oxygen	%	15 min	Sample	15 min
Xylem (YSI)	599100-01	ODO Local	Dissolved Oxygen	%	15 min	Sample	15 min
Xylem (YSI)		ExoTime	Sonde Data output time	UTC	15 min	Sample	15 min
Xylem (YSI)		ExoVolt	Power delivered to sonde	V	15 min	Sample	15 min
Xylem (YSI)	599102	BGA*	Blue Green Algae	RFU	15 min	Sample	15 min
Xylem (YSI)	599102	Cholorphyll*	Chlorophyll	RFU	15 min	Sample	15 min
Xylem (YSI)	599104	fDOM*	Dissolved Organic Matter	QSU	15 min	Sample	15 min
Forest Technology Systems	DTS-12	TurbAvg	Turbidity	NTU	15 min	Sample	15 min
Forest Technology Systems	DTS-12	TurbMed	Turbidity	NTU	15 min	Sample	15 min
Forest Technology Systems	DTS-12	TurbMin	Turbidity	NTU	15 min	Sample	15 min
Forest Technology Systems	DTS-12	TurbMax	Turbidity	NTU	15 min	Sample	15 min
Forest Technology Systems	DTS-12	TurbVar	Turbidity	NTU	15 min	Sample	15 min
Forest Technology Systems	DTS-12	TurbBFS	Turbidity	NTU	15 min	Sample	15 min
Forest Technology Systems	DTS-12	WaterTemp Turb	Turbidity	c	15 min	Sample	15 min
Forest Technology Systems	DTS-12	TurbWipe	Turbidity	Binary	15 min	Sample	15 min
Campbell	CS450	Stage	Water Depth	cm	15 min**	Average**	15 min
Campbell	CS450	WaterTemp PT	Water Temp	c	15 min	Sample	15 min
Campbell	CS450	StageNaNCounter	NaN counter	N/A	10 sec	sample	15 min
Campbell	CS450	StageOffset	Offset constant between pressure transducer depth and stage plate depth	cm	10 sec	sample	15 min

*These variables are only measured at advanced aquatic sites.
**Every 15 minutes, 25 measurements are made within about 20 seconds. The result is the average of the burst sample.

Baseline Climate Site Measurement Plan:

Manufactuer	Instrument	Variable Name	Variable	Units	Scan Rate	Processing	Storage Interval
Campbell	CR3000	RecNum	Record Number	N/A	10 sec	Sample	15 min
Campbell	CR3000	TimeStamp	Time Stamp	N/A	10 sec	Sample	15 min
Campbell	HC2S3	AirTemp_Avg	AirTemp	C	10 sec	Average	15 min
Campbell	HC2S3	RH	Relative Humidity	%	10 sec	Sample	15 min
Campbell	CS210	DewPt_Avg	Dew Point	C	10 sec	Average	15 min
Campbell	CS210	VaporPress_Avg	Vapor Pressure	kPa	10 sec	Average	15 min
Campbell	CS106	BP_Avg	Barometric Pressure	kPa	10 sec	Average	15 min
RM Young	05303-45	WindSp_Avg	Wind Speed	m/s	10 sec	Average	15 min
RM Young	05303-45	WindDir_Avg	Wind Direction average	degrees	10 sec	Average	15 min
RM Young	05303-45	WindDir_std	Wind Direction standard deviation	degrees	10 sec	Std Dev	15 min
Geonor	TB-200	Precip_tot_avg	Cumulative Precip	cm	10 sec*	Average*	15 min
Geonor	TB-200	Precip_freq_avg	Geonor frequency output	hz	10 sec*	Average*	15 min
Judd	DS	JuddDepth_avg	Snow Depth	cm	10 sec**	Average**	15 min
Judd	DS	JuddDepth_1	Snow Depth	cm	15 min	Sample	15 min
Judd	DS	JuddDepth_2	Snow Depth	cm	15 min	Sample	15 min
Judd	DS	JuddDepth_3	Snow Depth	cm	15 min	sample	15 min
Judd	DS	JuddTemp_Avg	Depth Sensor Temperature	C	10 sec	Average	15 min
Hukseflux	NR01	SWIn_NR01_Avg	Incoming SW	W/m2	10 sec	Average	15 min
Hukseflux	NR01	SWOut_NR01_Avg	Outgoing SW	W/m2	10 sec	Average	15 min
Hukseflux	NR01	LWIn_Cor_NR01_Avg	Incoming LW Temp Corrected	W/m2	10 sec	Average	15 min
Hukseflux	NR01	LWOut_Cor_NR01_Avg	Outgoing LW Temp Corrected	W/m2	10 sec	Average	15 min
Hukseflux	NR01	NetRad_NR01_Avg	Net Radiation	W/m2	10 sec	Average	15 min
Hukseflux	NR01	LWIn_UnCor_NR01_Avg	Incoming LW (uncorrected)	W/m2	10 sec	Average	15 min
Hukseflux	NR01	LWOut_UnCor_NR01_Avg	Outgoing LW (uncorrected)	W/m2	10 sec	Average	15 min
Hukseflux	NR01	Temp_NR01_Avg	Radiometer Body Temp	C	10 sec	Average	15 min
Apogee	SP-230	SWIn_SP230_Avg	Incoming SW radiation	W/m2	10 sec	Average	15 min
Hukseflux	NR01/SP-230	Heater_on	Heater on or off?	Binary	15 min	Sample	15 min
Campbell	CS210/NR01	DeltaTemp	(NR01 Sensor Body Temp) - (Dew Point Temp)	C	10 sec	Average	15 min
Campbell	CS210/NR01	DeltaTemp_runAvg	(NR01 Sensor Body Temp) - (Dew Point Temp)	C	10 sec	Average	15 min
Apogee	SQ-110	PARIn_Avg	Incoming PAR	mumol m-2 m-1	10 sec	Average	15 min
Apogee	SQ-110	PAROut_Avg	Outgoing PAR	mumol m-2 m-1	10 sec	Average	15 min
Apogee	SI-111	TargTemp_SI111_Avg	Surface Temp	C	10 sec	Average	15 min
Apogee	SI-111	Temp_SI111_Avg	Sensor Temp	C	10 sec	Average	15 min
Apogee	SI-111	m_SI111	m (slope for temp calc)	N/A	10 sec	Average	15 min
Apogee	SI-111	b_SI111	b (intercept for temp calc)	N/A	10 sec	Average	15 min
Apogee	SI-111	TargV_SI111_Avg	IR mv output	mv	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	VWC_5cm_Avg	5 cm Volumetric Water Content	%	10 sec*	Average*	15 min
Acclima	ACC-SEN-SDI	SoiTemp_5cm_Avg	5 cm Soil Temperature	C	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoilCond_5cm_Avg	5 cm Permitivity	?	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	Permitivity_5cm_Avg	5 cm Soil Conductivity	dS/m	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	VWC_10cm_Avg	10 cm Volumetric Water Content	%	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoiTemp_10cm_Avg	10 cm Soil Temperature	C	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoilCond_10cm_Avg	10 cm Permitivity	?	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	Permitivity_10cm_Avg	10 cm Soil Conductivity	dS/m	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	VWC_20cm_Avg	20 cm Volumetric Water Content	%	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoiTemp_20cm_Avg	20 cm Soil Temperature	C	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoilCond_20cm_Avg	20 cm Permitivity	?	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	Permitivity_20cm_Avg	20 cm Soil Conductivity	dS/m	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	VWC_50cm_Avg	50 cm Volumetric Water Content	%	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoiTemp_50cm_Avg	50 cm Soil Temperature	C	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoilCond_50cm_Avg	50 cm Permitivity	?	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	Permitivity_50cm_Avg	50 cm Soil Conductivity	dS/m	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	VWC_100cm_Avg	100 cm Volumetric Water Content	%	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoiTemp_100cm_Avg	100 cm Soil Temperature	C	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	SoilCond_100cm_Avg	100 cm Permitivity	?	10 sec	Average	15 min
Acclima	ACC-SEN-SDI	Permitivity_100cm_Avg	100 cm Soil Conductivity	dS/m	10 sec	Average	15 min
Campbell	CR3000	BattVolt	Battery voltage	V	10 sec	Sample	15 min
Campbell	CR3000	Panel_Temp	Panel Temp	C	10 sec	Sample	15 min
Campbell	CS210	RH_enc	Enclosure Humididty	%	10 sec	Sample	15 min
Campbell	18166	Door_Tot	Enclosure open door sensor	Binary	15 min	Total	15 min
Campbell	CR3000	n	Scan counter	N/A	10 sec	Total	15 min
Apogee	ST110	AirTemp_ST110_avg	Average air temperature -- Apogee thermistor	C	10 sec	Average	15 min
Apogee	ST110	AirTemp_ST110_max	Max air temperature -- Apogee thermistor	C	10 sec	Maximum	15 min
Apogee	ST110	AirTemp_ST110_min	Min air temperature -- Apogee thermistor	C	10sec	Minimum	15 min
Geonor	TB-200	Precip_offset	Current precip offset	cm	10 sec	Sample	15 min
Geonor	TB-200	Precip_HrDiff	Previous Hour's precip (used for heater cont)	cm	10 sec	Sample	15 min
Campbell	N/A	Evapotrans_ETr	Tall grass reference ET calculation	mm	10 sec	Sample	15 min
Campbell	N/A	Evapotrans_ETo	Short grass reference ET calculation	mm	10 sec	Sample	15 min
Apogee	TS100	Tachometer_TS100	Aspirated shield tachometer output	RPM	10 sec	Average	15 min
GeonorHeater	TB-200	GeonorHeater_Tot	Automated counter to indicate heater state	Binary	10 sec	Total	15 min
GeonorHeater	TB-200	GeonorHeater_Manual_Tot	Heater state counter for manual turn-on/off	Binary	10 sec	Total	15 min
InletTemp	PT1000	InletTemp_avg	Geonor inlet temperature -- troubleshooting	C	10 sec	Average	15 min

* Measurements made every 10 seconds during the final minute of the 15-min interval. The result is the average of the final 6 measurements.

** Measurements made every 10 seconds during the final minute of the 15-min interval. The result is the average of the final 6 measurements with outliers (defined as >90% of the offset or <-10) excluded.

Appendix D: Site Visit Checklist and Field Sheet (DAVE)

Climate

Field notes can be kept by individual technicians as they see fit. Regardless of the format, notes should contain the following information at a minimum.

- Location
- Date/Time of arrival and departure.
- Crew members.
- Weather observations, including what is in the forecast if it is pertinent (e.g., big snowstorm is bearing down on SLC).
- Notes about anything that could potentially impact data quality.
- Notes about any activities performed during the field visit. Record approximate time of field activities if possible.

Aquatic

Field notes can be kept by individual technicians as they see fit. Regardless of the format, notes should contain the following information at a minimum.

- Location
- Date/Time of arrival and departure.
- Crew members.
- Whether or not probes were pulled and associated times.
- Stage reading and associated time.
- Weather observations, including what happened recently or what is in the forecast (e.g., big rainstorm is bearing down on SLC).
- Notes about anything that could potentially impact data quality or help with post processing.
    - Ice/Debris buildup?
    - Clear or turbid water?
    - High or low water?
- Notes about any activities performed during the field visit. Record approximate time of field activities if possible.
- If calibrating, note the following:
    - Time sensor was pulled/removed
    - Setpoint/Pre/Post values for each standard used
    - Temperature of fluorescent solutions used for temperature corrections
    - Anything that may have affected the quality of the calibration

Field Note Check List

Location:	
Date/Time:	
Crew Members:	
Environmental Observations:	
Stage Reading (Aquatic Stations Only):	

Notes:	

Calibration Check List

Time sensor was pulled/removed:	
Setpoint/Pre/Post values for each standard:	
Temperature of fluorescent solutions used for temperature corrections:	
Anything that may have affected the quality of the calibration:	

Appendix E: Calibration/Maintenance Detailed Instructions

Regular Geonor Maintenance:

1. Connect to datalogger and record the most recent cumulative precipitation value.
2. Remove gauge cover.
3. Empty the antifreeze/water/oil solution if necessary. 600 mm gauges should be emptied when the bucket contains ~450-500 mm of liquid. 1000 mm gauges should be emptied when the bucket contains 850-900 mm of liquid.
4. If gauge is emptied, transfer water/antifreeze/oil solution to a 5 gallon carboy for transport away from field site. Dispose of antifreeze in accordance with university policies.
5. Add fresh antifreeze and oil (if necessary). 3-4 L of antifreeze should be sufficient to prevent freezing.
6. Connect to datalogger and record current cumulative precipitation value.
7. Update the precip offset constant in the datalogger program to compensate for the removal and subsequent addition of liquid from the bucket.

Once per year, perform checks on the function of the vibrating wire sensor, using the following procedures:

Empty Bucket Check:

1. Level bucket
2. Check frequency with empty bucket
3. Compare empty bucket frequency (f_0) with f_0 on calibration sheet
4. If difference exceeds 10 Hz, calculate new value for constant “A” using the equation in section 5.4 of the Geonor Manual

Precipitation in Bucket Check:

1. Fill bucket with 1kg of water, which is equivalent to exactly 50 mm of precipitation.
2. Send sensor back to Geonor for re-calibration if the addition of 1kg of water does not result in increase of 47.5 cm - 52.5 cm of precipitation on the datalogger.

EXO2 Sonde Calibration
Basic Calibration:

All of these procedures may be done in the field or lab except the dissolved oxygen (DO) sensor. The DO sensor must be calibrated in the field. After the initial deployment of the sonde most of the calibrations will be conducted in the field.

All EXO sensors (except the temperature sensor) will periodically need to be calibrated. Multiple sensors of the same type can be calibrated concurrently by installing sensors of the same type on one sonde. Note that calibrations occur one after the other, not simultaneously. The following steps should be followed for calibrations (Adapted from YSI Manual, EXO 2012).

Calibration Set-Up

1. Triple rinse the EXO calibration cup with water, then rinse with a small amount of the appropriate calibration standard for the sensor to be calibrated.
2. Fill up the sensor cup with calibration standard to the first line for calibrating multiple sensors. Fill up the sensor cup to the second line for calibrating one or two sensors.
3. Carefully clean and dry the sensor that is installed on the EXO sonde.
4. Install the sonde guard over the probe
5. Immerse the probe in the standard and tighten the calibration cup onto the EXO sonde.

Basic Calibration Using the YSI KOR software

1. Go to the 'Calibrate' menu in the KOR software and select the sensor to be calibrated.
2. Select the parameter for the sensor to be calibrated.
3. Enter the value of the standard. NOTE: Check that the value you enter is correct and its units match the units at the top of the menu.
4. Click 'Start Calibration' button.
5. Click 'Graph Data' button to compare pre-calibration and post-calibration values and verify that the value is within acceptable margin of error.
6. Click 'Complete' when all points have been calibrated.
7. View, export, and/or print the calibration worksheet.

CONDUCTIVITY-*Calibrates conductivity, specific conductance, salinity, and total dissolved solids.*

1. Clean the conductivity cell with the soft brush that came with the sensor.
2. Rinse the calibration cup with a small amount of conductivity solution
3. Fill up the sensor cup with the proper amount of conductivity calibration solution (the solution needs to be > 1000mS/cm, which can be purchased from Fisher Scientific).
4. Carefully immerse the probe into the solution, making sure the standard is above the vent holes on the conductivity sensor. Gently rotate and/or move the sonde up and down to remove air bubbles.
5. Wait 1 minute for temperature equilibration.
6. In the Calibration menu, select 'Conductivity' and then select specific conductivity.
7. Enter the value of the standard you are using (NOTE: Check that the value you enter is correct and its units match the units at the top of the menu).
8. Click Start Calibration

9. Wait until readings under Current and Pending data points are stable (approximately 40 seconds). If the readings do not stabilize after ~ 40 seconds gently rotate the sonde to remove air bubbles or press the ‘Wipe Sensors’ button.
10. Click ‘Apply’ to accept calibration.
11. Click ‘Complete’.
12. Click ‘Exit’.
13. Rinse the sonde and sensor in tap or purified water and dry.

DISSOLVED OXYGEN
****NOTE: This process needs to be done in the field. ****

1. Fill up large bucket/pot with water from the river that the sonde is going to be deployed in.
2. Turn on air pump to sparge the water.
3. Insert sonde into the water.
4. Wait approximately 15-20 minutes before proceeding to allow the temperature and oxygen pressure to equilibrate.
5. In the calibration menu select ‘ODO’, and then select ‘ODO % Local saturation’ (this will also calibrate ODO mg/L).
6. Click ‘1 Point’ for the Calibration Points.
7. Click ‘Start Calibration’.
8. Wait until readings under Current and Pending data points are stable (for approximately 40 seconds).
9. Click ‘Apply’ to accept calibration.

pH
This is a three-point calibration. The rivers we are working in likely have pH between 6 and 10, so pH will need to be calibrated to pH 4, pH 7 and pH 10 buffer solutions.

1. Rinse the calibration cup with a small amount of the pH 4 buffer solution.
2. Pour the correct amount of pH 4 buffer solution the calibration cup.
3. Immerse the probe end of the sonde into the solution, making sure the sensor’s glass bulb is in the solution by at least 1 cm.
4. Allow at least 1 minute for temperature equilibration before proceeding.
5. In the Calibrate menu select ‘pH’.
6. Click ‘3 Point’ for the Calibration Points.
7. Enter ‘4’ as the value of the first standard
8. Enter ‘7’ as the value of the second standard
9. Enter ‘10’ as the value of the second standard

NOTE: Observe the temperature reading. The actual pH value of all buffers varies with temperature. Enter the correct value from the bottle label for your calibration temperature for maximum accuracy. For example, the pH of one manufactures’ pH 7 Buffer is 7.00 at 25° C, but 7.02 at 20°C (This information is located on the pH buffer lable).

10. Click ‘Start Calibration’.
11. Wait until readings under Current and Pending data points are stable (for approximately 40 seconds)
12. Click ‘Apply’ to accept calibration. (It is best not to touch the sonde while stabilizing. If the sonde is having a difficult time stabilizing the data, press the ‘Wipe Sensor’ button).

13. Rinse the sonde in water.
14. Rinse the calibration cup in water
15. Rinse the calibration cup with a small amount of the pH 7 buffer solution
16. Pour the correct amount of the pH 7 buffer solution the calibration cup.
17. Immerse the probe end of the sonde into the solution, making sure the sensor's glass bulb is in the solution by at least 1 cm.
18. Allow at least 1 minute for temperature equilibration before proceeding.
19. Click 'Proceed' in the pop-up window.
20. Wait until readings under Current and Pending data points are stable (for approximately 40 seconds).
21. Click 'Apply' to accept the calibration.
22. Rinse the sonde and calibration cup in water.
23. Repeat Steps 15-21 for pH 10.
24. Click 'Complete'.
25. Click 'Exit.
26. Rinse the sonde and sensor in tap or purified water and dry.

TOTAL ALGAE

The EXO total algae sensor measures chlorophyll *a* and blue-green algae separately (chlorophyll *a* + blue-green algae = total algae). To measure them accurately you must calibrate chlorophyll and blue-green algae individually.

This is a 2-point calibration. One of the standards needs to be clear deionized or distilled water (0 mg/L), and this must be calibrated first. Enter value from EFFECT OF TEMPERATURE ON FLUORESCENCE TABLE. This solution is used in the calibration steps below.

Chlorophyll RFU (Relative Fluorescence Units)
1. Rinse the calibration cup with deionized or distilled water
2. Pour the correct amount of clear deionized or distilled water into the calibration cup.
3. Immerse the probe end of the sonde in the water.
4. In the Calibrate menu, select 'BGA-PC/Chlor'.
5. Select 'Chl RFU'.
6. Select '2-point calibration'.
7. Enter '0' for the first standard value.
8. Enter the appropriate value from the Effect of Temperature on Fluorescence Table for the second standard value. To ensure accuracy, measure the temperature of the calibration solution with a handheld thermometer and linearly interpolate to attain the best possible fluorescence value.
9. Click 'Start Calibration'.
10. While the readings are stabilizing, click the Wipe Sensors button to activate the wiper to remove any bubbles.
11. Wait until readings are stable (about 40 seconds).

12. Click 'Apply' to accept calibration.
13. Rinse the calibration cup with a small amount of the Rhodamine WT standard.
14. Place the sensors in the Rhodamine WT standard.
15. Click 'Proceed' on the pop-up window.
16. While the readings are stabilizing, click the 'Wipe Sensors' button to activate the wiper to remove any bubbles.
17. Wait until readings are stable (about 40 seconds).
18. Click 'Apply' to accept calibration.
19. Click 'Complete'.
20. Click 'Exit'.
21. Rinse the sonde and sensor in tap or purified water and dry.

Blue-green Algae RFU

1. Rinse the calibration cup with deionized or distilled water.
2. Pour the correct amount of clear deionized or distilled water into the calibration cup.
3. Immerse the probe end of the sonde in the water.
4. In the Calibrate menu, select 'BGA-PC/Chlor'.
5. Select 'BGA RFU'.
6. Select '2- point calibration'.
7. Enter '0' for the first standard value.
8. Enter the appropriate value from the Effect of Temperature on Fluorescence Table for the second standard value. To ensure accuracy, measure the temperature of the calibration solution with a handheld thermometer and linearly interpolate to attain the best possible fluorescence value.
9. Click 'Start Calibration'.
10. While the readings are stabilizing, click the 'Wipe Sensors' button to activate the wiper to remove any bubbles.
11. Wait until readings are stable (about 40 seconds).
12. Click 'Apply' to accept calibration.
13. Rinse the calibration cup with a small amount of the Rhodamine WT standard.
14. Place the sensors in the Rhodamine WT standard.
15. Click 'Proceed' on the pop-up window.
16. While the readings are stabilizing, click the 'Wipe Sensors' button to activate the wiper to remove any bubbles.
17. Wait until readings are stable (about 40 seconds).
18. Click 'Apply' to accept calibration.
19. Click 'Complete'.
20. Click Exit
21. Rinse the sonde and sensor in tap or purified water and dry.

fDOM

This procedure calibrates fDOM Quinine Sulfate Units (QSU)/ppb, and requires a 2-point calibration. One of the standards needs to be clear deionized or distilled water water (0 mg/L). The other value is obtained from EFFECT OF TEMPERATURE ON FLUORESCENE TABLE.

***DO NOT LEAVE SENSORS IN QUININE SULFATE SOLUTION FOR A LONG TIME. A CHEMICAL REACTION

OCCURS WITH THE COPPER ON THE SONDE (SONDE BULKHEAD, COPPER TAPE) THAT DEGRADES THE SOLUTION AND CAUSES IT TO DRIFT. ***

QSU-2-Point

1. Rinse the calibration cup with deionized or distilled water
2. Pour the correct amount of clear deionized or distilled water into the calibration cup.
3. Immerse the probe end of the sonde in the water.
4. In the 'Calibrate' menu, select 'fDOM', then select 'QSU/ppb'.
5. Select '2-point calibration'.
6. Ender '0' for the first standard value.
7. Enter the appropriate value from the Effect of Temperature on Fluorescence Table for the second standard value. To ensure accuracy, measure the temperature of the calibration solution with a handheld thermometer and linearly interpolate to attain the best possible fluorescence value.
8. Click 'Start Calibration'.
9. Wait until the readings are stable (about 40 seconds).
10. Click 'Apply' to accept calibration.
11. **Remove the central wiper from the EXO2 sonde before proceeding to the next step.**
12. Rinse the calibration cup with a small amount of the quinine sulfate standard.
13. Place the sensor in the correct amount of 300 mg/L quinine sulfate standard in the calibration cup.
14. Click 'Proceed' on the pop-up window.
15. While the readings are stabilizing, click the 'Wipe Sensors' button to activate the wiper to remove any bubbles.
16. Wait until readings are stable (about 40 seconds).
17. Click 'Apply' to accept calibration.
18. Click 'Complete'.
19. Click 'Exit'.

CALIBRATION SOLUTIONS, DYES, AND CHEMICALS PROCUREMENT

- For the pH and Conductivity sensors, buffers for pH 4, 7, & 10 and Conductivity 1413 uS/cm solutions may be purchased from AquaPhoenix Scientific, Inc.: http://www.aquaphoenixsci.com/ .
- For the fDOM sensor, solid quinine sulfate dihydrate with a high purity (>99%) and 0.1 N (0.05 M) sulfuric acid may be purchased from Fisher Scientific: http://www.fishersci.com/ (item #6119-70-6).
- For the Total Algae sensor, Rhodamine WT dye in solution form may be purchased from Kingscote Chemicals: http://kingscotechemicals.com/ (item #106023). Rhodamine WT dye can can vary somewhat in nominal concentration. The solution from Kingscote Chemicals is approximately 2.5%.

CALIBRATION SOLUTIONS PREPARATION

Quinine Sulfate Solution for fDOM Sensor

Use the following procedure to prepare a 300 µg/L solution of quinine sulfate (300 QSU) that can be used to calibrate the EXO fDOM sensor for field use.

1. Weigh 0.100 g of solid quinine sulfate dehydrate and quantitatively transfer the solid to a 100-mL volumetric flask.
2. Dissolve the solid in about 50 mL of 0.05 M (0.1 N) sulfuric acid (H_2SO_4).
3. Dilute the solution to the mark of the volumetric flask with additional 0.05 M sulfuric acid, and mix well by repeated inversion. This solution is 1000 ppm in quinine sulfate (0.1%).
4. Transfer 0.3 mL of the 1000 ppm solution to a 1000 mL volumetric flask.
5. Fill the flask to the top graduation with 0.05 M sulfuric acid. Mix well to obtain a solution that is 300 µg/L (300 QSU).
6. Store the concentrated standard solution in a darkened glass bottle in a refrigerator to retard decomposition. The dilute standard prepared in the previous step should be used within 5 days of preparation and should be discarded immediately after exposure to EXO's metal components.

Exposure of the dilute quinine sulfate solution to any copper-based component of the EXO sonde and sensors (primarily the wiper assembly) will begin to degrade the solution significantly within minutes. Thus, the calibration should be performed as quickly as possible upon immersion of the sensors into the quinine sulfate solution and the used standard should be discarded. When quinine sulfate standards are required in the future, perform another dilution of the concentrated solution.

Effect of temperature on fluorescence

The intensity of the fluorescence of many dyes shows an inverse relationship with temperature. This effect must be accounted for when calibrating the EXO fDOM sensor with Rhodamine WT. Enter the QSU calibration value from the table below that corresponds to the temperature of the standard.

Effect of temperature on fluorescence

The intensity of the fluorescence of many dyes shows an inverse relationship with temperature. This effect must be accounted for when calibrating the EXO Total-Algae sensor with Rhodamine WT. Enter the µg/L or RFU value from the table below that corresponds to the temperature of the standard.

Temp (°C)	RFU Chl	µg/L Chl	RFU BGA-PC	µg/L BGA-PC	Temp (°C)	RFU Chl	µg/L Chl	RFU BGA-PC	µg/L BGA-PC
30	14.0	56.5	11.4	11.4	18	17.6	70.8	17.5	17.5
28	14.6	58.7	13.1	13.1	16	18.3	73.5	19.1	19.1
26	15.2	61.3	14.1	14.1	14	18.9	76	20.1	20.1
24	15.8	63.5	15.0	15.0	12	19.5	78.6	21.2	21.2
22	16.4	66	16.0	16.0	10	20.2	81.2	22.2	22.2
20	17.0	68.4	17.1	17.1	8	20.8	83.8	22.6	22.6

Effect of temperature on fluorescence

The intensity of the fluorescence of many dyes shows an inverse relationship with temperature. This effect must be accounted for when calibrating the EXO fDOM sensor with Quinine Sulfate Solution. Enter the QSU or RFU value from the table below that corresponds to the temperature of the standard.

Temp (°C)	RFU	QSU	Temp (°C)	RFU	QSU
30	96.4	289.2	18	101.8	305.4
28	97.3	291.9	16	102.7	308.1
26	98.2	294.6	14	103.6	310.8
24	99.1	297.3	12	104.6	313.8
22	100	300	10	105.5	316.5
20	100.9	302.7	8	106.4	319.2

Rhodamine WT Dye Solution for Total Algae Sensor

Use the following procedure to prepare a Rhodamine WT solution for use as a sensor stability check reagent for the EXO Total Algae (Chlorophyll and Blue-green Algae) sensor.

1. Accurately transfer 5.0 mL of the Rhodamine WT solution into a 1000 mL volumetric flask.
2. Fill the flask to the volumetric mark with deionized or distilled water and mix well to produce a solution that is approximately 125 mg/L of Rhodamine WT.
3. Transfer this standard to a glass bottle and retain it for future use.
4. Accurately transfer 5.0 mL of the solution prepared in the above step to a 1000 mL volumetric flask.
5. Fill the flask to the volumetric mark with deionized or distilled water. Mix well to obtain a solution, which is 0.625 mg/L in water (a 200:1 dilution of the concentrated solution).
6. Store the concentrated standard solution in a glass bottle in a refrigerator to retard decomposition. The dilute standard prepared in the previous step should be used within 24 hours of its preparation.
7. Discard the used standard. When Rhodamine standards are required in the future, perform another dilution of the concentrated Rhodamine WT solution after warming it to ambient temperature.

Appendix F: Station Problem Log Template

Example Monitoring Log
2/7/2014
TWDEF

- QC – Weird spikes in humidity on 2/6 – 2/7. Maybe the sensor got wet?

Waterlab

- No new problems noted

Main Street

- QC – More recent high specific conductivity, might be correlated with turbidity to some extent

Mendon

- QA – diurnal pH signal continues to get more amplified

Golf Course

- No new problems noted

Example Problem Tracking Table

Date	Site	Problem	Priority	Status	Comments
1/15/2014	Mendon	New Dessicant Needed	Low	Unresolved	
1/24/2014	Waterlab	Database values persist when sonde is disconnected	Low	Unresolved	
1/27/2014	Golf Course	Diurnal signal in Judd	Low	Unresolved	
2/1/2014	Main Street	Battery Too Low	High	Resolved	

1. The pressure transducer should NOT be pulled for cleaning unless there is reason to suspect serious build-up of sediment or biological matter. Pulling the pressure transducer affects the resulting data. If the pressure transducer is pulled, the following procedure should be followed:
    a. Make note on the field sheet that the probe was pulled.
    b. Try to clear the holes that let water into the probe without removing the cap. It might be effective to use a squirt bottle or an air-filled syringe. Ensure that you do not create any sort of seal on the cap of the sensor if you are squirting air or water as this can damage the transducer's membrane. The cap should only be removed as a last resort. If the cap is removed, DO NOT touch or apply any pressure to the membrane.
    c. With the cap in place, submerge the probe in water (use the bucket) before returning it to the housing pour water down the housing with the probe, and

gently shake the probe up and down in the water when returned to the housing. This may reduce the buildup of bubbles on the membrane and the effects of the bubbles diffusing from the membrane.

d. Ensure that the transducer is at the bottom of the housing before replacing the cap. You can usually feel and/or hear the sensor contacting the bolts at the bottom of the housing by gently shaking the sensor up and down.
e. Ensure that the housing cap is snugly secured to the housing.